Ronald E. Goldstein's

Esthetics in Dentistry

THIRD EDITION

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Preface to Third Edition

I owe so much of my career in esthetic dentistry to my first and most important mentor… my father, Dr Irving H. Goldstein, a great dentist, civic leader, and philanthropist. I learned so much watching him create the most beautiful smiles and only wish Dad had kept a photo library as I have done in my career. He taught me that being an average dentist was never an option… rather to always work to be the best, and at 84 years, I am still striving every day I practice.

I was first drawn to the study of esthetics a number of years before my 1969 article "The study of the need for esthetic dentistry" was published in the *Journal of Prosthetic Dentistry*. That article identified dentistry's lack of appreciation for the patients' appearances and their self-perception.

During the first half of the 1970s, I avidly pursued my study of esthetics, investigating every known aspect of dentofacial appearance. I became convinced of the huge untapped potential the field offered for improving patient outcomes and enhancing dental practice. Eventually, I was inspired to dedicate my professional career to promoting a comprehensive interdisciplinary approach to dentistry that united function and esthetics in total dentofacial harmony.

When the first edition of this text was published in 1976, the United States was in the midst of a celebration marking the 200th anniversary of our birth as a nation. It was an unprecedented national observance of the highly successful American Revolution. At the time, I considered the two events—both of considerable importance to me—distinct from one another. Since that time, however, I have come to recognize that, although the publishing of any textbook could never be considered in the same breath with the emergence of a nation, both events were indeed revolutionary.

Six decades ago, esthetics was considered, at best, a fortuitous by-product of a dental procedure—a bridesmaid, but certainly not a bride. In the years that have ensued, esthetics has taken its rightful place, along with functionality, as a bona fide objective of dental treatment. The revolution that has transpired has not only enhanced our knowledge of the field but also in methodology and technology. Today's patients are highly informed about the possibilities of esthetic dental restorations and fully expect that esthetics will be considered, from the inception of treatment to the final result.

Consumers know that dental esthetics play a key role in their sense of well-being, their acceptance by others, their success at work, in relationships, and their emotional stability. Informed by magazines, books, internet, and ongoing social media coverage, plus driven by the desire to live better lives, patients seek out dentists who can deliver superior esthetic services.

The ongoing effort to meet these demands with state-of-the-art and science treatment represents the continuation of that revolution. At the time this text book first appeared, I hoped that esthetics would eventually hold a preeminent position in our profession. That goal has been accomplished. Esthetics is recognized worldwide today as a basic principle of virtually all dental treatment.

We have been so fortunate in having over 75 world authorities helping to update the 47 chapters in two volumes. Virtually every phase of esthetic dentistry has now been included. It is my hope that, in some small way, this updated edition will serve to advance all aspects of the esthetic dental revolution and, in so doing, help patients and practitioners achieve even greater, more satisfying outcomes.

I feel so fortunate that three of the world's best known, talented, and respected academicians, clinicians, and teachers agreed to co-edit this third edition with me—Drs Steven Chu, Ernesto Lee, and Christian Stappert have continuingly contributed greatly in making the third edition more far-reaching into the high-tech worldwide revolution in esthetic dentistry.

Ronald E. Goldstein

Acknowledgments

So many people have worked on various aspects of this third edition that it would take far too much space to mention all of them. However, there were those who gave significant time to the project, and it is those people who I will attempt to thank at this time.

Most helpful in every way was the extraordinary 7-year effort of my personal editorial assistant, Annette Mathews. Annette's attention to detail and meticulous follow-through helped us greatly to complete this third edition. Despite the frustration of dealing with three different publishers, Annette helped coordinate with over 75 contributors, in addition to continuously proofreading the 47 chapters. I have had the pleasure of working with many individuals in my 60 years of practice, but none better than Annette. She wins the prize!

Others who assisted me on various aspects of the book were Daria Molodtsova, Candace Paetzhold, and Yhaira Grigsby.

My clinical office staff has always been generous with their help over the years. Those assistants who have been most helpful with this edition were Sondra Williams and Charlene Bennett.

It also takes a talented group of professionals for the day-to-day support necessary to sustain a lengthy project such as this text. I am most appreciative of the support from my long-time partners, David Garber and Maurice Salama. No one could ask for a more understanding and gifted friend than David. Maurice and Henry Salama have always been ready to lend a hand or help solve a dilemma as only they can. Wendy Clark, Nadia Esfandiari, and Maha El Sayed were particularly helpful during the writing and editing stages. Thanks also to Pinhas Adar, who has always been willing and available to help with technical or illustrative assistance. Thanks also to Zach Turner for his excellent illustrations throughout the text.

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Ronald E. Goldstein

PART I
PRINCIPLES OF ESTHETICS

Chapter 1 Concepts of Dental Esthetics

Ronald E. Goldstein, DDS and Gordon Patzer, PhD

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Beauty is in the eye of the beholder.

Margaret Hungerford

What is esthetics?

Mosby's Dental Dictionary defines esthetic dentistry as, "the skills and techniques used to improve the art and symmetry of the teeth and face to enhance the appearance as well as the function of the teeth, oral cavity, and face."[1] This definition positions appearance as a focal point of esthetic dentistry. Dental esthetics (also spelled aesthetics) connects with the principal aspect of appearance—physical attractiveness. Accordingly, esthetic dentistry provides benefits that extend far beyond total dental health toward total well-being throughout life.

Each of us has a general sense of beauty. Our own individual expression, interpretation, and experiences make it unique. In addition, we are also influenced by culture and self-image. What one culture perceives as disfigured may be beautiful to another. Chinese women once bound their feet, and Ubangis distend their lips. Individuals' sense of what is beautiful influences how they present themselves to others. Esthetics is not absolute, but extremely subjective.

> *Many factors and dimensions determine a person's appearance, among which physical attractiveness predominates and which esthetic dentistry can affect favorably. The entirety of the physical attractiveness aspect of appearance calls for the label,* physical attractiveness phenomenon.
>
> Gordon Patzer

Physical attractiveness phenomenon is a bias based on physical attractiveness. As discomforting as it may be for people to acknowledge, the reality lives. Individuals with an appearance of higher physical attractiveness *do* experience benefits throughout life that their counterparts of lower physical attractiveness *do not*. This takes place uniformly regardless of age, gender, race, ethnicity, socioeconomic level, geographical location, political

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structure, time in history, and so on. Indeed, esthetic dentistry naturally plays a critical role in a person's appearance, particularly in the link between dental esthetics and physical attractiveness. Therefore, it is reasonable to recognize esthetic dentistry as one dimension of physical attractiveness phenomenon. It is also reasonable to view the reality caused by, or at the least correlated with, physical attractiveness phenomenon to be significantly interrelated. In other words, esthetic dentistry possesses considerable capability, opportunity, and responsibility concerning the benefits and detriments that individuals experience throughout their lives.

Notions that esthetic dentistry is only about vanity and caters exclusively to the rich and famous fail tests of reality. Dental professionals who provide esthetic dentistry and recipients of these services readily offer evidence contrary to this. Yes, function matters tremendously. It is essential throughout dentistry, but coupling function with form that improves appearances matters even more. No, dental esthetics is not about vanity, the rich, or the famous. It is about realization that esthetic dentistry done well can contribute to the lives of all people in all walks of life far beyond the in-office, oral cavity, dental treatment received. As dental esthetics exert a key role in a person's looks, those looks carry influences internally concerning self-image, confidence, and happiness, and externally concerning what others see. In other words, at the same time that esthetic dentistry contributes to total dental health (making it a health science,) a person's ability to retain or to enhance appearances of his or her teeth contribute accordingly to the world's interactions with that person and vice versa.

Historical perspective of dental esthetics

Cosmetic dental treatment dates back more than four millennia. Throughout history, civilizations recognized that their accomplishments in the field of restorative and cosmetic dentistry were a measure of their level of competence in science, art, commerce, and trade. There are repeated references in history to the value of replacing missing teeth. In the El Gigel cemetery located in the vicinity of the great Egyptian pyramids, two molars encircled with gold wire were found. Gold was also used to splint anterior teeth and may be thought of as a luxurious way of saving teeth. This was one of the first pieces of evidence showing the Etruscan culture valued the smile as an important part of physical attractiveness. It was apparently a prosthetic device.[2] In the Talmudic Law of the Hebrews, tooth replacement is permitted for women. The Etruscans were well versed in the use of human teeth or teeth carved from animal's teeth to restore missing dentition[3] (Figure 1.1).

Other historical evidence that ancient cultures were concerned with cosmetic alteration of the teeth includes reference to the Japanese custom of decorative tooth-staining called *ohaguro* in 4000-year-old documents. Described as a purely cosmetic treatment, the procedure had its own set of implements, kept as a cosmetic kit. The chief result of the process was a dark brown or black stain on the teeth. Studies suggest that it might also have had a caries-preventive effect[4] (Figure 1.2).

Figure 1.1 Over 4000 years ago, the Etruscans demonstrated the earliest treatment related to esthetic dentistry by using gold wire to save diseased teeth to maintain the beauty of the smile. This reproduction shows copper wire. Figure courtesy of the Royal College of Surgeons of Edinburgh.

Figure 1.2 An example of dental esthetics practiced from ancient times in Japan, likely around 500 AD, called ohaguro, in which people stained their teeth to be black in color. This practice continued into the Meiji era, which ended in the early 20th century. Figure courtesy of Dr Peter Brown.

Smiles are evidenced as early as 3000 BCE.[1] A smile on the face of a statue of an early king of Abab is noted in the art of Sumer. Aboucaya noted in his thesis that the smile was absent or not very marked in early works of art and, when present, was almost always labial. The dentolabial smile, where the teeth are seen behind the lips, starts to emerge in the first decades of the 20th century. This is attributed to an increased emphasis of awareness of the body and art of cosmetics due to the evolution of social life and the change in habits and manners. Teeth began to play an increasingly important role as more attention was paid to the

Figure 1.3 **(A)** This 2000-year-old Mayan skull provides some of the best evidence that jadeite inlays were used for cosmetic, rather than functional, purposes.

face, which exhibited more open and unrestricted expressions. The resulting emphasis on dental treatment and care also created an interest in the improvement of the esthetics of the smile.

At the height of the Mayan civilization, a system of dental decoration evolved in which some teeth were filed into complicated shapes and others were decorated with jadeite inlays (Figure 1.3A and B). These dental procedures were purely cosmetic and not restorative. Although the intent of these ancient attempts at cosmetic dentistry was strictly ornamental, there were sometimes beneficial side effects, such as the possible caries-preventive consequence of *ohaguro*. More often, however, the side effects were harmful. Some Mayans, seeking to brighten their smiles with jadeite, developed periapical abscesses because of careless or overenergetic “filers of the teeth,” as their dentists were called. Today, dental esthetics is founded on a more ethically sound basis: the general improvement of dental health. But the same desires of those ancient men and women to submit to dental decoration as an outward portrayal of the inner self motivate today’s adults to seek esthetic treatment. Distant history shows, without exception, labial smiles with lips closed and thus teeth not seen, rather than smiles with lips open and teeth visible. History made today and in the future likely will be substantially different, with quite dramatic changes over time with smiles more commonly showing teeth. Nevertheless, smiles with lips articulated to reveal teeth do not appear in history until the early 1900s, and then only very gradually and nearly only in images representing American history and, less so, history representing other Western cultures.

This change during history with smiles increasingly revealing teeth, albeit initially, parallels numerous other pertinent changes. First is the change regarding broader developments throughout populations particularly related to an individual’s appearance in step with physical attractiveness phenomenon. Second, it is certainly reasonable to speculate that the change in smile appearances has been due in large part to esthetic capabilities within the dental profession, as well as changes in societal attitudes. It is certainly correct to attribute the interest in greater visibility of teeth, akin to the “American smile,” wanted and displayed today and no doubt increasingly in the future, to these developments. Although esthetic dentistry can help achieve self-assurance, it must always be predicated on sound dental practice and keyed to total dental health. The limitations of esthetic treatment must also be communicated to the patient.

Figure 1.3 **(B)** Aside from jadeite inlays, the Mayans also valued using special tooth carvings to enhance physical appearance. However, there are still cultures that practice filing teeth for cosmetic enhancement (https://anthropology.net/2007/06/01/damien-hirsts-diamond-encrusted-skull-jeweled-skulls-in-archaeology/).

The social context of dental esthetics

A desire to look attractive is no longer taken as a sign of vanity. In an economically, socially, and sexually competitive world, a pleasing appearance is a necessity. In today’s technology-driven society, social media contributes to a person’s image being viewed more than ever. In addition, high definition has driven many television personalities to improve their physical appearance. As a result, more and more people are considering esthetic dentistry as a necessity to maintain an appealing look. The reason? Dr Johnnetta Cole, past president of Spellman College, tells the author, “Because people have to look at me.”

Since the face is the most exposed part of the body, and the mouth a prominent feature, teeth are getting a greater share of attention. “Teeth are sexy” announced a leading fashion magazine, and it then went on to elaborate in nearly 500 words (Figure 1.4A and B). The headline was just the capstone of a string of magazine articles that drew new attention to teeth. Gradually, the public has been made more aware of the “aids to nature” that Hollywood stars have been using since movies began. They discovered that their favorite actors, models, and singers used techniques of dental esthetics to make themselves more presentable and attractive. Some followed the Hollywood lead and asked their dentists to give them teeth like those of some celebrities and thus learned of methods and materials that could improve their appearance.

In the United States today, we place a premium on health and vitality. In fact, these two words are now intertwined with images of beauty. Goleman and Goleman[5] reported that researchers found that attractive people win more prestigious and higher-paying jobs. At West Point, cadets with Clint Eastwood-style good looks—strong jaws and chiseled features—rise to higher military ranks before graduation than their classmates. They also found that good-looking criminals were less likely to be caught; if they did go to court, they were treated more leniently. Teachers were found to go easier when disciplining attractive children; both teachers and pupils consider attractive children as

Figure 1.4 **(A)** Discolored teeth and leaking and discolored fillings marred the smile of this 24-year-old internationally known ice skating performer. (Note also the slight crowding of the front teeth, with the right lateral incisor overlapping the cuspid.)

Figure 1.4 **(B)** A new sense of self-confidence and a much more appealing smile was the result of six full porcelain crowns. The teeth appear much straighter, and the lighter color brightens the smile and enhances the beauty of her face and lips.

smarter, nicer, and more apt to succeed at all things. Many studies on self-esteem have illustrated that body image was one of the primary elements in self-rejection.[3,6] Television reinforces in us an extraordinarily high standard of physical attractiveness, and Hollywood has long rewarded beauty and given us standards that are probably higher than most of us will ever achieve.

Society chooses leaders to set unspecified but pervasive standards of acceptable dress, behavior, and recreation. The swings of fashion filter down from the posh salons of couturiers patronized by the wealthy, or up from department store racks from which the majority buy their clothing. A catchphrase repeated on radio or television instantly becomes part of the national language, and songs that began as commercials wind up topping the popular music charts.

Uninfluenced by the esthetic standards set by society, many individuals want to change their appearance to emulate their chosen leaders. General social attitudes profoundly influence an individual's idea of what is attractive: "natural," "beautiful," and "good looking" hold different meanings within the population (Figure 1.5A and B). The female shown in Figure 1.5C was happy with her diastema, thinking it was "cute" and part of her personality. Occasionally, patients take extreme measures to call attention to the mouth in an attempt to achieve an attractive image (Figure 1.6). Therefore, it is the responsibility of the dentist to understand what the patient means when using a particular term, and to decide to what degree the patient's ideal may be realized. The patient's own feeling of esthetics and concept of self-image is most important.

Esthetic dentistry demands attention to the patient's desires and treatment of the patient's individual problems. Esthetic dentistry is the art of dentistry in its purest form. The purpose is not to sacrifice function but to use it as the foundation of esthetics.

> *The excellence of every art is its intensity, capable of making all disagreeables evaporate, from their being in close relationship with beauty and truth.*
>
> John Keats

Esthetics: a health science and service

Is esthetic dentistry a health science and a health service?[7] Or is it the epitome of vanity working its way into a superficial society?

The answer to these questions lie in the scientific facts gleaned from over a thousand studies proving the direct and indirect relationship of how looking one's best is a key ingredient to a positive self-image, which in turn relates to good mental health. The authors of a survey of nearly 30,000 people point to a relationship between psychosocial well-being and body image.[8] They found that feeling attractive, fit, and healthy results in fewer feelings of depression, loneliness, and worthlessness. This study also found that the earlier in life appearance is improved, the more likely it is that the person will go through life with a positive self-image. Sheets states that, "An impaired self-image may be more disabling developmentally than the pertinent physical defect."[9] For instance, adults who reported having been teased as children were more likely to have a negative self-evaluation than those who were not teased (Figure 1.7A and B).

According to Patzer, the face is the most important part of the body when determining physical attractiveness.[10] Specifically, "the hierarchy of importance for facial components appears to be mouth, eyes, facial structure, hair, and nose" (Table 1.1). Therefore, it becomes apparent that not only should esthetic dentistry be performed but it should also be performed as early as possible. It is not necessary for every dentist to master all of the treatments available. However, the advantages, disadvantages, possible results of treatment, maintenance required, and life expectancy of each treatment modality should be thoroughly understood by all dentists. A willingness to refer to another dentist when he or she is more capable of satisfying the patient's desires is both ethical and necessary for good patient relations. Your patient will likely return to you with trust and loyalty for your good judgment in referring for the specific esthetic treatment. The alternative is that your previously satisfied patient may leave you for another dentist if you

Figure 1.5 **(A–C)** Esthetic values change with social attitudes. (A) This patient once thought that showing gold was desirable, and it was accepted in her socioeconomic peer group. (B) When her status changed 10 years later, so did her attitude, and the gold crowns were removed. It is important to “wear” these temporary acrylic crowns for 1–3 months to make certain the patient will continue to like his or her new look. (C) This lady was happy with her diastema, thinking it was “cute” and part of her personality.

Figure 1.6 Example of an individual during contemporary times who defines good-looking teeth best when adorned with an inlaid diamond and multiple open-faced gold crowns depicting various shapes.

do not offer the requested treatments or belittle their effectiveness without offering an alternative. The fact is, all esthetic treatment modalities work on indicated patients. A good example would be a patient with teeth yellowed due to aging. If you do not provide vital tooth bleaching as one of your routine esthetic dentistry treatments, refer to a colleague who does provide this service. Most likely, the patient will return to your office for routine treatment. Patients may actually appreciate you more, realizing that you are more concerned with their well-being than your own.

Two questions seem in order. On the basis of the previous premise linking a great smile to overall success in life, are we as dentists doing all we should to motivate our patients to improve their smiles? Are we as a profession doing all we should to motivate the 50% of the population who do not normally visit the dentist to have their smiles esthetically improved? Based on the enormous amount of research showing the advantages of an attractive smile, the answer to both questions would seem to be “No.” We can and should do much more to inform the public about why a great smile is an important asset and that we as a

Figure 1.7 **(A)** This 13-year-old girl reported that boys "called her names," referring to her tetracycline-stained teeth.

Figure 1.7 **(B)** Although bleaching was attempted, bonding the four maxillary incisors was required to properly mask the tetracycline stains. Unless attention is paid to esthetics in young people, severe personality problems may develop. Improving one's self-confidence through esthetic dentistry can make all the difference in having a positive outlook on life.

Table 1.1 Numerical Ranking of Relative Importance of Face Components Using Three Different Research Methodologies

	Rank Order	Ratings by Self-Method	Ratings by Others Method	
			Dissected Photos	Intact Photos
Mouth	1	$r = 0.54$	$r = 0.53$	$r = 0.72$
Eyes	2	$r = 0.51$	$r = 0.44$	$r = 0.68$
Hair	3	$r = 0.49$	$r = 0.34$	Not assessed
Nose	4	$r = 0.47$	$r = 0.31$	$r = 0.61$

profession are the logical group to help accomplish this goal. Furthermore, we need to show how easy and painless it can be to achieve. One survey of dentists revealed 83% want greater effort by organized dentistry to promote the value of dentistry to the public.[11] Fitting promotional information can be delivered effectively online through popular social media alternatives as well as through radio, television, and print.

Understanding the patient's esthetic needs

A practicing dentist needs to be acquainted with certain generalities concerning the psychological significance of the patient's mouth. He or she should be familiar with basic considerations that apply to esthetic treatment as well as be aware of various problems that such treatments may incur. To be better equipped to anticipate any such problems, a better understanding of physical attractiveness phenomenon is essential.

Physical attractiveness phenomenon

Physical attractiveness is how pleasing someone or something looks. It is a reality perceived. And, as in nearly all of life, perception is more important than reality. However, given its esthetic essence, its variable/invariable nature constituted by tangibles and intangibles, perception of physical attractiveness is physical attractiveness. Modifiers qualify where and on which continuum the perceived physical attractiveness rates. Levels and descriptors range from low or extremely low to high or extremely high physical attractiveness, from very physically unattractive to very physically attractive, and so on.

Its basic definition applies equally to words used interchangeably—beauty, handsomeness, good looks, ugliness, cuteness, and so forth—as well as words used tangentially that express level and polarity such as gorgeous, stunning, head-turner, hunk, hottie, hot, voluptuous, pretty, homely, dog, pretty ugly. Sexiness does not define physical attractiveness. They are two different traits among many that can differentiate or describe a person. The terms are accordingly neither synonymous nor accurately interchanged. Sexiness expresses a level of sexual or erotic arousal.

Figure 1.8 Although physical attractiveness and sexiness are two separate traits, this model represents a combination of both.

A person whose appearance represents high or low physical attractiveness may or may not represent high or low sexiness. To be good-looking is not necessarily to be sexy nor vice versa. These two characteristics can certainly at times overlap and closely interrelate, but they are separate traits not unlike other distinguishing characteristics in these regards; whereby people viewed as more physically attractive are viewed concurrently more favorably on many other visual and nonvisual criteria (Figure 1.8). Although both men and women can be judged physically attractive with or without a great smile, so can they be judged as sexually appealing. However, there are definite attributes to the smile that can enhance one's attractiveness as well as one's sexiness.

Whether speaking about physical attractiveness or sexiness, teeth represent a key feature. Teeth add to or subtract from these desired appearances due to their prominent and inescapable presence (Figure 1.8). As noted earlier, teeth get a substantial share of attention in fashion magazines and in everyday interactions. The reason? The face is the most exposed part of a person combined with movements of the mouth caused by speaking and by many moods expressed in the face. These readily seen movements accordingly draw notice and attention to the observed person's teeth. Following the eyes' attention to a person's teeth,

Table 1.2 Impressions About Persons of Higher and Lower Physical Attractiveness

Persons of Higher Physical Attractiveness		Persons of Lower Physical Attractiveness
Curious	rather than	Indifferent
Complex	rather than	Simple
Perceptive	rather than	Insensitive
Happy	rather than	Sad
Active	rather than	Passive
Amiable	rather than	Aloof
Humorous	rather than	Serious
Pleasure-seeking	rather than	Self-controlled
Outspoken	rather than	Reserved
Flexible	rather than	Rigid
More happy	rather than	Less happy
Better sex lives	rather than	Less good sex lives
Receive more respect	rather than	Receive less respect

framed by moving actions of the mouth, people rightfully or wrongly infer far more information about the person observed. Accordingly, teeth considered to look esthetically appealing tend to be accompanied with corresponding inferences, assumptions, stereotypes, and expectations about individuals whose teeth communicate good and positive, bad and negative, or somewhere in between (Table 1.2).

Research methodology

Researchers use observation, survey, and experiment, along with variations of each, to study physical attractiveness phenomenon. Surveys are abundant to contemporary society but have limited application for this research area. A survey might ask people (respondents) directly or indirectly whether another person's physical attractiveness influences their assumptions and expectations about the person, likely behaviors toward the person, and so forth. Such a survey can obtain insightful data depending on the circumstances. When it comes to appearances and particularly physical attractiveness, respondents too often provide less than truthful responses to be in line with societal ideals. For that reason and others, when asked, people routinely and inaccurately self-report that another person's physical attractiveness makes no difference. However, when placed in parallel "candid camera" situations, evidence time after time confirms that "actions speak louder than words" when dealing with physical attractiveness phenomenon.

The dichotomy between what most people say regarding another person's physical attractiveness and what these same people do is well documented. Representing anecdotal data, simply focusing on this aspect expressed in the words and actions of friends often reveals the reality of respective differences. Mass media investigations provide equally strong findings through often-entertaining field experiments; examples include American television programs broadcast nationally as reported by correspondent John Stossel on the ABC News program *20/20*, correspondent Keith Morrison on the NBC News program *Dateline NBC*, and supermodel turned television host Tyra Banks on *The Tyra Banks Show*. The physical attractiveness variable in each of these instances was manipulated either by casting multiple actors considered to possess high or low physical attractiveness or by making-up individual actors accordingly. Research procedures then record with hidden cameras and hidden microphones the reactions and interactions with these actors by members of the public. Despite less stringent scientific research procedures, these mass media investigations yield findings overwhelmingly parallel and supporting of the attitudes and behaviors reported repeatedly in scholarly journal articles investigating the consequences of physical attractiveness.

The importance of facial appearance

Allport observes, "Most modern research has been devoted not to what the face reveals, but what people think it reveals."[12] He describes tendencies to perceive smiling faces as more intelligent and to see faces that are average in size of nose, hair, grooming, set of jaw, and so on, as having more favorable traits than those that deviate from the average. Summarizing an experiment by Brinswick and Reiter, Allport notes, "One finding…is that in general the mouth is the most decisive facial feature in shaping our judgments."[4] Meerloo observes, "Through the face, one feels exposed and vulnerable. One's facial expression can become a subject of anxiety."[13]

Studies suggest that even infants can tell an attractive face when they see one, long before they learn a society's standards for beauty. Results of experiments with two groups of infants were reported by psychologist Judith Langlois and five colleagues at the University of Texas at Austin. One group consisted of infants aged 10–14 weeks with an average age of 2 months and 21 days. Sixty three percent of the infants looked longer at attractive faces than at unattractive faces when shown pairs of slides of white women. The second group consisted of 34 infants whose ages ranged from 6 to 8 months. Seventy one percent of the infants looked longer at attractive faces than at unattractive faces.[14–18]

Any dentist dealing with appearance changes in the face must consider the psychological and the physical implications of the treatment. The consideration must involve not only results and attitudes following treatment but also causes, motivations, and desires that compel the patient to seek esthetic treatment (Figure 1.9A and B).

"The psychological concept of self and body image is totally involved in esthetics,"[19] notes Burns, continuing with the observation that dentofacial deformities have been largely regarded in

Figure 1.9 **(A and B)** This girl shows why she chose not to smile. Despite the total breakdown of the oral cavity, her motive in seeking dental treatment was esthetic.

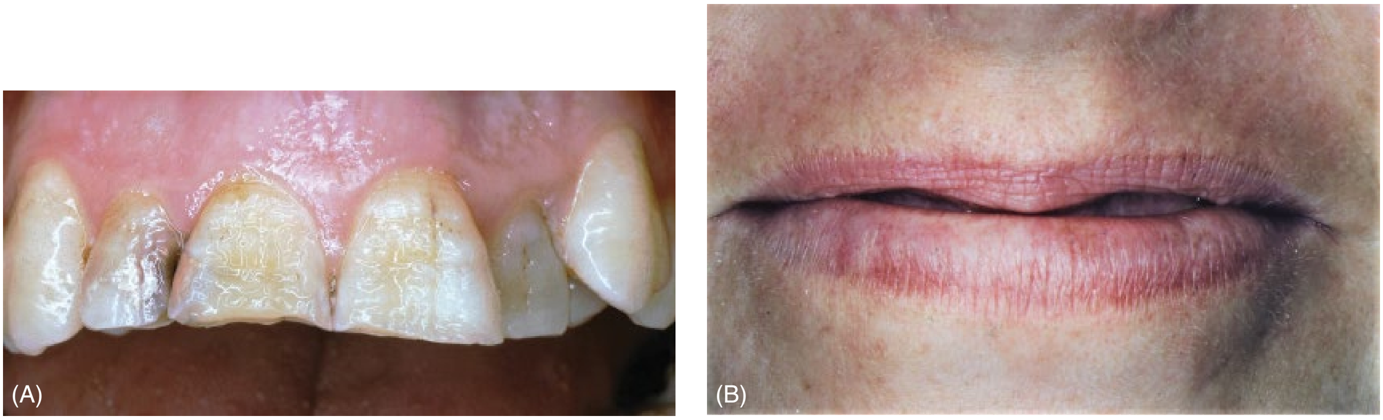

Figure 1.10 **(A and B)** This woman developed a habit of smiling with her lips together to avoid showing her unsightly maxillary incisors.

terms of diagnosis and treatment, rather than in terms of their psychological ramifications. Burns' consideration of the psychological aspects of esthetic treatment stems from his initial observation that the mouth is the focal point of many emotional conflicts. For example, it is the first source of human contact—a means of alleviating or expressing discomfort or expressing pleasure or displeasure (Figure 1.10A and B).

Functions of teeth

The appearance of a person's teeth communicates much about that person. Therefore, it is not surprising what people actually want to achieve with their teeth and smile. The functions of teeth in the minds of many people include the role of communicating information. Part of the way we communicate is through smiling at one another. Proper functioning of teeth for these people means more than to chew well and pain-free. They believe consciously or subconsciously that the look of their teeth substantially influences the perception of themselves by themselves and by others. Accordingly, the look of another person's teeth can influence the perception of these people. The reality is that the esthetic appearance of a person's teeth does contribute to the person's overall appearance and connects that person to physical attractiveness phenomenon.

Demeaning comments, shunning, and even bullying becomes a way of living for individuals sentenced to visibly missing, crowded, spaced, or protrusive teeth, or other dental anomalies. This is true at least for those individuals without the means for corrective action toward less negative appearances of their teeth. These individuals—male and female, young and old—make ill-fated attempts to avoid those negative reactions. Typical attempts include avoiding all smiling for fear of showing their esthetically unappealing teeth, or concocting a smile that never shows teeth, or using a hand or napkin to cover the mouth while speaking face to face. As well as looking a bit foolish or robotic, their thoughts and actions take a toll on these individuals. The tolls range from avoiding valuable social interactions to missing employment opportunities.

Tolls on a person can be particularly great on those of younger ages, in elementary school through high school. The negative consequences go far beyond affecting only self-image and self-confidence. Their reactions can exert their own toll with damage and costs to others and one's self. Evidence of such reactions makes news reports periodically and too frequently. For example, those bullied can become antisocial and even take up criminal ways, and, in some cases, end either their own life and/or the lives of others.

The mouth can be a particularly significant component of a person's physical attractiveness, which at the same time is rather inseparable from teeth and smile. One of psychology's most revered, Gordon Allport, once observed that people perceive smiling faces to be more intelligent[12] and, citing another research project noted, "…in general the mouth is the most decisive facial feature in shaping our judgments" about a person.[2] Accordingly, actions that include esthetic dentistry likely should be performed at earlier rather than later ages. Consider the 13-year-old girl pictured in Figure 1.7. Before esthetic dental treatment, she reported that kids called her names due to the appearance of her teeth. Professionals would readily interpret these taunts as demeaning with potential negative influences far beyond this girl's early teen years.

An improved self-image leading to increased self-confidence with assistance from esthetic dentistry is not limited to teenage girls. A good smile in these regards can produce improvements in psychological and social well-being for individuals of all ages in all walks of life. Figure 1.4A and B shows the before and after photos of teeth of an internationally accomplished ice skater, mid-20s in age, reported to have gained a new sense of self-confidence after cosmetic dentistry transformed her unpleasing smile into a much more appealing smile.

Personal values

The depth and breadth of a person's physical attractiveness far exceeds first impressions. Hidden and not-so-hidden values drive thoughts and actions that produce significant consequences whereby higher physical attractiveness is overwhelmingly beneficial and lower physical attractiveness is overwhelmingly detrimental. Awareness of this reality provides insight into why and how physical attractiveness can strongly motivate people to value it, retain it, and pursue more of it.

Consider the value of physical attractiveness embraced by Lucy Grealy, a well-educated, best-selling author, known to have many friends, loving family members, sincere romantic relationships, and mass media critical acclaim for her book, *Autobiography of a Face*. In review of a book written by a long-term friend that describes Ms Grealy as a cancer survivor and recipient of 38 operations, *The New York Times* states:

> "Stricken with Ewing's sarcoma at the age of nine, Grealy [who died at age thirty-nine] endured years of radiation and chemotherapy followed by a series of reconstructive operations, most of them unsuccessful. Yet it was the anguish of being perceived as ugly, and of feeling ugly, that she identified as the tragedy of her life. …Grealy came to feel that her suffering as a cancer patient had been minor in comparison."

Values placed on a person's own physical attractiveness vary between individuals. Although the real-life case above might reflect a small, unreasonable, extreme portion of people, it might not. "Beauty was a fantasy, a private wish fraught with shame" for Ms Grealy, who was never able to free herself from "her desire to be beautiful." At various levels, all people throughout their lives hold personal feelings to be more physically attractive. Despite sometimes denial or lack of awareness, evidence overwhelmingly shows that most if not all people value higher levels of physical attractiveness.

As well as valuing others more or less as influenced by their physical attractiveness, it influences one's own value. Researchers for the 2005 Allure State of Beauty National Study that surveyed more than 1700 Americans concluded, "…among the most surprising statistics from the study is that enhancing their [physical] appearance fuels women's confidence." Data from that 2005 survey showed "Ninety-four percent [of the respondents] agree that the more beautiful they feel, the more confident they are." The two factors are interrelated intricately as signaled by the high portion of respondents, 94%, who "say that when they feel more confident, they take more time to look good."

Employment: a closer look

Employment in direct regard to physical attractiveness phenomenon merits a closer look because of the prominent role that gainful work commands throughout nearly every person's life. Two *Newsweek* magazine surveys in 2010 summarized the findings found consistently as reported in scholarly journals. *Newsweek* collected their data from 202 corporate hiring managers in positions ranging from human resource employees to senior-level vice presidents and from 964 members of the public with survey procedures that ensured a nationally representative sample. The subtitle for the reporting article proclaims, "The bottom line? It pays to be good-looking." Their conclusion based on these data: "…paying attention to your looks isn't just about vanity, it's about economic survival [and]…managers are looking beyond wardrobe and evaluating how 'physically attractive' applicants are." Also concluded, these 2010 data "confirm what no qualified (or unqualified) employee wants to admit: that in all elements of the workplace, from hiring to politics to promotions, looks matter, and they matter hard."

Here are some of those specific findings, which highlight how or why looks matter more than you might have imagined.

- **Getting hired**—Among managers, 57% believe that a (physically) "unattractive [but qualified] job candidate will have a harder time getting hired; 68% believe that, once hired, looks will continue to affect the way managers rate job performance." Among members of the public, "63 percent said being physically attractive is beneficial to men who are looking for work, and 72 percent said it was an advantage for women in any job search" (Figure 1.11A–C).
- **Looks above education**—Asked to use a 10-point scale to rate a series of character attributes with 10 being the most important for securing employment, "looks came in third (with a mean score of 7.1), below experience (8.9) and confidence (8.5), but above where a candidate went to school (6.8) and a sense of humor (6.7)."
- **Return on investments**—For individuals considering where or how best to invest their job-hunting resources, 59% of "hiring managers advised spending as much time and money 'making sure they look attractive' as on perfecting a résumé."
- **Lessons learned**—Reverse older or heavier looks, in light of the managers at 84% and 66% respectively stating that, "they believe some bosses would hesitate before hiring a qualified job candidate who looked much older than his or her co-workers" and "they believe some managers would hesitate before hiring a qualified job candidate who was significantly overweight."

For employment decisions, it can be legal to differentiate/discriminate in light of a person's physical attractiveness; that is, if these differentiations are truly based on differences of physical attractiveness and not based on differences of factors prohibited by federal law such as age, sex, race, and so forth. Accordingly, 64% of hiring managers shared these sentiments, stating, "they believe companies should be allowed to hire people based on looks—when a job requires an employee to be the 'face' of a company." It is also important to realize just how much a great smile can be, especially to a person who otherwise might not be judged as attractive. A person can be fat or thin, tall or short, but a winning smile can make the difference in being hired or not.

The business of looking good

Pursuits to look good—whether to retain or to increase physical attractiveness—continue despite downturns and upturns in the broader economy. Proof of collective expenditures can be seen in the somewhat regular mass media reports that highlight annual numbers for sales and services in related industries and professions. Underlying these expenditures, options available to maintain and enhance an individual's physical attractiveness are ever increasing along with continuously evolving wants, demands, innovations, and technological advances.

Providers of products and services to meet the wants of people concerning physical attractiveness range from companies within the cosmetics and beauty sector of world commerce to the professional practitioners regulated through local state licensing requirements. A list of the most notable commerce entities with focus on physical attractiveness begins with major diversified corporations (Unilever, Procter & Gamble, etc.) and continues with major branded companies (Estee Lauder, L'Oreal, etc.). The cosmetic surgery profession likely represents the most visible among professionals regulated by state licensing, with their associations (American Society for Aesthetic Plastic Surgery [ASAPS], American Association of Plastic Surgeons [AAPS], etc.) tabulating and disseminating information about their collective procedures performed.

Suppliers and providers pertinent to the business of looking good are expansive and commonly referred to in summary manner as the beauty industry. A wide array of products and services constitute this industry, sometimes with varying definitions used

Figure 1.11 **(A–C)** This young woman refrained from smiling because she was embarrassed by her high lip line that revealed too much of her gums. She said it affected her personality and relationships. She received implants, orthodontics, bleaching, cosmetic contouring, and gum surgery to lengthen her teeth and give her a more attractive medium lip line and overall smile.

Figure 1.11 (Continued)

to categorize the variety of products and services. Nevertheless, consumer purchases in pursuits to enhance or retain physical attractiveness total large annual sales. For example:

- Personal care products contributed US$236.9 billion in 2013 to the US economy, spanned 3.6 million US jobs held by individuals of diverse backgrounds, and in 2014 accounted for a $5.8 billion export trade surplus (http://www.personalcarecouncil.org/sites/default/files/2016YearInReviewFinal.pdf).
- Hair care services generate nearly $20 billion in annual sales in the United States alone, and $160 billion worldwide (http://www.firstresearch.com/industry-research/Hair-Care-Services.html).
- Retailers focused entirely on cosmetic and beauty products generate $10 billion annual sales and number about 13,000 stores (Figure 1.12A–C).

Cosmetic surgery represents a prominent option for people to enhance or retain their physical attractiveness. It accordingly represents a sizeable portion of consumer purchases that are reasonable to align with the beauty industry moniker. In these regards, the two leading professional organizations for surgeons certified by the American Board of Plastic Surgery who specialize in cosmetic plastic surgery—the American Society of Plastic Surgeons (ASPS) and the American Society for Aesthetic Plastic Surgery (ASAPS)—each with thousands of members, some of whom overlap with membership in both societies, systematically collect statistics from their members about types and numbers of procedures performed annually.

Recent annual statistics from both ASAPS and ASPS, which today have their largest ever memberships, document strong motivation by people to enhance or retain one's own physical attractiveness regardless of personal costs, efforts required, and economic conditions. Late 2010, ASAPS reported "Despite Recession, Overall Plastic Surgery Demand Drops Only 2 Percent From Last Year" based on 2009 statistics, their most recent annual data available from their members at that date. Early 2011, ASPA reported "Plastic Surgery Rebounds Along with Recovering Economy; 13.1 Million Cosmetic Procedures Performed in 2010, up 5%," based on 2010 statistics from their members. Over a longer time span, ASAPS data reveal that cosmetic procedures have increased 147% in number since beginning in 1997 to collect these statistics.

Bottom-line statistics, in one of the worst general economic times in American history, include ASAPS reporting nearly

Consumers spent nearly $10.5 billion in 2009 for cosmetic surgery procedures (ASAPS data). Breast augmentation was the most frequent surgical procedure, and facial fillers (such as Botox) were the most frequent nonsurgical procedure. Demographically, although people seeking cosmetic procedures remained in the same approximate proportions as reported in earlier years, they increasingly cross differences in race and ethnicity (whose collective minorities represented 22% of all cosmetic procedures with Hispanic/Latino at 9%, African American at 6%, Asians at 4%, and 3% for other non-white people), as well as differences in gender and age.

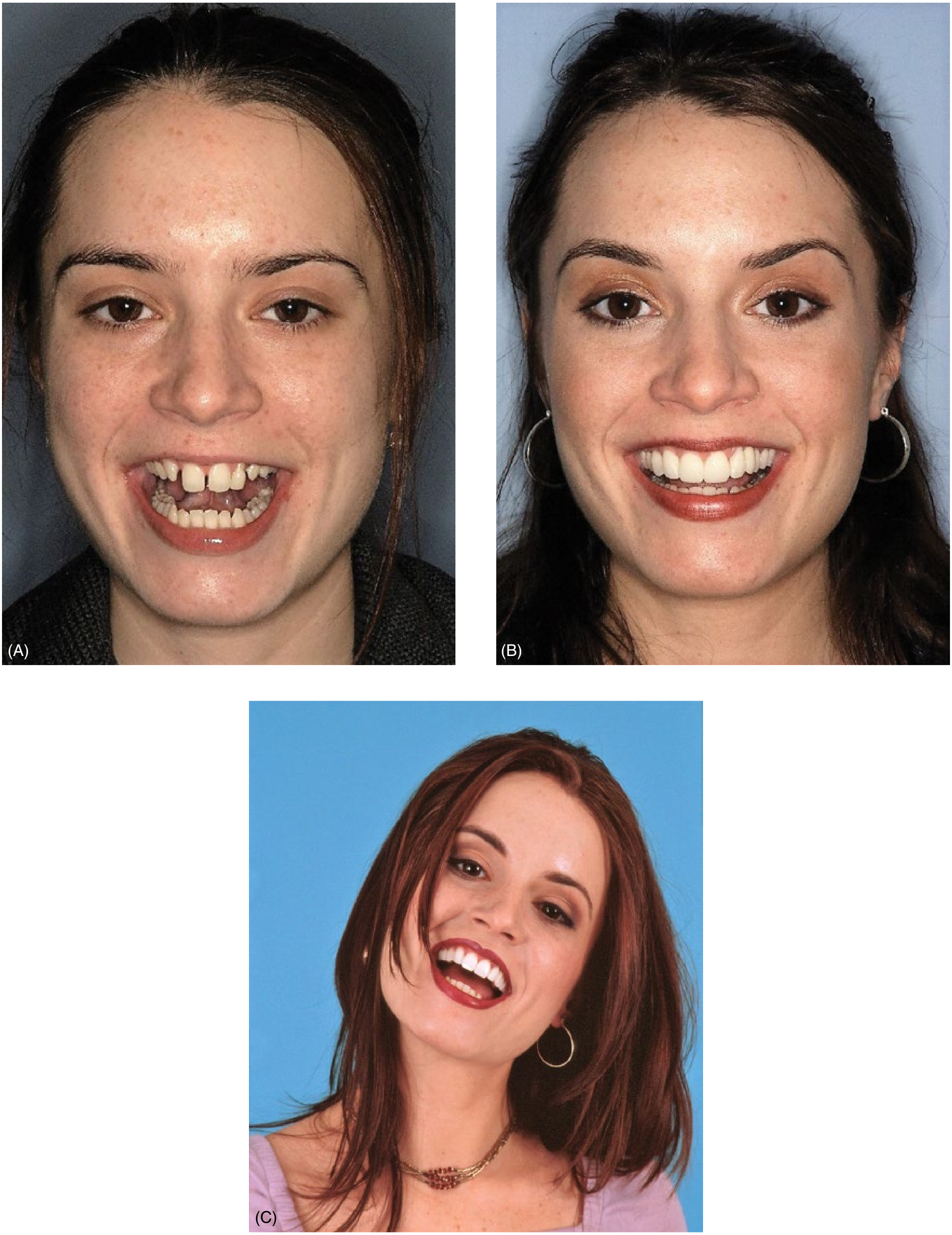

Figure 1.12 **(A–C)** Before and after full face smile photos: this 22-year-old waitress was too embarrassed to smile, which limited her full potential both socially and in reaching her career goals. Porcelain veneers and a resin-bonded fixed bridge were made without reducing the tooth structure. The result of her new smile and full hair and face make-over was a life-changing physical and mental transformation for this young woman.

10 million cosmetic procedures (surgical and nonsurgical) during 2009. That finding is despite economic conditions that delayed and decreased expenditures for most all products and services, with expectations for corresponding growth of purchases to resume as the economic improves. Accordingly, a year later in an improving but still bad overall economy, ASPA reported more than 13 million cosmetic procedures performed during 2010.

Today, people motivated to pursue various physical attractiveness options locate the necessary financial resources in creative ways. No longer do they rely solely on personal savings in pursuit of looking better. Suitable efforts and expenditures directed toward a person's physical attractiveness certainly can be correct, and a wise return on investment given our world in which looking better in nearly all circumstances has benefits throughout life.

Patient response to abnormality

The smile is the baby's most regularly evoked response and eventually signifies pleasure. Thus, any aberration it reveals can naturally be a point of anxiety. Frequently the response to a deformity or aberration can be out of proportion to its severity. Abnormality implies difference, a characteristic undesirable to most people. To diminish differences, they may resort to overt or subtle means of hiding their mouths (Figure 1.7A and B). However, as Rottersman notes, "The response may not be out of all proportion to the stimulus. This is a signal for the doctor to exercise caution, and to attempt to discern what truly underlies the patient's response" (W. Rottersman, personal communication). Understanding the patient's motives requires acute perception on the dentist's part, informed by a thorough examination and history that reveal the patient's actual dental problems.[20] The patient's own assessment of his problems and his reaction to them are of equal importance. The dentist should be alert for a displacement syndrome, in which an anxiety aroused by real and major emotional problems may be transferred to a minor oral deformity. When a patient with a long-standing complaint finally presents for treatment, the dentist must determine what prevented him or her from coming for treatment sooner. A patient who criticizes a former dentist is apt to be hostile, and the dentist should not present a treatment plan before determining what the patient believes treatment can accomplish.

Psychology and technology

For all patient treatments intended to change facial appearances, it is important to consider psychological dimensions as well as the treatment procedure and technology. Esthetic dentistry demands attention to the individual patient's desires, goals, and motivations, as well as physical conditions. Patients interested in esthetic dentistry present any number of scenarios. Every patient is an individual who likely requires individual attention to an extent. As well as actual dental conditions, their reasons for seeking treatment might reflect varying wants, feelings and anxieties, personalities and self-images, and unrelated or unrealistic perspectives, motivations, goals, and expectations. Complicating the reasons are interconnected influences from spouses, coworkers, aging, cultural changes, changes in socioeconomic level, and so forth. Stated succinctly by one dentist, "The reasons why patients seek esthetic treatment are as varied and intricate as the reasons they avoid. …such as orthodontic, cosmetic restorative, cosmetic periodontal, plastic or orthographic surgery, or any combination of these."

> The individual's own feelings about dental esthetics are in some ways the most important. They determine his or her self-image in conjunction with that individual's perception of what and who are important in their lives. As much as possible, the dentist who devotes time to esthetic dentistry then functions as a vehicle of sorts to help patients realize their wants in the realm of feasibilities. Accordingly, practitioners of esthetic dentistry must understand what patients mean with their particular words and take appropriate actions in the context of ethics, good judgment, and technological capabilities.

A patient's own assessment of, reaction to, and perspective of dental issues are important. At the same time, the dentist needs to be alert to potential displacement syndrome whereby the patient transfers attention from unrelated or unrealistic emotions and problems to a minor or uncorrectable dental malady. Relative to other areas, esthetic dentistry may encounter more of these situations with variations. For example, before presenting a treatment plan for patients with a long-standing complaint about a dental issue, it should be determined why the person did not come sooner for treatment. Similarly, before presenting a treatment plan for a patient who might be highly critical of a former dentist or dental treatment, it should be determined what the patient believes treatment now can accomplish. See also Chapter 2 in this volume.

Patient types and dentist alerts

The reasons why patients seek esthetic treatment are as varied and intricate as the reasons they avoid it. How adults feel about and care for their mouth often reflects past, current, and future oral developmental experiences. Adults in their mid-20s may not have developed a sense of the meaning of time in the life cycle. Lack of oral health care may reflect a denial of mortality and normal body degeneration. Between the ages of 35 and 40 adults become reconciled to the fact they are aging and a renewed interest in self-preservation emerges. This interest is often directed toward various types of self-improvement such as orthodontic, cosmetic restorative, cosmetic periodontal, plastic or orthognathic surgery, or any combination of these. Patients sometimes cloak their actual dental needs with peripheral and unrealistic motivations, perceptions, and goals. At least some insight to understanding tangential orientations of these different types of patients might be necessary to complement a thorough examination and history.

Our teeth and mouths are critical to psychological development throughout life. Often, the way we treat our mouths and teeth indicates how we feel about ourselves. If we like ourselves, we work toward good oral health. Once we have reached this goal, our sense of well-being is increased (Figure 1.13A–C).

Figure 1.13 **(A)** This patient chose not to smile which affected her self-image and personality. **(B)** Since our teeth and mouths are critical factors in psychological development in life, it is not difficult to see why this patient chose not to smile.

Figure 1.13 **(C)** The smile was restored with an upper-implant-supported denture and a lower fixed and removable partial denture. Following a complimentary make-over, it is easy to see why this lady has a completely different outlook on life with her new self-image.

Burns, in his discussion of motivations for orthodontic treatment, cites the results of a study by Jarabak who determined five stimuli that may move a patient toward orthodontia. The motives, also applicable to esthetic dentistry, are as follows: (1) social acceptance, (2) fear, (3) intellectual acceptance, (4) personal pride, and (5) biological benefits. (It should be noted that these stimuli pertain only to patients who cooperate in treatment.)[6,19]

A spirit of cooperation and understanding between you and your patient is paramount to successful esthetic treatment. This relationship is a kind of symbiosis in which each contributes to the attitude of the other. The necessity for close observation and response on your part, particularly to nonverbal clues offered by the patient, cannot be overemphasized. The confidence generated by a careful and observant dentist will be perceived by the patient; so, unfortunately, will a lack of confidence. A competent, confident, professional dentist can reinforce the positive side of the ambivalence that patients feel toward persons who can help them but who they fear may hurt them.

Much psychological theory in dental esthetics must be formulated through analogy because of the comparatively recent recognition of the importance of dental esthetics and the consequent lack of a comprehensive database. The most obvious parallel field is plastic surgery. In a pioneering paper published in 1939, Baker and Smith[21] posited a system that categorized 312 patients into three groups based on personality traits as they related to a desire for corrective surgery, the motives for requesting it, and the prognosis for successful treatment.

- Group I—Ideal individuals for successful treatment with well-adjusted personalities, moderate success in life, aware that all life problems cannot be solved by better-looking teeth, and realistically want treatment to improve esthetics and/or for greater comfort. In your own practice, patients who fall into the first group are moderately successful people who want repair of their disfigurements for cosmetic reasons or comfort, not as an answer to all their problems. They do not expect too much from the improvement and they have a realistic visual concept of the outcome. They are ideal subjects for successful treatment.
- Group II—Irksome individuals of two types. The very irksome type are individuals who remain unhappy with results despite the excellent technical outcome achieved through prior treatment, indicating the same will happen with future treatments. Underlying that unhappiness, they continue past dysfunctional thinking about their prior appearance defects causing unrelated life problems outside the oral cavity or they find actual life with better-looking teeth to be not as great as they had earlier unrealistically fantasized. A substantially less irksome type in this Group II category are passive apologetic individuals who are grateful for any and all treatment, even though past results proved technically unsatisfactory as likely will be results of future treatments.
- Group III—Individuals with psychotic personalities for whom treatment outcomes will never be satisfactory in their view, regardless of actual technical results. Their visibly unattractive dental esthetics that existed before treatment served then as a focal point of their life problems and will probably continue always. With these people, any esthetic correction serves only to disrupt the rationalization process. Soon, some other defect is seized upon as the focus for their continuing psychotic delusions. These individuals warrant other professional treatment such as psychological or psychiatric counseling because dental treatment alone likely only disrupts their delusional rationalizations with no significant benefit in the longer term.

As expressed above, patients focused on cosmetic dentistry can be greatly appreciative and/or greatly demanding. Nevertheless, they must all be satisfied with their results. This satisfaction usually means their concept of a natural looking outcome that meets their pretreatment expectations and receives “a thumbs up” approval in the eyes of the patient and the most significant other(s) in the patient’s life. Advance measures, pretreatment, by the dentist to improve the likelihood of posttreatment satisfaction include the following:

- Listen well to the wants and perspectives of the patient before embarking on treatment. This “listening” extends to observing well any possible pertinent nonverbal clues exhibited by the patient.
- Discuss well any concerns, questions, expectations, and as much or little detail as appropriate for the individual patient.
- Present treatment options along with their procedures, timelines, advantages, and disadvantages or limitations.
- Be “realistically idealistic,” expressing the ideal but realistic scenario while being neither unrealistically optimistic that then builds too high of expectations that cannot be met and will generate dissatisfaction. Nor should you be unreasonably pessimistic. The latter balances lower expectations that results will nearly always meet and exceed and for that reason will nearly always generate substantial satisfaction with positive word-of-mouth evaluative comments to family and friends.
- Trial smile procedures are discussed in detail in Chapter 3.

The dentist–patient relationship should be long term, which by definition concerns posttreatment. Esthetic dentistry offers this opportunity more so than other dental treatments. Patients typically deliberate over this decision longer and with more thought invested than for other dental treatments. This greater investment in the decision process combined with improvement of appearance/physical attractiveness, as well as dental health, sets the stage for a rather special bonding consequence analogous to that between a cosmetic surgeon and a patient. To increase this likelihood, just as there are pretreatment alerts and actions for dentists when delivering esthetic treatments, there are posttreatment alerts and actions. For patients satisfied with their results, reinforcing words and careful direction for maintenance along with additional optional treatments might be well appropriate. This situation certainly poses opportunity for good word-of-mouth comments by the patient to family, friends, and potentially coworkers. Alternatively, the patient might experience confusion posttreatment. Commonly known as buyer's remorse, it is a mental uncertainty or uneasiness about whether the decision, effort, and cost were worth the change or lack of change in appearance. Dentists who perceive such will serve everyone well by explaining fully the situation and maybe at the same time meeting with the most significant other(s) in the patient's life.

Psychology and treatment planning

Esthetic dental treatment can enhance a patient's own intensely personal image of how he or she looks and how he or she would like to look. As Frush observes, "A smile can be attractive, a prime asset to a person's appearance, and it can be a powerful factor in the ego and desirable life experiences of a human being. It cannot be treated with indifference because of its deep emotional significance." Frush notes that in any esthetic treatment there is the need for consideration of a patient's satisfaction with the natural appearance and function of the result. Artificial appearance or failure to satisfy the patient's expectations may damage his or her ego. Frush terms such damage a negative emotional syndrome (J.P. Frush, personal communication).

Frush continues, "The severe emotional trauma resulting from the loss of teeth is well recognized, and dentists, being the closest to this emotional disturbance, normally have a deep desire to help the patient through the experience as best they can. It is of prime importance to understand that a productive and satisfying social experience after treatment depends upon the acceptance of the changed body structure and the eventual establishment of a new body image by the patient as it is. The acceptance of treatment by the patient is made considerably easier when the prosthesis accomplishes two basic esthetic needs: the portrayal of a physiologic norm, and an actual improvement in the attractiveness of the smile and thus all related facial expressions." Facilitating such acceptance requires several things from the dentist: (1) constructive optimism, never exceeding the bounds of fact and candor; (2) specific demonstration of the means and methods to be employed in treatment; and (3) an open discussion of all patient anxieties and the proposed treatment options.

> Healthy teeth are taken for granted; when they are painful, they become a point of exclusive attention. However, such overt stimulus is not necessary for a patient to become obsessively concerned about the appearance or health of the teeth. As an integral component of the body image, teeth can be the focus of feelings ranging from embarrassment to acute anxiety. As noted earlier, teeth may not be the actual cause of the disturbance, but instead the object of displaced anxieties.

All of these anxieties related to dental deformities are influenced by the patient's own view of the dental deformity and the reaction of other people to that deformity. Root notes that, "The first and foremost psychological effect of dentofacial deformity manifests itself in a sense of inferiority. This sense of inferiority is a complex, painful, emotional state characterized by feelings of incompetence, inadequacy, and depression in varying degrees."[22] These feelings of inferiority are a significant part of a patient's self-image, desire for treatment, and expectations of what the treatment can accomplish. Every patient is an individual and requires individual treatment. Generalities almost never apply; they are more useful as guidelines and suggestions than as prescribed courses or methods of treatment.

Predicting patient response

When certain patients appear for treatment, it is wise to proceed with extreme caution, and it is suggested that function alone be used as the criterion for operative intervention. Regardless of the technical success of the procedure, it would only serve to exacerbate, rather than remove, expression of their incipient psychosis. Many times, the restorations look good to you, but the patient still expresses dissatisfaction. This dissatisfaction may be a manifestation of some underlying fear or insecurity rather than a desire for artistic perfection in the restoration. Desire for artistic perfection may be indicative of a patient's underlying problems and may make it impossible for you to treat that person successfully. If we can know enough about the patient's personality to determine the various factors influencing his or her desire for esthetic correction, we would then be better equipped to predict the degree of psychological acceptance of that correction.

> How can these patients be recognized by the busy dentist? Although experience may be the best teacher, the cardinal requirement is to show an interest in the patient's complete makeup. Look at the patient as an integrated human being, not just as another oral cavity. Baker and Smith offer the following questions to help evaluate patients:[21]
>
> 1. What was the patient's personality prior to the disfigurement?
> 2. What was the patient's emotional status when first conscious of his or her disfigurement?
> 3. What part has the disfigurement played in forming the present personality? In other words, is there some limitation in personality development because, for instance, the patient does not smile? What habit patterns have developed?
> 4. What will probably be the emotional effect of the esthetic correction of the defect?

Obviously it will take some time to arrive at the answers. The conclusion should reveal to which group this patient belongs, and in this way you can better predict the patient's acceptance of the esthetic results. Consideration of the emotional status of any patient who seeks esthetic treatment is important. It can help preclude unpleasant reactions toward either the treatment or you in those cases where treatment, though functionally and artistically successful, is unsatisfactory to the patient. Therefore, the patient's entire personal, familial, and social environment must be considered in relation to esthetics.

Figure 1.14 **(A)** This patient reached a point in her life where she realized her smile was looking much older than she felt.

Figure 1.14 **(B)** A new smile make-over helped restore her youthful smile and self-esteem.

"Crossroads"

Well-adjusted individuals go through life, treating esthetic dental problems as tooth-by-tooth decisions. However, many individuals reach a point in their lives where they look in the mirror and realize their smile is looking much older than they feel. Such was the case with the patient in Figure 1.14A and B. Many years ago, the American Dental Association even made a movie about these individuals who reach a "crossroads" in their lives.

And, in those regards, the patient's entire personal, familial, and social environment must be considered in relation to esthetics.

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Chapter 2 Successful Management of Common Psychological Challenges

Shirley Brown, DMD, PhD

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I had rarely heard him sounding so emphatic or so perplexed. My friend and colleague, Dr J, is a renowned restorative dentist. He called to refer a patient to my psychotherapy practice:

"I told her I might be able to help her, but that I won't even touch her mouth until she sees you for psychotherapy."

Really? What's the issue?

"Well, she's a lovely 45-year-old, a successful radiologist who, since having a porcelain crown placed on tooth number 5 about a year ago, believes that she is hideous and refuses to be seen in public. She's had to resign from her medical practice. Other than doctors' appointments, she won't leave the house. She even cuts her own hair! She harassed the office of the dentist who made her the crown to such a degree that he had to change the office phone number. Each plastic surgeon she consults tells her she's just aging, which has convinced her of a local conspiracy against her by plastic surgeons. The dentist who treated her is very capable, and a number of terrific dentists have refused to treat her. The thing is, she actually does have some occlusal problems, and I agree the crown could look a little more harmonious. The woman is truly suffering, and I think I could help her. But not until she's had some therapy!"

Ok. Well, thanks for the referral… I'll try to get her scheduled and see what I can do. I'll be in touch.

Ronald E. Goldstein's Esthetics in Dentistry, Third Edition. Edited by Ronald E. Goldstein, Stephen J. Chu, Ernesto A. Lee, and Christian F.J. Stappert.

Introduction

One of the greatest challenges in dental practice is the psychologically difficult patient. We dentists are entertained by sharing our tales of the strange and outrageous, patient "war stories." Patients, for their part, lament the apparent obliviousness of the "typical" dentist, who fills the mouth with instruments and cotton before embarking on provocative topics of conversation. Patient behaviors in the dental chair range from routine to irrational, and dentists' management skills range from naturally talented to insensitive and impatient. Certainly, most dental school applicants emphasize their "people skills" in their application essays. Yet dental education generally lacks formal training in psychology or patient management. This state of affairs leaves many dentists poorly equipped to successfully handle the challenging patient encounter, and many patients wishing for greater mental comfort from their dental experiences. The benefits of closing the often wide gap between patient demand and dentist skills are many, and include reduced stress for all concerned, better treatment plan acceptance, better clinical outcomes, and practice growth through referrals from satisfied patients. Since it can be nearly impossible for patients to evaluate a dentist based on his or her technical proficiency, it is pain management and patient comfort that distinguish the patient-rated "great" dentists from all others. This results in enhanced referral rates as well as reduced risk of malpractice suits.

For the dentist whose practice focuses primarily or largely on esthetic procedures, there are additional, very particular considerations in the area of patient management. This is due to the fact that higher concentrations of certain patient types are more likely to seek esthetic dentistry. These include individuals going through normative life transitions when their physical appearance has greater than usual salience, such as early and middle adulthood, as well as patients with certain pathologies of mood, behavior, and personality, such as depression, eating disorders, and narcissistic personality disorder (NPD). See Table 2.1.

This chapter provides you with detailed background information on each of the most common patient challenges that you are likely to encounter and clear guidelines for improved management of these patients. Case examples will provide "real-life" illustrations and will go beyond the usual sharing of bizarre or frustrating experiences with patients to a more informed and practical understanding from which to enhance the success and satisfaction of esthetic dental practice.

Brief description of psychological terms and concepts

Mood disorders are the most common psychological diagnoses in the general population and thus in dental practice (20.8% in the US adult population).[1] The rate of major depression has been estimated at 19%,[1] the rate of bipolar disorder (BD; formerly manic depressive disorder) is estimated to be 3.9%,[1] the rate of anxiety disorders, such as obsessive-compulsive disorder (OCD), is estimated to be 18.1% of the US population.[1] These three main

Table 2.1 Disorders of Special Concern to Esthetic Dentists

Category	Disorder
Mood disorders	Depression Bipolar disorder (BD) Obsessive-compulsive disorder (OCD)
Eating disorders	Anorexia nervosa (AN) Bulimia nervosa (BN)
Personality types	The anxious patient The angry patient The demanding patient
Narcissistic personality disorder (NPD)	
Life event stress/ adjustment disorder	
Body dysmorphic disorder (BDD)	

mood disorders should be clearly understood by the esthetic dentist because of management demands and because psychoactive medications commonly used to treat these syndromes can affect the oral cavity significantly. In addition, body dysmorphic disorder (BDD), which is a less prevalent subcategory of OCD, is particularly important to understand as it presents extreme and special challenges and protocols for the dental practice.

Eating disorders, which include anorexia nervosa (AN) and bulimia nervosa (BN),[2] are of high and increasing prevalence in the general population, estimated at 2.7% in US children and adolescents; AN is estimated at 0.6% in US adults (0.9% female and 0.3% male), and BN at 0.6% in US adults (0.5% female and 0.1% male).[1] Although both of these syndromes present the dentist with specific clinical and management challenges, there is a higher concentration of individuals with BN who seek esthetic dental procedures. This is in part because people whose work places them in the public eye, such as modeling, acting, and television talent, are under higher pressure to maintain thinness and therefore at greater risk of becoming bulimic. Of all the eating disorders, BN results in the greatest degree of damage to oral structures, particularly the anterior esthetic zone of the mouth, for reasons to be described. Mortality rates from medical complications and suicide have been estimated at 4% for AN and 3.9% for BN, the highest of all mental disorders.[3]

Personality disorders are a group of conditions in which the individual's persistent style of thinking, feeling, and behaving deviate significantly from social norms and interfere with personal and professional relationships. These differences stand apart from the symptoms of mood disorders, which can cooccur, and generally respond to long-term psychotherapy but not to psychoactive medications. Of the 10 main personality disorders, NPD stands out as a significant source of management challenge for the dentist. Prevalence rates for the personality disorders cannot be meaningfully estimated due to the difficulty of accurate survey measurement.

Patients with difficult personalities that are not so extreme as to be diagnosed as "disordered" will also be discussed (such as being angry or demanding), as they comprise a large segment of the esthetic dentistry patient population.

Adjustment disorders are diagnosed when individuals lack adequate coping skills to handle specific life events, such as relationship breakups, poor grades, job loss, illness, and aging. This diagnosis is rendered when there is a specific event that causes marked distress that interferes with social and/or occupational functioning, in excess of what would normally be expected. It has been criticized as being too vague a diagnostic category, yet clinicians do find it to be useful and the dentist is likely to encounter it. Some patients will be reacting within normal limits to stressful life events, and others will react pathologically. Both subcategories will potentially require extra management care to optimize dental treatment success.

Mood disorders

Depression

Case example: Depression

Steve, a patient who had an esthetic reconstruction 2 years previously, arrives for his recall visit. On his medical update form, Steve indicates that since his last recall he is now taking a new medication, the antidepressant Zoloft (sertraline). His oral examination reveals poor oral hygiene, gingival inflammation, and incipient marginal caries around several of his all-ceramic crowns. When gently queried by his dentist, Steve discloses that in the past year he had experienced a major depressive episode that included a suicide attempt. He had been hospitalized, successfully stabilized, and is now doing much better in regular weekly psychotherapy and antidepressant therapy. Steve admits that his mouth is constantly quite dry and his gums bleed when he brushes his teeth. He admits to having ceased all flossing during his illness, but is ready to "get back on track with everything."

Case example: Undiagnosed depression

Susan arrives for her new patient visit after having made and canceled three previous appointments. She makes little eye contact and interacts only minimally with the front desk staff. The receptionist alerts the dentist to her unusual behavior. Susan mentions to the hygienist conducting the oral exam that her reason for seeking treatment is to improve the esthetics of her smile, in the hope that looking better would help her feel better. Her oral exam reveals poor oral hygiene, and all of her incisors are chipped, discolored, and evidence severe occlusal wear. The hygienist passes all of this information on to the dentist, so that when he begins his consultation he is suspicious that Susan might have a psychological problem, perhaps depression. Indeed, since he is aware of the typical signs of the disorder, the dentist is able to include specific questions in the interview while reviewing Susan's medical history, and thereby learn that Susan is feeling blue and weepy, having trouble sleeping, and does not have her usual energy. This had been her condition for the past 2 months.

These two patients exemplify some of the major challenges facing the dentist when dealing with patients with depression, a highly prevalent mood disorder. In the case of Steve, the challenge is primarily clinical management of his present mental and dental status coupled with enhanced oral disease prevention. For Susan, the challenges include detecting the possibility of undiagnosed depression, successful referral for mental health treatment, and staging of esthetic dental rehabilitation to minimize treatment failure and maximize the positive effects of improved dental esthetics on her overall health and well-being.

Elements of successful dental treatment of behaviorally challenging patients include careful screening and assessment, psychiatric consultation or referral, and clear communication, particularly in the area of treatment planning. The extra time and effort can be more than offset by enhanced patient comfort and compliance, and thus greater treatment success and dentist satisfaction. It is also very effective to foster close communication among all members of the dental team—from receptionist to hygienist to assistant to dentist—since patients often reveal important information to staff members, who can alert and guide the dentist to a possible management problem early enough in the process that critical adjustments can be made and conflicts or errors prevented.

Box 2.1 lists the diagnostic criteria for major depression in the current *Diagnostic and Statistical Manual* used in psychiatry and psychology (*DSM-5*).[2] It is helpful for dentists and their treatment teams to be familiar with these criteria when evaluating new and returning patients for esthetic treatment. It is also advisable that medical history forms used in esthetic dental practice include specific questions that can gently yet clearly elicit signs that a patient may be suffering with depression, whether previously diagnosed or not.[4,5] Alternatively, you may prefer to administer a brief, validated depression questionnaire such as the Beck Depression Inventory (BDI).[6] Although Steve was forthcoming about his depression history, many patients unfortunately feel too stigmatized to offer such details voluntarily. Specific questions and validated questionnaires are no guarantee, but they do increase the probability of disclosure significantly. Box 2.2 lists suggested depression-related questions for inclusion on medical history forms.

Our patient Steve illustrates some of the most important management considerations when dealing with a history of depression. First and foremost, you and your staff should approach a patient like Steve in a manner that is respectful, concerned, and competent. He should be made to feel comfortable with having disclosed details of his illness, since only with such disclosure can he be treated safely and effectively. He should be reassured that his dental needs can be addressed, after some preliminary data gathering, and that his psychiatric history will be kept confidential. It will be necessary for the dentist to obtain the patient's written consent to communicate with the psychiatric treatment team, in this case consisting of his psychiatrist and psychotherapist. This consent must be given by the patient to all of the doctors who wish to communicate with each other, and is a standard aspect of psychotherapy practice.

Once consent for release of information has been obtained, the dentist should speak to the patient's prescribing psychiatrist

Box 2.1 Diagnostic criteria for major depressive disorder.

Five (or more) of the following symptoms have been present during the same 2-week period and represent a change from previous functioning.

1. Depressed mood most of the day, nearly every day, as indicated by either subjective report (e.g., feels sad or empty) or observation made by others (e.g., appears tearful). Note: in children and adolescents, can be irritable mood.
2. Markedly diminished interest or pleasure in all, or almost all, activities most of the day, nearly every day (as indicated by either subjective account or observation made by others).
3. Significant weight loss when not dieting or weight gain (e.g., a change of more than 5% of body weight in a month), or decrease or increase in appetite nearly every day. Note: in children, consider failure to make expected weight gains.
4. Insomnia or hypersomnia nearly every day.
5. Psychomotor agitation or retardation nearly every day (observable by others, not merely subjective feelings of restlessness or being slowed down).
6. Fatigue or loss of energy nearly every day.
7. Feelings of worthlessness or excessive or inappropriate guilt (which may be delusional) nearly every day (not merely self-reproach or guilt about being sick).
8. Diminished ability to think or concentrate, or indecisiveness, nearly every day (either by subjective account or as observed by others).
9. Recurrent thoughts of death (not just fear of dying), recurrent suicidal ideation without a specific plan, or a suicide attempt or a specific plan for committing suicide.

Box 2.2 Depression - related questions for inclusion on medical history forms.

Since your last dental visit, have you been bothered by any of the following?

- Attention problems or difficulty focusing
- Feeling hopeless or helpless
- Crying spells
- Increased appetite
- Decreased appetite
- Inadequate sleep or insomnia
- Excessive sleepiness
- Lack of energy
- Loss of interest or pleasure in your usual activities
- Persistent sadness or low mood
- Increased irritability
- Increased worry about your health
- Suicidal thoughts

about his antidepressant therapy and document medical approval for dental treatment. Possible interactions of the antidepressant medication with agents and medications that may be used in dental treatment, including local anesthetics, vasoconstrictors, antibiotics, and analgesics, should be discussed, and medical permission documented, particularly if he has any other medical conditions, like cardiac disease. *This is vitally important* because antidepressant medications can interact adversely with epinephrine, codeine, benzodiazepines, and erythromycin, and can cause orthostatic hypotension. These concerns are particularly important in patients with preexisting cardiac disease, in whom the risk of atrial fibrillation and ventricular tachycardia may be increased.[7] While these interactions are less frequent with newer antidepressants, such as Wellbutrin (bupropion), and selective serotonin reuptake inhibitors (SSRIs)—the category of antidepressants to which Zoloft (sertraline) belongs—they continue to be a concern with older categories of antidepressants still in use, such as tricyclic antidepressants (TCAs) and monoamine oxidase inhibitors (MAOIs).[7]

It may be advisable for you to consult with the patient's psychotherapist at this stage as well, gaining any suggestions for ways to be more responsive to his needs, to establish a collaborative professional relationship, and to partner with the therapist in staging the treatment to maximize its positive impact on his self-esteem and emotional stability. Once he has been medically cleared for treatment, and you have attained a fuller understanding of his psychiatric history and current status, you may proceed with the dental treatment plan.

Steve's oral examination findings were consistent with the typical presentation of depressed individuals: due to low mood, oral hygiene is often neglected, leading to gingival inflammation and periodontal disease. Xerostomia is a common side effect of most antidepressant medications (Figure 2.1).[7,8] Individuals often use sugar-sweetened candy and beverages to stimulate salivation, and it is not unusual for the quality of their diets to deteriorate while experiencing major depression. These factors combine to increase the caries rate in patients with major depression.[7,8]

Therefore, treatment planning should focus on treating and preventing periodontal disease, through subgingival scaling and root planning, restoring the dentition through caries elimination, and enhanced emphasis on in-office oral hygiene therapy and improved home care. More frequent recalls and topical fluoride applications have been strongly recommended.[8] The dentist should not hesitate to recommend an improved, less cariogenic diet to both the patient and the medical treatment team. Artificial saliva products and sugar-free candies and gum to stimulate salivation can be very helpful in reducing the effects of xerostomia.[7,8]

Susan, the other new patient profiled above, certainly seemed to be an excellent candidate for esthetic restoration, based on

Figure 2.1 Individuals with mood disorders may present with rampant caries, due to poor oral hygiene and xerostomia from some psychoactive medications.

her oral examination. However, her behavior and medical history suggested that she might be suffering from an as yet undiagnosed major depressive episode. The best way for you to approach a patient like Susan would be to establish rapport with her as well as possible in the initial visit by carefully reviewing her medical and dental histories and gently inquiring as to whether she had considered that she might be suffering with depression. You should be prepared to give her contact information for several well-regarded psychiatrists and psychotherapists in the community. The best-case scenario is that you have accurately detected a case of depression and that the patient will follow up with psychiatric treatment.

Whether or not this occurs, the dental treatment plan should begin with scrupulously clear communication between you and the patient. You should use photos of esthetic smiles to elicit a sense of what she expects as an esthetic result, and ascertain whether or not her expectations are reasonable. If they are not, some extra time spent illustrating what she *can* expect will help to prevent disappointment and difficulties at the end of the active treatment phase. Once you and the patient have worked out an agreement on the esthetic goals, you should prepare a detailed treatment plan—including such details as a description of what she will experience with her temporary restorations, how long appointments should take, the projected interval of time between appointments, and the realistic appearance of the final restorations.[4,5] The patient should then be asked to sign a statement indicating that she has understood and agrees to the treatment plan. In this way, important details are discussed in advance, consent to the treatment plan is as fully informed as possible, and treatment can proceed in an atmosphere of enhanced trust.

Successful behavioral management might require the patient's visits to be shortened to accommodate her emotional state. She may also require extra encouragement and reassurance. Clinical dental management should include intensive oral hygiene instruction and frequent oral prophylaxis with topical fluoride application, particularly if the patient commences pharmacotherapy with antidepressant medication, putting her at risk of xerostomia and caries. As Susan's depression ameliorates, and as Steve continues to enjoy emotional stability through psychiatric care, the improvement in their smiles is likely to contribute significantly to their emotional health. It is well documented that renewed dental health, especially when dental esthetics have been improved, can contribute to a depressed patient's recovery and long-term emotional stability through enhanced self-esteem and confidence (Figure 2.2).[4,5,7,8]

Figure 2.2 Dental restoration can enhance optimism and self-esteem in patients with a history of mood disorder.

Bipolar disorder

Case example: Bipolar disorder

A patient, who at his last visit disclosed a history of depression, seems to be euphoric. He arrives late, explaining that he was delayed because he had to stop and write down ideas for a novel that is sure to win a Pulitzer or Nobel Prize. He charmingly offers to "make it up" to the office staff by buying everyone dinner after work. He speaks so rapidly and loudly that it is hard to understand him, and he bounces from one unrelated topic to another.

This is an unlikely scenario, but if it were to occur, your best course of action would be to urge the patient to seek emergency psychiatric care for bipolar disorder (BD). Individuals experiencing a manic episode, as illustrated above, often experience a very rapid mood swing back to deep depression, and self-destructive—even suicidal—behaviors are not uncommon. The scenario is unlikely, since a manic, euphoric patient is probably not going to be thinking about visiting his dentist! The diagnostic criteria for BD are extremely complex, and therefore beyond the scope of this chapter. The interested reader is advised to consult the *DSM-5*.[2]

You are much more likely to encounter a patient with BD who has been previously diagnosed and whose mood has been stabilized by psychiatric treatment. As with depression, you should obtain the patient's written consent to consult with the psychiatric treatment team, to review the patient's current mental status, medications, and any risk of adverse interactions with local anesthetics and other medications commonly used in dental treatment, as well as possible considerations for dental treatment timing and staging.

Patient management should be guided by the awareness that, despite psychiatric treatment, the patient with BD may still suffer rapid mood changes that may affect oral hygiene, commitment to treatment, and ability to tolerate extensive dental procedures.[9,10] As with unipolar depression, it is advisable for you to do your utmost to make sure the patient's expectations of the final result are realistic, to provide a detailed treatment plan, and to have the patient sign an agreement based on the aforementioned criteria. This patient will likely require a little extra patience and encouragement, and possibly shorter appointments. The patient with established BD is likely to be taking an antidepressant as well as a mood stabilizer, such as lithium or lamotrigine, all of which may cause chronic xerostomia. A dry mouth management protocol may be required.

Whereas the patient with BD going through a depressive phase will often present with poor oral hygiene, those having just experienced a manic phase of the disorder may show evidence of overly vigorous flossing and brushing, such as notched gingival lesions and excessive cervical tooth abrasion.[9] Once again, thorough and frequent oral prophylaxis and oral hygiene instruction are of paramount importance, along with use of topical fluorides and dietary counseling.

As with the depressed patient, a relatively small investment in time, effort, and information gathering promotes successful relationships and treatment of the esthetic dental patient with BD. The opportunity to enhance the self-esteem and psychological well-being of such patients can be particularly satisfying for the esthetic dental team.

Obsessive-compulsive disorder

Case example: Obsessive-compulsive disorder

Jerry had been a highly particular patient from his very first visit, but his behavior really raised alarms when he failed to show up for his recall appointment, especially when he disclosed the reason for his "no-show." He had chosen to be treated in this practice based on its reputation not only for high-quality esthetic dentistry, but even more for its adherence to strict sterilization guidelines. Office sterility was, according to Jerry, always his greatest concern. After his previous dentist retired it had taken him a while to find another office he could trust to be as clean as he needed it to be. Jerry was willing to drive from his home over an hour away from the practice.

Another concern of Jerry's was radiation exposure. He refused most dental radiographs, except when a tooth was symptomatic or to check an endodontic procedure, and insisted on being fully swathed in lead aprons. Jerry also elected to have his procedures done without local anesthetic. He explained that the discomfort was less aversive than his concern about possible needle contamination. The dental team members were willing to comply with these limitations and were careful to document in the patient's chart whenever he declined a recommendation.

Jerry was otherwise a patient who was easy to accommodate: he paid his bills on time, complied with treatment, and reliably arrived early for his appointments, always providing adequate notice when he needed to change his appointment schedule.

When he failed to arrive for his recall, the dentist and his staff were concerned, since it was so extraordinary, and their concerns were only heightened when they learned his reason: "You see, after I drove to the appointment and parked my car, I remembered that the hygienist had just returned from her maternity leave. I became afraid that if someone didn't pick up after their dog and I unknowingly stepped in it, I could pass the germs on to the hygienist, who might then pass them on to her new baby and make her sick. I just couldn't come in. So I drove all the way back home. I'm so sorry!"

At this point, the dentist decided to contact a psychologist to whom he often referred, who confirmed that Jerry was most likely suffering with a type of anxiety disorder known as obsessive-compulsive disorder (OCD), the diagnostic criteria of which are found in Table 2.2. The dentist's role, in this instance, was to

Table 2.2 Diagnostic Criteria for Obsessive Compulsive Disorder (OCD)

Must exhibit obsessions or compulsions	The obsessions and/or compulsions cause marked distress, are time-consuming (take more than 1 h per day), or interfere substantially with the person's normal routine, occupational or academic functioning, or usual social activities or relationships.
	The content of the obsessions or compulsions should not be restricted to any other major Axis I psychiatric disorder, such as an obsession with food in the context of an eating disorder.
Obsessions	Recurrent and persistent thoughts, impulses, or images experienced, at some time during the disturbance, as intrusive and inappropriate and cause marked anxiety or distress.
	These thoughts, impulses, or images are not simply excessive worries about real life problems.
	There is some effort by the affected person to ignore or suppress such thoughts, impulses, or images, or to neutralize them with some other thought or action.
	At some time, the affected person recognizes that the obsessions are a product of his or her own mind rather than inserted into his or her own mind from some outside source.
Compulsions	Repetitive activities (e.g., hand washing, ordering, checking) or mental acts (e.g., praying, counting, repeating words silently).
	The person feels driven to perform these in response to an obsession or according to rules that must be applied rigidly.
	These behaviors or mental acts are performed in order to prevent or reduce distress, or prevent some dreaded event or situation.
	However, they are either clearly excessive or not connected in a realistic way with what they are designed to neutralize or prevent.

speak with Jerry about this possibility, gently encourage him to obtain professional help, and offer several good referral options for psychologists and psychiatrists. Jerry selected one of the psychologists on the dentist's list, an international expert who happened to have her research center and practice in the area.

This case illustrates the relative ease with which a demanding patient can be accommodated, and the importance of building rapport and trust between the patient and the dental team. Without such trust, it would have been much less likely that the dentist would have felt comfortable discussing the suspected problem with Jerry, and even less likely that Jerry would have acted on the recommendation. When he returned for his recall after successful stabilization of his OCD, he was extremely grateful to the dental team for their sensitivity and help, and was able to proceed with esthetic dental treatment.

Eating disorders

Case example: Bulimia nervosa

At age 23, Jenna had secretly suffered with severe bulimia for 10 years when she made what turned out to be a fateful dental appointment. Years later, looking back on how she began her recovery from bulimia, it would seem ironic that she would credit her dentist with responsibility for helping her to take the first steps toward a more normal life. And yet she now realized that the effects of so many years of multiple daily vomiting episodes had produced a distinctive and characteristic pattern of damage in her mouth. Being gently yet firmly confronted with it by her new dentist, she could no longer continue denying that she had a severe problem and needed help.

Her recovery began when a friend remarked that her front teeth looked a little strange. She realized she had convinced herself that no one noticed her teeth, but that this was clearly a distortion of reality. Her embarrassment prompted two reactions: first, and characteristically, a new round of intense binging and purging, but second, and more importantly, a decision to find an excellent dentist, one who practiced far enough away from where she lived that he would not be likely to know her parents or any of her friends. She made an appointment for an examination. Filling out the medical history form raised her concerns about detection somewhat, since they included specific questions about recent weight fluctuations and eating habits. She hesitated over these, and then decided to answer them as truthfully as she could without divulging just how severe her eating problems were.

Fortunately, her dentist was well informed as to the characteristic presentation of individuals with bulimia. Indeed, the suspicions raised by his new patient's appearance and history were confirmed by even a cursory look at her face and mouth. The first thing he noticed about her was how tense her facial musculature appeared, especially her upper lip. This was a facial posture that had become natural to her, as the need to hide her worsening anterior dentition had progressed over the years of binging and purging.

The dentist also noticed the puffiness of her cheeks and the squarish appearance of her lower face that were the results of parotid swelling, findings that he knew were common in patients who habitually induced vomiting. He was also able to glance at her hands, where he saw the characteristic callus on the knuckle that had been raised by being scraped against her front teeth countless times during purging by stimulating the palate with her index finger to induce vomiting.

The dentist knew that bulimia is an extremely secretive disorder, one that sufferers were deeply ashamed to admit to and that he would have to approach his new patient with sensitivity and care. He was prepared with a bulimia hotline number, eating disorder treatment and support websites, and names of local treatment centers and therapists whom he trusted. So he explored the subject with her using a recommended approach:

"It's my job to understand problems that you're having with your mouth but that may influence your overall health as well. I'm here to help you beyond just repairing your teeth. The changes in your teeth are ones I usually see in people who vomit very often, and your responses to some of the questions on the medical history form are ones that I usually see in people who have an eating problem. Have you been having a problem with binging and purging?"

The preceding case study illustrates the vital role that the informed dental team can play in the diagnosis and treatment of individuals with eating disorders like bulimia nervosa (BN). There is also wide agreement that, due to the often severe damage to the dental anterior esthetic zone inflicted by frequent vomiting, as well as the prevalence of this syndrome in young women and other individuals highly concerned about their appearance, the esthetic dental team is more likely than others to encounter increased numbers of eating-disordered individuals seeking their services. The diagnostic criteria for anorexia nervosa (AN) and BN are listed in Table 2.3. Both anorexia and bulimia are extremely serious psychological disorders that can end in death as a result of severe physical complications or suicide.

Bulimia nervosa

In contrast to someone with anorexia, who will present with obvious emaciation, the new dental patient with BN will not likely be identified based on weight, since individuals with BN typically appear to be of normal or average weight. This greatly increases the likelihood that dentists will encounter new patients with *undiagnosed* BN. The informed dental team can play a crucial role in the detection, referral for treatment, and case management (i.e., secondary prevention) of BN.[11–15] As illustrated by the case study earlier in this section, this is because individuals with BN, who due to intense shame about their disorder often remain untreated for years and even decades, usually display a distinct pattern of oral and physical findings that are pathognomonic of BN. The dentist and team who are equipped with knowledge about these findings may therefore be the first to detect BN, presenting a unique opportunity and responsibility to diagnose, refer, and help manage the medical and psychological treatment of these patients.

Table 2.3 Diagnostic Criteria for Anorexia Nervosa (AN) and Bulimia Nervosa (BN)

Anorexia nervosa	Refusal to maintain body weight at or above a minimally normal weight for age and height (e.g., weight loss leading to maintenance of body weight less than 85% of that expected; or failure to make expected weight gain during period of growth, leading to body weight less than 85% of that expected).
	Intense fear of gaining weight or becoming fat, even though underweight.
	Disturbance in the way in which one's body weight or shape is experienced, undue influence of body shape on self-evaluation, or denial of the seriousness of the current low body weight.
Bulimia nervosa	Recurrent episodes of binge eating. An episode of binge eating is characterized by both of the following:
	1. Eating, in a discrete period of time (e.g., within any 2 h period), an amount of food that is definitely larger than most people would eat during a similar period of time and under similar circumstances.
	2. A sense of lack of control over eating during the episode (e.g., a feeling that one cannot stop eating or control what or how much one is eating).
	Recurrent inappropriate compensatory behavior to prevent weight gain, such as self-induced vomiting; misuse of laxatives, diuretics, enemas, or other medications; fasting; or excessive exercise.
	The binge eating and inappropriate compensatory behaviors both occur, on average, at least once a week for 3 months.
	Self-evaluation is unduly influenced by body shape and weight.
	The disturbance does not occur exclusively during episodes of AN.

An esthetic dentistry practice is likely to encounter a higher number of individuals with BN because there is high overlap between individuals at elevated risk of becoming affected by bulimia and the patient population of an active esthetic dentistry practice. High-risk populations for BN include:

- girls and young women
- middle-aged women
- gay men and sexually conflicted younger men and boys
- certain athletes—gymnasts, wrestlers, jockeys
- dancers, especially classical ballet
- fashion models
- people in the public eye—actors, TV talent
- people of relatively high socioeconomic status
- people in high-pressure professional positions, especially female chief executive officers.

Therefore, it is essential for the esthetic practice to be equipped to detect, communicate, refer, and help manage the patient with BN and to stage esthetic reconstruction to produce the most positive influence on the patient's recovery and the greatest longevity of the dental restorations. Detection can best begin by embedding specific questions in the new patient medical history form (see below). A positive response to any of these questions should raise the suspicion of the member of the team administering and reading the form; these positive responses should be flagged for the dentist at the first visit.

Suggested questions for patient medical history form:

- Do you spend a lot of time worrying about your weight and wishing you were thinner?
- Does your weight often fluctuate by more than 5 lb (2.25 kg)?
- Have you ever tried to make yourself vomit after eating too much?
- Have you ever used laxatives to lose weight?
- Do you go on diets frequently?
- Do you exercise specifically to make up for extra calories?
- Have you developed chronic painless swelling below your ear(s)?

As you move on to the oral exam, you should assess the appearance and symmetry of the patient's face, since people with BN frequently present with swelling of one or both parotid glands (Figure 2.3). The presence and extent of parotid swelling correlate with the duration and frequency of daily vomiting. It is not unusual for parotid swelling and the resulting squarish appearance of the lower face to be the patient's presenting complaint. As in the case of Jenna described above, many people with bulimia develop a tight lip posture when they speak and smile, a habitual way of attempting to hide the damage to their front teeth. In addition, people who vomit frequently may present with significant eye puffiness.

You might also attempt to visualize the patient's index and middle finger knuckles for calluses (Russell's sign; Figure 2.4). These can develop from the repeated action of scraping the knuckles against the upper teeth, in the process of using the fingers to induce the gag reflex in the soft palate to induce vomiting after a high-calorie binge.

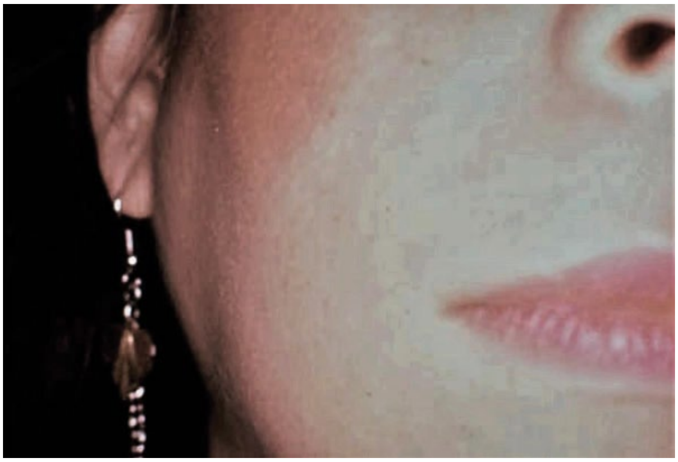

Figure 2.3 Parotid gland enlargement in bulimia nervosa.

Figure 2.4 Russell's sign: knuckle calluses resulting from induced vomiting in eating disordered patient.

Figure 2.6 Palatal enamel erosion and "amalgam islands" from frequent vomiting in BN.

Figure 2.5 Typical glassy erosion—perimylolysis—seen in bulimic individuals. Note lingual erosion of cuspids and bicuspids, with narrow enamel band at gingival margins.

The most common and most damaging finding in the mouths of people with BN, particularly after at least 2–3 years of multiple daily vomiting episodes that repeatedly bathe the teeth in corrosive stomach acids, is a unique pattern of dental erosion. Known as *perimylolysis*, this erosion typically occurs on the palatal surfaces of the upper anterior teeth, with thinning and notching of the incisal edges of the upper and lower anterior teeth, and posterior amalgam or composite restorations that appear as raised islands, where the enamel has eroded around them, along with smooth, glassy loss of contour on unrestored teeth.[11,13,14] In the early stages of the disorder, the erosion will be milder and appear as glassy smoothing of normal anatomy. When advanced, this erosion often causes thermal sensitivity, another common presenting complaint (Figures 2.5 and 2.6).

Self-induced vomiting may cause visible traumatic lesions on the soft palate and upper pharynx. Xerostomia is also a frequent finding, the result of poor nutrition and dehydration. Many individuals with BN seem to be fastidious about their oral hygiene, so the caries rate may not be increased. However, where there is extensive cervical erosion after many years of vomiting, exposed dentin surfaces can become carious. Furthermore, many patients with BN experience periods of depression, during which time they may neglect their hygiene and experience increased caries, particularly if they tend to binge on cariogenic foods.[16] (See Chapter 22 in this volume, entitled Abfraction, Abrasion, Attrition, and Erosion.)

Any combination of positive answers to screening questions and positive physical and oral findings should raise serious suspicions that the new patient is presenting with a case of undiagnosed BN. At this point, many dentists might experience uncertainty about how to proceed. It is an unfortunate, if understandable, fact that most dentists do not feel equipped to confront their patient with these concerns.[13,15] Given the high likelihood of encountering patients with undiagnosed BN in an esthetic dentistry practice seeking to improve their oral health and especially a damaged smile, it is incumbent on you to gain confidence in your ability to speak with these patients about their bulimia and establish a safe environment. See the suggested script used by Jenna's dentist in the previous case example of BN.

Naturally, many individuals who have been hiding their bulimia for a long time will initially deny their problem. They may even have learned to attribute the erosion to high consumption of lemons or to chronic acid reflux from gastroesophageal reflux disease (GERD). It is also the case that some new patients will have experienced weight change and body size preoccupation—and indicate such on their medical history form—without suffering from an eating disorder. You and your team should be very aware, therefore, that enamel erosion from habitual lemon or acidic soft drink consumption occurs primarily on the *facial* and *cervical* surfaces of the teeth, and erosion from GERD occurs primarily on the *occlusal* surfaces in the *posterior* region of the mouth where the acidic refluxed material pools. Only long-term, repeated vomiting produces the particular erosion pattern of perimylolysis: *mostly on the palatal surfaces, mostly on the anterior teeth*, where the stomach acids are propelled during vomiting, and where the rasping thrust of the tongue's action accelerates the erosion.

Alone, or especially in combination with any of the other common signs of bulimia—that is, parotid enlargement, palatal lesions, knuckle callus, and positive responses to the medical intake questions—this erosive pattern of perimylolysis is pathognomonic for BN and should immediately signal you to step into the vital role of secondary prevention of this potentially life-threatening syndrome.[11,13,15]

The patient who denies the problem—and this is expected—should nevertheless be offered the names and contact information of local treatment centers and therapists who specialize in eating disorders. It is also very helpful to provide a list of online resources, such as informational and supportive websites and hotlines, for people struggling with eating disorders. Many practitioners fear that if they persist in this way, they may lose the patient. Actually, this can be accomplished in a nonconfrontational yet concerned manner that the patient is much more likely to experience as caring and vitally helpful, even if he or she continues to deny the problem. With the goal of retaining the patient while encouraging him or her to seek medical and psychological care, it is recommended that you schedule the patient for an initial oral prophylaxis and treatment planning appointment at this time, while also letting the patient know that you intend to follow up regarding your concerns.

At subsequent appointments, the subject of BN should be raised again in a concerned manner, and the patient should be told that you recommend only palliative care until the teeth are no longer vulnerable to ongoing erosion, since this will significantly compromise the process and prognosis of the restorations. While palliative therapy is occurring, you will have more opportunities to encourage the patient to seek therapy and the prospect of a beautiful, definitive esthetic reconstruction can be highly motivating. Nevertheless, if the patient continues to deny the problem and refuses to seek therapy, you will have to decide at this point whether or not to proceed with definitive care, given that an acceptable prognosis for dental treatment depends on cessation of the vomiting habit. Many practitioners elect to proceed with treatment, at least placing temporary restorations, in an effort to continue to engage and motivate the patient with improved function and appearance. If you do elect to proceed, you should thoroughly document your efforts to get the patient into therapy for the BN, and that your recommendation to delay definitive care was overridden by the patient.

If, as hoped, the patient does admit to her problem and does follow through with treatment, you should remain actively engaged in the therapeutic process through coordinating care with the medical/psychological/nutritional team. Nutritional interventions are among the central features of rehabilitation for patients with eating disorders. It is not unusual for the medical team to prescribe simple carbohydrates, since these provide a ready source of calories without producing the sense of stomach fullness that can be aversive to people with eating disorders. If the dental team is involved in coordinating care, it is appropriate to recommend to the medical team that non-sweet foods, such as cheese, be consumed at the same time to buffer salivary acidity and reduce the deleterious effect of simple sugars on the teeth. The promise of a beautiful smile can be a powerful motivator for commitment to therapy and recovery from BN if definitive esthetic rehabilitation is timed optimally in the patient's course of therapy. A useful worksheet for dental treatment planning of the patient with a diagnosed eating disorder is found in Table 2.4.

Throughout dental treatment, whether palliative or definitive, as long as the patient continues to induce vomiting—even when the frequency of vomiting has been significantly reduced—the patient should be advised not to brush the teeth immediately after vomiting, as this accelerates enamel erosion. Rinsing immediately with water is the best measure, followed, if possible, by a 0.05% sodium fluoride rinse to neutralize acids and protect tooth surfaces and restoration margins.[11]

Anorexia nervosa

People with AN are easy to recognize, since they usually appear emaciated, and they will likely present for dental treatment during or following psychiatric and medical stabilization. Therefore, it is unusual for the dental team to be in a position of detecting a case of AN. Nevertheless, it is important that you and your team be knowledgeable about the disorder to deliver safe, appropriate, and timely treatment. It is also important because some patients have a history of cycling from AN to BN and back again numerous times during the course of their illness, so that they may present with signs of both disorders over time. Significant medical problems are associated with both AN and BN. These may include dehydration, hypothermia, electrolyte abnormalities, abnormal cardiac function, gastrointestinal complications, endocrine disturbances, osteoporosis, amenorrhea, and infertility. This incomplete list highlights the urgency of pretreatment consultation with the patient's medical team. The patient's physician should be consulted regarding any current medical issues that could be exacerbated by dental treatment. If the patient is not felt to be medically stable, all dental treatment other than acute palliation should be delayed.[11]

Common oral manifestations of AN result largely from malnutrition, and include soft tissue lesions such as glossitis, angular cheilitis, candidiasis, and mucosal ulceration. Elevated caries rates are sometimes seen when the individual neglects oral hygiene, which is common, and when highly cariogenic, sugar-rich foods are prescribed to bring about rapid weight gain during medical stabilization.[12]

You should consult with the treatment team members—internist or family physician, psychiatrist, psychotherapist, and, possibly, nutritionist—to optimize the timing of esthetic dental reconstruction, such that the patient is medically and psychologically stable enough to tolerate dental treatment. Since it is common for patients with AN to be treated for concurrent depression and/or anxiety, the psychiatrist should be consulted regarding the patient's medications and possible interactions and precautions. The psychotherapist can provide any special guidelines for making the patient more comfortable during treatment. For example, some patients recovering from AN feel anxious when *any* references—even flattering ones—are made to their appearance or their health. In such cases, it is a simple matter for the dental team to be informed, so that in their interactions with the patient they will attempt to omit such well-meaning but unwelcome comments. Once the patient has been medically

Table 2.4 Worksheet for the New Dental Patient With a Diagnosed Eating Disorder

Name						
Birth date						
I. History						
A. Type of disorder						
B. History of disorder						
1) Age at onset						
2) Current status	Active		Inactive			
3) Frequency of episodes at most active stage						
4) Periods of abstinence						
5) Precipitating factors						
II. Past medical/dental treatment for disorder						
A. Medical treatment						
B. Psychological treatment	In-patient:		Out-patient:			
C. Dental history						
1) Initial detection of oral/dental problems						
2) Preventive measures						
3) Restorative therapy						
4) Frequency of preventive/treatment appointments						
III. Current status						
A. General health quality	Date of most recent physical exam:					
B. Under active medical care?	Yes		No			
Under active psychological care?	Yes		No			
C. Medications and dosages						
D. Disorder under control?	Yes		No		For how long?	
E. Examination findings						
Head and neck						
Lymph nodes	+	–	Intraoral			
Skin	+	–	Occlusion	+	–	
Symmetry	+	–	Lips	+	–	
Temporomandibular joint	+	–	Mucosae	+	–	
Parotid swelling	+	–	Gingiva	+	–	
Commissures	+	–	Palate	+	–	
			Throat	+	–	
			Tongue	+	–	
Dentition						
Enamel erosion						
Location	Upper anterior:		Palatal	Incisal	Cervical	
	Lower anterior:		Lingual	Incisal	Cervical	
	Upper posterior:		Premolar	Molar	Occlusal	Cervical
	lower posterior:		Premolar	Molar	Occlusal	Cervical

(*Continued*)

Table 2.4 (Continued)

Name						
Extent	Mild		Moderate	Severe		
Symptomatic	No		Cold	Hot	Sweet	
IV. Patient concerns						
Esthetic						
Comfort						
Parotid swelling						
Nutrition						
Other						
V. Treatment options						
A. Medical/psychological referral/continuation						
B. Eating disorder treatment referral/continuation						
C. Support group referral/continuation						
D. Dental therapy						
1) Emergency						
2) Palliative						
3) Preventive						
4) Definitive						
VI. Patient questions/comments:						

Adapted by a worksheet provided by Dr Robert Cowan, University of Missouri School of Dentistry.

cleared, treatment should be able to proceed without significant difficulty. The standard guidelines of regular oral prophylaxis, topical fluoride application, thorough oral hygiene instruction, and emphasis on good home care apply to the anorexic patient. These patients often suffer with xerostomia, both from their antidepressant medications as well as dehydration caused by their poor nutrition.[13,14] In such cases, artificial salivas and a dry mouth protocol are helpful, and the patient's nutritionist can be enlisted to support and reinforce it.

If the patient with an eating disorder is a minor

Given that the average age of onset of eating disorders has been shifting from the late teens to the earlier teens, it is likely that some of the patients with eating disorders encountered in the practice will be minors. Each state in the USA has its own statutes delineating the age at which patient–doctor communication is protected by privacy laws, and it is often younger than the legal age for other privileges, like alcohol consumption. Other countries will also have their own specific laws about this. In the Commonwealth of Pennsylvania, for example, the legal drinking age is 21, yet the age at which doctor–patient communication becomes protected is 14. You should become acquainted with your own state's or country's statutes. If the new patient with a suspected eating disorder is a minor, you must approach the patient's parent(s). This can be especially challenging in close communities where the patient's parents may be friends, acquaintances, or colleagues of yours. Nevertheless, you have a responsibility to sensitively approach the parent with your findings and concerns, and urge medical and psychological care.

Eating disorders are serious psychological illnesses that can and do result in death from physical complications and suicide. They rarely resolve without treatment, and early detection vastly improves prognoses. The dental team is in a unique position to detect and refer for life-saving treatment, with the additional role of providing a powerful motivator for recovery in the form of a beautiful new smile.

Personality factors in esthetic dentistry

Case example: Narcissistic personality disorder

The patient was a well-known actress. She intended to have extremely white porcelain veneers fabricated for all of her teeth. She arrived in the office after having conducted a wide search to locate "the world's best" esthetic dentist. She expressed conviction that her new dentist was, indeed, "a genius," where all dentists she had seen previously were "incompetent hacks." After treatment planning and discussion about the optimal shade for her full-mouth veneers (i.e., more natural, not bright white), although she refused to be persuaded, a full-day appointment was scheduled for tooth preparation, impressions, and temporization. A half hour after her appointment time, when she still hadn't shown up, the receptionist contacted her assistant by cell phone and was told that since her plastic surgeon had had an unexpected cancellation that morning, she had decided to have a breast augmentation and lift instead. She demanded to be treated in the dental office the next day, offering no apology for breaking the full-day appointment without even the consideration of an explanatory phone call. For a steeply increased fee, she was rescheduled for the next day. Immediately after being seated in the dental operatory, she lifted her shirt to a roomful of team members, revealing her bra-less self and asking: "How do you think they turned out?"

"Personality" has been defined as "the sum total of all the behavioral and mental characteristics by means of which an individual is recognized as being unique" (*World English Dictionary*), or "the essential character of a person" (Dictionary.com). In addition, "personality arises from within the individual and remains fairly consistent throughout life" (About.com). Everyone has a personality, some traits of which can manifest in a dental patient as being "difficult" or "challenging." In some cases, these difficulties or challenges are so extreme as to be clinically pathological, as illustrated in the above case example. This is an admittedly extreme—but actual—example of the behavior of a patient who has a diagnosable case of narcissistic personality disorder (NPD), the diagnostic criteria for which are found in Table 2.5.

In discussing personality, we are now shifting from psychological problems that can be successfully treated with medications and psychotherapy, many of which have a partial basis in neurochemical imbalances (such as depression, OCD, and eating disorders), to those that are very different in a number of important ways. Whereas many people with mood disorders and eating disorders often seek psychological and psychopharmacological treatments, people with personalities that are difficult or clinically disordered rarely seek psychological treatment, with the exception of the anxious personality type. This is because they most often perceive any problems they have in their personal or professional lives as external to them, not their "fault." Sometimes these "difficult" traits even have benefits, as noted in the adage "The squeaky wheel gets the grease," where the behaviors that make them difficult nevertheless compel others to comply with their wishes and demands. Furthermore, some personality traits that cause problems in relationships can confer advantages in certain careers. One need look no further than many successful politicians for a clear example of this phenomenon.

The earlier focus of this chapter was on teaching the dental team to detect serious psychological problems and then facilitating referral for psychiatric care, or dealing appropriately with a previously diagnosed disorder through consultation and collaboration with psychological professionals. In contrast with all of the previous disorders, personality disorders should *not* be assessed or discussed with the patient by the dental team. The focus with challenging personality traits and personality disorders is for the reader to gain the ability to interact skillfully and with minimal frustration for all concerned while providing excellent esthetic dental care.

Table 2.5 Diagnostic Criteria for Narcissistic Personality Disorder (NPD)

A. Significant impairments in personality functioning manifested by:
   1. Impairments in self functioning (a or b):
      a. Identity: excessive reference to others for self-definition and self-esteem regulation; exaggerated self-appraisal may be inflated or deflated, or vacillate between extremes; emotional regulation mirrors fluctuations in self-esteem.
      b. Self-direction: goal-setting is based on gaining approval from others; personal standards are unreasonably high in order to see oneself as exceptional, or too low based on a sense of entitlement; often unaware of own motivations.

   And
   2. Impairments in interpersonal functioning (a or b):
      a. Empathy: impaired ability to recognize or identify with the feelings and needs of others; excessively attuned to reactions of others, but only if perceived as relevant to self; over- or underestimate of own effect on others.
      b. Intimacy: relationships largely superficial and exist to serve self-esteem regulation; mutuality constrained by little genuine interest in others' experiences and predominance of a need for personal gain.

B. Pathological personality traits in the following domain: Antagonism, characterized by:
   1. Grandiosity: feelings of entitlement, either overt or covert; self-centeredness; firmly holding to the belief that one is better than others; condescending toward others.
   2. Attention seeking: excessive attempts to attract and be the focus of the attention of others; admiration-seeking.

C. The impairments in personality functioning and the individual's personality trait expression are relatively stable across time and consistent across situations.
D. The impairments in personality functioning and the individual's personality trait expression are not better understood as normative for the individual's developmental stage or sociocultural environment.
E. The impairments in personality functioning and the individual's personality trait expression are not solely due to the direct physiological effects of a substance (e.g., a drug of abuse, medication) or a general medical condition (e.g., severe head trauma).

The anxious patient

For most people, it is impossible to conceive of dental treatment without anxiety. It remains the most pervasive reaction to dental care, unfortunately, despite enormous advances in pain control, patient comfort, and dentists' management skills. Some patients are able to adequately manage their anxiety in the dental chair. However, many others are unable to cope with the anticipation and experience of some inevitable discomfort, and act out their anxiety through expressions of fear and dread, physical tension while in the dental chair ("white knuckling"), and flinching at the slightest touch, to name just a few of the challenging behaviors that are all too familiar to every practicing dentist and hygienist.[16]

Some patients will have a diagnosed anxiety mood disorder, such as generalized anxiety disorder (GAD) or panic disorder, while others suffer from characteristic high anxiety as a personality style. Patients with an anxiety mood disorder will often be under psychiatric care for their mood problem, and will be taking medications such as antidepressants and anxiolytics (e.g., benzodiazepines). The medical history form should reveal these medication regimens, and as with all patients undergoing psychiatric care, you should, after assuring the patient of confidentiality and obtaining consent, consult with the patient's psychiatrist and psychotherapist to clear them for treatment and obtain guidance on possible drug interactions and specific management strategies. As always, you should generate a detailed treatment plan that is carefully reviewed with the patient until there is consensus on *realistic* goals and outcomes, and obtain the patient's signature of informed consent to this treatment plan.

Although the reasons for patient anxiety may appear to be self-evident, *the tremendous value in talking to the patient about his or her anxiety cannot be over-emphasized*. And while many dentists may not consider themselves to be strongly empathetic and may believe that it is impossible to learn empathy, the simple sentence "I notice you seem to be very anxious. Would you like to talk about it?" is really very easy to learn and deliver sincerely, no matter one's empathy level. Simply asking the question signals the patient that the dentist is aware and concerned, which makes the anxious patient begin to feel a bit safer and more open to relaxing or at least coping better. More often than not, the patient will reveal that he or she wants more information about the procedure.

With a small allocation of extra time to answer the patient's questions about what to expect, you can provide the patient with better mental preparation and greater ability to accept and brace for some unavoidable discomfort. Some patients appreciate being offered a hand mirror for observing the procedure, which gives those who want it a perceived measure of control that modulates their anxiety. Even the smallest attention on your part to the patient's anxiety provides the thing he or she seeks most: *validation* of his or her concerns. Simple validation—even when there is no possible modification in the procedure to improve actual patient comfort—can greatly mitigate the effects of patient anxiety and facilitate smoother and more successful treatment.

Many fine esthetic practices have found that offering relaxing, spa-derived amenities, such as personalized music systems, foot massage, and soothing aromatic oils in the operatory are both relaxing to patients and profitable to the practice. A number of noted dentists have also been motivated to learn and offer hypnosis to their anxious patients, to excellent effect. These special efforts require a small investment in time and resources relative to the large benefits in enhanced patient comfort, satisfaction, and subsequent referral rates.

The angry patient

As is the case with anxiety, the angry dental patient may be reacting to a situation, or be angry by disposition or personality. Situational anger triggers might include the perception of being poorly treated by your staff, harboring lingering resentment about a previous dentist's treatment, belief that your fees are excessive,[17] and even resentment of the patient's own dental condition that requires treatment and expense! There are also myriad reasons for patient anger which are entirely unrelated to the dental experience. Each patient presents for treatment with a distinctive array of personality traits, life pressures, and conflicts that they may proceed to express when they are in the vulnerable position of dental patient, often with significant verbal and nonverbal hostility to the dental team (Figure 2.7).

Whether the patient's anger is dispositional or situational, your focus should be on improved communication with the patient. Again, this does not require becoming the patient's psychotherapist. *Always* attempt to avoid responding to an angry patient with defensiveness, counter-argument, or confrontation, no matter the provocation, but rather maintain a posture of open curiosity and professionalism. A leading question, such as "You seem to be upset. Would you like to talk about it?" can defuse the patient's anger by giving him or her the chance to express the cause of his feelings, and give you a corresponding opportunity to take responsibility and ameliorate the problem (if, for example, the patient feels mistreated by the staff), or at least to express genuine sympathy or empathy, and thereby validating the patient's feelings. Again, the value of simple *validation*, even in the absence of a remedy, cannot be over-emphasized as a way to reduce tensions and facilitate the treatment process.[5]

If, after you have made such a sincere effort at communication, the patient persists with his or her hostile stance, you should strongly reconsider whether to continue with treatment or refer the patient to another office. The dental team is in no way required to withstand continued hostile behavior from a patient, particularly following sincere attempts to explore, mitigate, and validate the patient's complaints.

The demanding patient

This is the category of challenging patients who are considered to be demanding because they attempt to dictate elements of the treatment plan or the sequencing of treatment for reasons that are *not* related to financial constraints. These patients may, for example, demand that a tooth be restored with a bonded onlay when the dentist recommends a full crown, or that an anterior tooth be restored with esthetic bonding rather than a porcelain veneer, in both cases due to a strong preference for what they perceive as a more conservative treatment or because of suspicion that the dentist's recommendation is driven by profit over clinical necessity.[5,17] Another patient may demand that an esthetic reconstruction be done in phases, rather than more comprehensively. There are many more examples of demanding patients that experienced dentists can relate.

You are, by definition, being called on to improve the patient's appearance, with which the patient is, by definition, dissatisfied,

Figure 2.7 Angry patient preparing to record conversations with the dental team, due to previous dental experiences that have made her distrustful.

sometimes mildly, often extremely. Appearance is powerfully related to self-esteem, confidence, and social and professional success.[18–21] It follows, then, that patients seeking esthetic dental treatment will often present with demands, driven by trepidation about treatment outcome, but also by unsatisfying or unsuccessful previous dental experiences, or those of friends or relatives. This reality reinforces the urgent need, highlighted repeatedly throughout this chapter, for you to routinely spend extra time with patients at the very beginning of the relationship, in order to elicit—as thoroughly as possible—a sense of the hopes, fears, past negative experiences, and any other agenda that the patient may harbor, before commencing treatment. In addition to improving the congruence between the patient's esthetic goals and what you feel is realistically possible, this dialogue will afford the patient an opportunity to air any issues and particular demands, and you an opportunity either to modify the patient's demands through information and reassurance, or to assess your capacity to meet these demands (Figure 2.8).

Figure 2.8 Demanding patient using drawing to dictate tooth form.

You should make vigorous efforts not to ignore or dismiss such patient demands, because this is most likely to escalate their intensity and increase the possibility of anger, frustration, stress, and compromised treatment outcomes. Where you assess that the demand does not compromise the case, such as when it is an issue of sequencing, it is sometimes advisable to simply comply with the patient's request. However, when you feel that the special demands cannot be met without compromising treatment quality or treatment philosophy, you are entitled and advised to strongly consider suggesting that the patient seek treatment elsewhere.

It is more likely that this extended assessment time will yield improved rapport and congruence between you and your prospective patient, and eventual treatment success. As ever, the treatment plan should be as detailed as possible with respect to the sequence and length of appointments, the appearance and maintenance of temporary restorations, the estimated total treatment time, and the appearance of the final result. Obtaining the patient's signed informed consent to treatment is especially necessary for this type of patient.

Treating the patient with Narcissistic Personality Disorder

The foregoing discussion has focused on describing the major personality types that are likely to present for esthetic dental care, and relatively common-sense strategies for improved management that require little extra effort for you and your team to implement, in the service of greater patient retention and satisfaction.

But what about the extremely challenging behavior exhibited by the patient in the case study at the beginning of this section? This question highlights an important consideration in esthetic dental practice: it is *vital* that you be self-aware enough to know your style and strengths with regard to interacting with highly challenging patients. If your honest self-assessment reveals that you would prefer not to treat patients with very challenging personality disorders, you should direct your screening efforts and policies to minimize acquiring such individuals as patients. By contrast, if you feel undaunted and well-equipped by temperament to serve even the very challenging patient personalities, you then need to consider how best to do so while minimizing conflicts and suboptimal outcomes.

How, then, might you approach treating the patient with a personality that is so extreme as to constitute a personality disorder—most commonly NPD—the typical attitudes and behaviors of which go well beyond what is considered within normal limits for demands and challenges on the part of dental patients? (Note: while NPD is just one of numerous recognized personality disorders, the others are less common and of lower concern to the dentist.) And if you prefer not to treat patients with NPD, how can they be screened during the first or second visit, before a commitment to working together has been made?

A critical feature often seen in a new patient with NPD is that the individual has previously visited one or more dentists and describes them in highly disparaging terms, usually coupled with giving you—the prospective new dentist—excessive, lavish praise and certitude, describing you as "of the very highest caliber, highly recommended, the best dentist." This behavior should immediately raise your suspicion and alert you to future challenges should you decide to accept the individual as a patient. Such information can often be elicited by any member of the team during the initial assessment by including in written or verbal form an assessment item such as: "Please tell us a little about your previous dental experiences." (Figure 2.9A and B).

An esthetic dentistry practice is more likely to attract such patients, as a review of the diagnostic criteria for NPD reveals, especially the grandiosity, preoccupation with beauty and success, and sense of entitlement. For this reason, accepting such patients into treatment is a decision that should be made after careful and clear consideration of your personal resources and tolerance for behavioral challenge, against the preference for serving as many patients as possible for a thriving practice. This is a decision that you should feel empowered to make on a case-by-case basis, taking into account such factors as your team's current level of patience and tolerance as well as the current health of your practice.

It is completely appropriate for you to refuse treatment and refer the patient elsewhere, indicating to the person that the team feels the practice is not a good fit for his particular needs. This may be awkward, but not nearly as uncomfortable as accepting such patients when you and your team are not up to the challenge.

Some patients with NPD will not be successfully screened, or you may simply decide to accept the individual as a patient, despite the probability of numerous challenges. In such cases, the following is a list of helpful strategies for reaching an agreeable and realistic treatment plan:

- Listen carefully to the patient during the initial interview, and note any extreme or possibly unrealistic demands or expectations, especially with regard to the esthetic goals.
- Schedule extra treatment planning time to review the patient's goals and expectations, with photographs if possible, and work toward congruence between patient goals and clinical realities.
- Develop and present a highly detailed treatment plan, and obtain the patient's signature of understanding and consent for the treatment plan, as well as office policies and fees for missed and broken appointments.
- Establish a clear understanding and agreement regarding the cost of treatment and schedule of payments; that is, agree with the patient in advance on when payments will be made and when treatment will be paid in full. The patient should sign the fee and payment agreement, which should be a standardized office form so that the patient does not feel singled out.
- Understand that it is likely the patient will at some point test the limits established earlier, and work out a consistent approach to dealing with this patient with the entire office team that is firm but flexible (when possible).
- Some dentists have a policy of raising fees for patients they anticipate will be behaviorally challenging. This solves the problem in two ways: (1) the patient may balk at the high cost and turn elsewhere, which saves you from the aggravation, or (2) if the patient accepts the higher fee, you will feel compensated for the extra time and management effort, and thus less stressed. There is no contraindication to this policy.

It is important for you to understand that every patient has a personality, and these span a spectrum from "normal" to disordered, with many shades between the extremes. This means that many people will present with personality challenges, some even characteristically "narcissistic." In fact, the very focus of esthetic dentistry on appearance inherently attracts some degree of self-focus. It is possible to characterize many patients who seek esthetic dentistry as "self-absorbed," maybe even somewhat grandiose and entitled, even if they do not meet the criteria for NPD. The dentist who attempts to screen out all such patients is likely to have a failing esthetic practice! Thus, it is best for you and your team to cultivate your own faculties of patience,

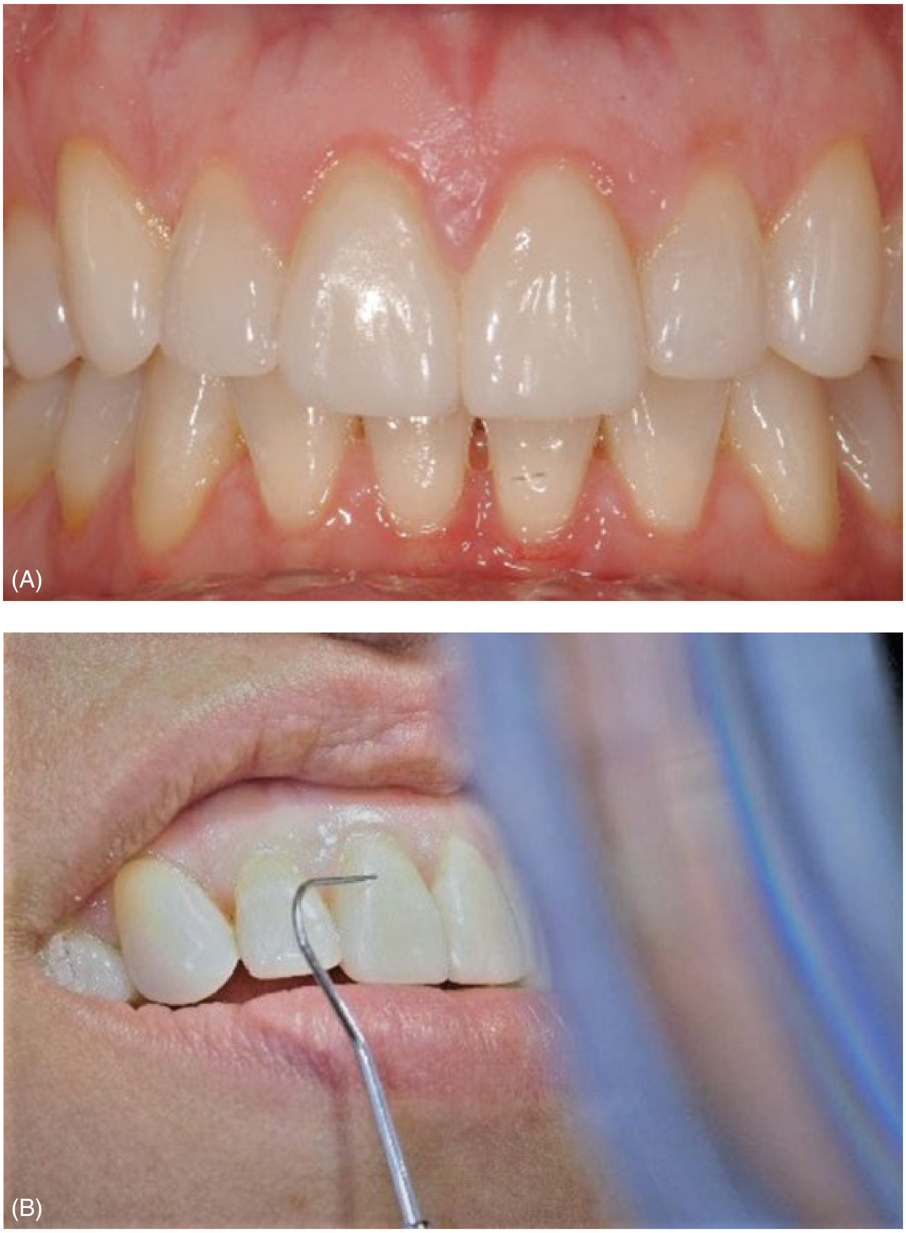

Figure 2.9 **(A)** This patient presented with slight discoloration on her central incisors. Two porcelain veneers were bonded in place after she signed the release form stating she "loved the results." **(B)** This photo captures one of many tiny complaints as she returned every 7–10 days for 3 months with her explorer. She was diagnosed with Body Dysmorphic Disorder and was successfully treated psychiatrically.

compassion, humor, creativity, emotional intelligence, and flexibility, and enjoy the many benefits in personal and professional satisfaction for being facile at managing the vast and varied range of patient personalities.

Life event stress and adjustment disorder

Just as every patient has a personality, so each person experiences life event stresses. Some of these will be unexpected—such as the death of a loved one, job loss, infertility, and divorce. Even planned and happy changes, such as wedding engagements, births, and job promotions, create stress in the individual, because they cause a disruption of homeostasis, which human physiology prefers.

There are also normative transitions that create life event stress. Adolescence is rife with such challenges, as is applying to college and graduate schools, job-hunting, pregnancy, parenting, children leaving home, parental aging, menopause, and retirement.

Most often, people experience heightened stress during such times of loss or transition, followed by adaptation and a return to their baseline functioning. When stressed individuals *do not* return to baseline after a reasonable period of reaction and poor coping, they may be diagnosed with an adjustment disorder (for diagnostic criteria, see Box 2.3). Adjustment disorders may engender either depressed or anxious moods or even both. If the patient is being treated with antidepressant or anxiolytic

Box 2.3 Diagnostic criteria for adjustment disorder.

The development of emotional or behavioral symptoms in response to an identifiable stressor(s) occurs within 3 months of the onset of the stressor(s). These symptoms or behaviors are clinically significant, as evidenced by either of the following:

- **marked distress in excess of what is expected from exposure to the stressor**
- **significant impairment in social or occupational (academic) functioning.**

Box 2.4 Diagnostic criteria for body dysmorphic disorder.

- **Preoccupation with an imagined defect in appearance. If a slight physical anomaly is present, the person's concern is markedly excessive.**
- **At some point during the course of the disorder, the individual has performed repetitive behaviors (e.g., mirror checking, excessive grooming, skin picking, reassurance seeking), or mental acts (e.g., comparing his or her appearance with that of others) in response to the appearance concerns.**
- **The preoccupation causes clinically significant distress or impairment in social, occupational, or other important areas of functioning.**
- **The preoccupation is not better accounted for by another mental disorder (e.g., dissatisfaction with body shape and size in AN).**

medications, the dentist should follow the procedure detailed earlier: consent, consultation with the psychiatrist for medical clearance and clarification of any treatment precautions, and consultation with the psychotherapist for specific helpful management recommendations.

During times of transition and heightened stress—whether expected or not—many people will experience a wish to improve their appearance as a means of feeling better. Therefore, you are more likely than others to encounter new and existing patients experiencing life event stress and adjustment problems, from adolescents to younger adults, or, particularly in older adults, as part of an overall "makeover" that may include new diet and exercise regimens as well as cosmetic surgery.

Successful treatment of these patients requires sensitivity, sympathy, empathy, compassion, diplomacy, and possibly a little extra listening time. Knowing about and understanding the difficulties faced by people going through these life stage issues can be very helpful. To be successful, consider taking some time to educate yourself about these subjects, train your staff to be attuned to developments in patients' lives in order to pass on any important developments to you and any other clinicians in the office, and possibly include questions regarding any recent stresses in the medical history and update forms.

Catering to patients going through specific transitions, such as by spending extra time asking about the changes the patient is experiencing and following up thoughtfully at each visit, or offering to coordinate esthetic dental care with other specialists the patient may be seeing, can give patients going through difficult times the feeling of being understood and validated.

The dental patient with body dysmorphic disorder

Returning, finally, to the real-life vignette that introduced this chapter, my friend, the eminent dentist Dr J, was completely correct in assessing his new patient as having a problem so severe that he should not agree to treat her before she underwent successful psychological care. Dr J was aware of the unique challenges of patients with body dysmorphic disorder (BDD) seeking esthetic dentistry, and his new patient raised several significant red flags. She had a cosmetic defect that was minor, but her reaction to it was excessive, and her preoccupation with it was so chronically distressing that she was unable to function professionally. She harbored the delusional belief that since the crown was inserted she had become hideously ugly. She had seen numerous other dentists and cosmetic surgeons before Dr J, some of whom had found her unreasonable and somewhat menacing. This patient clearly had a delusional variant of BDD, the diagnostic criteria of which appear in Box 2.4.

BDD is a form of anxiety disorder that is classified as a subtype of OCD. It is appropriate for this chapter on management of challenging esthetic dental patients to begin and end with BDD, because while this syndrome is not highly prevalent in the population, studies have demonstrated that it is over-represented in the offices of cosmetic surgeons and esthetic dentistry practices.[22,23] Furthermore and most significantly, *patients with BDD should not be treated for their defect, whether real or perceived, unless and until they have been psychologically stabilized.*[22,23]

This recommendation is made to safeguard both patient and practitioner. Studies have shown that for most patients, treating the "defect" can intensify the preoccupation, or simply divert it to a new focus.[22,23] The patient in the case example had in fact presented to her previous dentist with excessive concern about the appearance of her premolar, but he failed to detect the BDD, and went on to crown the tooth. This resulted in a severe intensification of her psychological illness. Fortunately, although the patient became extremely debilitated and nonfunctional, she did not attempt suicide. This is a very real concern, since completed suicide in BDD occurs at an elevated rate. The rate of suicide attempt among patients with BDD has been estimated at 27.5%, and the rate of suicidal ideation has been estimated at 78%.[24]

Treating the "defect" also produced extreme duress for the treating dentist and his practice for months afterward, as the patient sought follow-up correction in a harassing manner that required drastic action in the form of changing phone numbers. In fact, the dentist was fortunate that no other protective measures were required, since it is a matter of record that individuals with BDD have stalked and attacked their cosmetic surgeons.[22] It is also an unfortunate fact that there are frequent lawsuits against cosmetic surgeons but there are no definite statistics regarding the proportion of individuals with BDD who bring lawsuits against their dentists.

It is *urgent* for the dental team to carefully assess the patient they suspect may have BDD before embarking on treatment. Although there is no single question that can disclose BDD, it is always recommended that any new patient be asked an open question about their chief complaint and their reason(s) for seeking treatment. Some "red flag" behaviors and responses that should raise suspicions during the initial interview include:

- excessive concern about a minor or imperceptible dental defect
- highly specific concern about the defect, often accompanied by diagrams and photos
- admitting to spending 1 hour or longer per day thinking about the defect and looking in the mirror, as well as chronic repeated mirror checking
- high dissatisfaction with previous treatment/dentist
- history of "doctor shopping"
- highly unrealistic expectations of treatment, such as belief that correcting the defect will yield professional or romantic success
- "camouflaging" behavior, such as habitually covering the mouth with a hand, scarf, or other item.

A number of other psychiatric disorders commonly co-occur with BDD, including depression, OCD, social phobia, and eating disorders. A history of drug and alcohol abuse is not uncommon, and, as mentioned, suicidal ideation is a frequent issue. Inquiring in the initial interview or medical history as to any history of these common comorbidities can help determine whether the patient indeed suffers with BDD.

Once you have further confirmed a suspicion of BDD, you should privately and sensitively inform the patient that you feel it is not in the patient's best interest to proceed with dental treatment at this time.[22–24] This discussion should be handled in a kind and considerate yet straightforward manner, attempting to avoid offending the patient, but also resisting any attempts by the patient to persuade you to treat. This is another excellent example of the great value of keeping an identified list of trusted local psychiatrists and psychotherapists whose contact information can be given to the patient immediately, greatly facilitating referral and acceptance of vitally needed psychiatric care. Cognitive behavior therapy (CBT) has been shown to be effective in treating patients with BDD, as have antidepressant medications, particularly SSRIs (Figure 2.10A–D).[22,23]

After the patient has been successfully stabilized psychologically, it may be possible for esthetic dental treatment to proceed. To Dr J's credit, he correctly assessed his patient, correctly deferred dental treatment and instead referred her for immediate psychological care. She was successfully treated with a

Figure 2.10 **(A–D)** Patient with body dysmorphic disorder (BDD) who required four different provisional bridges to wear on different occasions.

combination of psychotherapy and antidepressant therapy, after which Dr J was able to improve the patient's occlusion and dental esthetics to her satisfaction. He did this in close consultation with her treatment team for proper timing and staging of care, exemplifying the effectiveness of a team approach to care, with the dentist providing critical input and receiving needed guidance for a successful and stable outcome for this highly challenging patient.

Conclusion

You do not need to become a trained psychologist to become skillful at managing patients with mental illness and behavioral challenges. Teamwork, with your own staff and the patient's other medical providers, enhanced communication with patients, and the other basic guidelines described in this chapter can empower you and any motivated dentist to greatly improve your ability to not just tolerate the challenging patient, but experience personal gratification in handling such challenging cases. This is my hope. During our collaboration in treating the very difficult patient with BDD, my friend and colleague Dr J mentioned that it was important to his own sense of professional competence and value to be able to: (in his words): "help any patient in need of dental treatment, even one who is so mentally ill." With motivation and openness to some of the approaches described in this chapter, this enhanced personal competence is certainly within your reach.

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Chapter 3 Esthetic Treatment Planning: Patient and Practice Management Skills in Esthetic Treatment Planning

Ronald E. Goldstein, DDS and Maurice A. Salama, DMD

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There is no way to overemphasize the importance of comprehensive treatment planning. Achieving success in esthetic dentistry requires both time and attention to a thorough diagnosis followed by either a single best or alternate treatment plans. The patient who presents with what he or she perceives as a simple problem is still entitled to an expert diagnosis and forecast of any potential problems and ideas for present or future treatment. I have practiced this philosophy for over 50 years and have found that patients appreciate this service regardless of whether they chose to accept an ideal or compromised treatment plan.

Ronald E. Goldstein's Esthetics in Dentistry, Third Edition. Edited by Ronald E. Goldstein, Stephen J. Chu, Ernesto A. Lee, and Christian F.J. Stappert.

The objective has and should be to let our patients know how they can not only look their best but also hopefully keep their teeth in good health for a lifetime.

Most esthetically motivated patients who first appear for consultation are eager to begin corrective treatment. Nevertheless, their enthusiasm and, at times, their self-diagnosis should not alter or influence your esthetic diagnosis. Failure to attend to this caution could lead to treatment failure.

Mutual agreement and informed consent

Although the functional aspect of every case should be the dentist's primary consideration, esthetics may well be the patient's *main* concern. Therefore, assurance must be given that success in esthetics is based on a careful and accurate complete diagnosis. In fact, ethically and legally, the dentist is obliged to inform the patient of various treatment alternatives. The standard of care diagnosis and treatment planning today is such that every patient needs to be considered from an interdisciplinary perspective. Regardless of whether or not you plan on referring your patients for specialty consultation, we have an obligation to either get that specialist opinion from others or take on the responsibility ourselves. The authoritarian concept that there is only one way to treat a problem and the old maxim "the doctor knows best" are both outdated. Once the treatment alternatives have been explained, the patient has the ultimate responsibility for making the decision to accept treatment. However, unless the patient's final decision for treatment is within the dentist's ethical and legal bounds, he or she should not be accepted for therapy into that particular practice.

> It is essential that the patient make an informed decision, after receiving from the dentist and staff a thorough explanation of his or her condition and the ramifications of treatment, including the advantages and disadvantages of each treatment alternative. Since this may take a considerable amount of time, much of it can and should be provided by a knowledgeable and experienced staff member. At the same time, the patient should be given printed or even video material for further consideration at home. There are numerous patient education short videos that can be easily attached to email or put on USB drives for the patient to review with his or her spouse, friend, relative, or significant other.

This is the new digital age of "informed consent." Printed information, whether reprints of various popular magazine articles or handouts especially prepared in the dental office, should support and give credibility to the treatment plan proposed. Presenting alternative treatment plans will also allow the patient to choose (usually with your advice) among alternative plans rather than alternative doctors. The dentist who gives the patient a one-choice solution to a complex esthetic problem may also be telling the patient, "Choose between me and my one plan, or find yourself another dentist." The wise dental consumer may elect to obtain a second opinion, to see whether other alternatives are available. New digital treatment planning tools and software are available today that are patient friendly, such as XCPT software, Consult-Pro, CASEY, and, on the implant side, Materialise and Kodak.

Before the initial visit

A patient's perception of the dental practice begins even before his or her first visit. It begins with the telephone call to schedule an appointment. The manner in which the potential new patient is handled by the receptionist, what is said and the tone over the telephone, helps to establish the desired image. If the potential new patient is not treated with professionalism, it may give the impression that the dental practice behaves this way as a whole. It is imperative that this screening is performed to correctly schedule the appropriate time and dentist.

Understanding your patient's personality

Esthetic treatment entails attention to pathology and function; it also requires attention to the patient's attitudes. These attitudes reflect the patient's self-image, which is the sum of appearance, personality, and position in the social milieu, as well as interrelationships with family, friends, business associates, and casual acquaintances.

Successful esthetic dentistry requires skills that involve more than the ability to diagnose and correct functional and pathologic irregularities. Each patient is an individual with a unique problem or concern and should be evaluated as a personality while considering the problem/solution diagnosis. The dentist who is able to master the art of understanding personalities and how to relate to each type will achieve greater treatment planning acceptance. Levin[1] identifies four personality types and suggests the proper response to each of these types.

1. **Driven**: bottom-line person, focuses on results, decides quickly, time-conservation oriented, highly organized, likes details in condensed form, businesslike person, assertive, dislikes small talk. Respond to this personality in a quick, efficient manner, and maximize use of appointment time.
2. **Expressive**: loves to have a good time, cheerleader type, wants to feel good, highly emotional, makes decisions quickly, dislikes details or paperwork, often disorganized and irresponsible, likes to share personal life. Respond to this personality by discussing the benefits of treatment through photographs and stories; engage in small talk, and sound excited.
3. **Amiable**: attracted by people with similar interests, reacts poorly to pressure or motivation, emotional, slow in making decisions, fears consequences, slow to change, a follower more than a leader. Manage this personality type by presenting information over a period of several visits.

4. **Analytical**: requires endless detail and information, technologic mind, highly exacting and emotional. Hardest of the four to reach a decision. Handle this personality type by providing additional information in the form of written, objective materials when suggesting a form of treatment.

The dentist and staff should master the identification of these four personality types. Understanding them and how to relate to each will enhance the doctor–patient relationship as well as the doctor–staff relationship. Interpersonal skills are just as important as technical skills. As Levin says, "After all, we are not just technicians; we are doctors to people."[1] Basically, a personal, communicative relationship between dentist and patient is required.

Educational materials

The dentist's first priority should be to start educating the patient about the techniques and philosophy of the esthetic dental practice. The more understanding that patients have regarding their dental problems and potential solutions, the easier and more effective the first and future meetings will be.

A consumer book like *Change Your Smile*[2] can be of immense value. It is important to have copies of the book (Figure 3.1A) in the reception area and to give or loan a copy of the book for new patients prior to their first visit or certainly prior to discussing various treatment plans. In addition to broadening their understanding of esthetic dentistry, the book helps to prepare them to anticipate realistic fee scales for the various esthetic procedures, each of which is discussed in detail including fee range, advantages, disadvantages, results of treatment, maintenance required by the patient, and realistic esthetic results. This book explains the differences in esthetic dentistry treatment. For example some treatments require payment in advance and insurance rarely covers the costs of such treatments. It is best to give or loan a copy to each new patient before the first visit. Copies can be purchased from the publisher and given to each patient. When purchased in bulk it can be an economical marketing tool for the dental office. This book explains procedures and fees, even for those who are not referred specifically for cosmetic dentistry (Figure 3.1B).

Provide a self-smile analysis

A self-smile analysis, or comparable index, should be explained and made available to the patient before their first visit (Figure 3.2). The importance of such a self-evaluation cannot be overstated. Through this self-analysis, you can begin to recognize and understand the problems uppermost in the patient's

Figure 3.1 **(A)** Although it is best for new patients to receive and read *Change Your Smile* before their first appointment, it is important to have copies in your reception room to reeducate your existing patients.

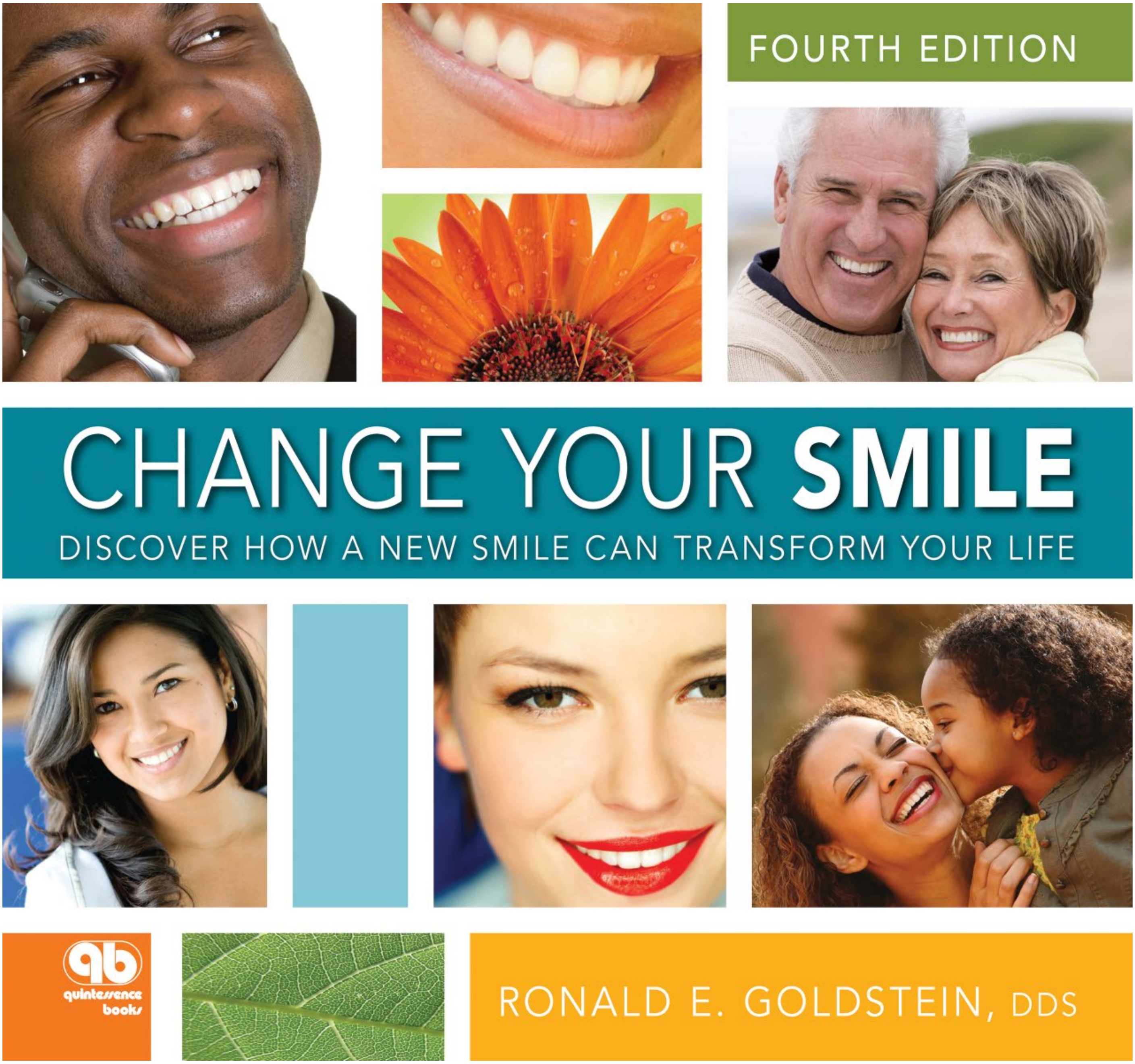


Figure 3.1 **(B)** A major advantage of having patients review *Change your Smile*[2] before presenting your treatment plan is for them to view realistic fee ranges, advantages, disadvantages, treatment results, and required maintenance for most all esthetic treatments. From *Change Your Smile*, 4th edn. Ronald E. Goldstein, DDS. Reproduced with permission of Quintessence Publishing Co Inc., Chicago.

mind concerning his or her appearance, particularly as he or she is affected by the face, mouth, and smile. It also serves as a documented and convenient starting point for a specific discussion of esthetic treatment that will be workable for the dentist and satisfying to the patient. The self-smile analysis provides a means by which the dentist can avoid two common errors: the beliefs that patients care little about their smiles and that they are willing to accept any recommended course of treatment. Experience indicates that if you accept at face value a patient's remarks such as "If it's good and it lasts, I really do not care what it looks like" or "You are the doctor," you may soon have a dissatisfied patient. Memories can be short, and patients may easily forget the condition of their mouth before treatment, choosing instead to concentrate on anything, however trivial, that they regard as an imperfection. Such reactions illustrate again the depth and breadth of consideration, somatic and psychological, involved in esthetic treatment, and they point to the practical and esthetic value of the self-smile analysis.

SMILE ANALYSIS

Yes No TEETH

☐ ☐ 1. In a slight smile, with teeth parted, do the tips of your teeth show?
☐ ☐ 2. Are the lengths of your central incisors in good proportion with your other front teeth?
☐ ☐ 3. Are the widths of your central incisors in good proportion with your other front teeth?
☐ ☐ 4. Do you have a space (or spaces) between your front teeth?
☐ ☐ 5. Do your front teeth stick out?
☐ ☐ 6. Are your front teeth crowded or overlapping?
☐ ☐ 7. When you smile broadly, are your teeth all the same light color?
☐ ☐ 8. If your front teeth contain tooth-colored fillings, do they match the shade of your teeth?
☐ ☐ 9. Is one of your front teeth darker than the others?
☐ ☐ 10. Are your six lower front teeth straight and even in length?
☐ ☐ 11. Are your back teeth free of stains and discolorations from unsightly restorations?
☐ ☐ 12. Do your restorations—fillings, porcelain veneers, and crowns—look natural?
☐ ☐ 13. Do any of your teeth have visible cracks, chips, or fractures?
☐ ☐ 14. Do you have any missing teeth that you have not replaced?

GUMS

☐ ☐ 15. When you smile broadly, do your gums show?
☐ ☐ 16. Are your gums red and swollen?
☐ ☐ 17. Have your gums receded from the necks of your teeth?
☐ ☐ 18. Do the curvatures of your gums create half-moon shapes around each tooth?

BREATH

☐ ☐ **19.** Is your mouth free of decay and gum disease, which can cause bad breath?

FACE

☐ ☐ 20. Do your cheeks and lip area have a sunken-in appearance?
☐ ☐ 21. Does the midline of your teeth align with the midline of your face?
☐ ☐ 22. Do your teeth complement your facial shape?
☐ ☐ 23. Is the shape of your teeth appropriately masculine or feminine for your overall look?

Figure 3.2 The advantage of having your patients complete a self-smile analysis like this one is to help them visualize and communicate to you all potential problems before treatment planning is initiated. From *Change Your Smile*, 4th edn. Ronald E. Goldstein, DDS. Reproduced with permission of Quintessence Publishing Co Inc. Chicago.

There are several ways to get a self-smile analysis form accessible to your patients:

1. Email a copy of your selected version to each new patient, or make it available to download from your practice website.
2. Include it in an information package you mail to new patients.
3. Provide *Change Your Smile*[2] and have them use the self-smile analysis form (p. 4; Figure 3.2).

The advantage of this last method is that *Change Your Smile* contains so much more additional information. It will provide your new patient with treatment alternative summary sheets that will give them more insight into their esthetic problem.

The initial visit

The dentist–patient relationship is the necessary foundation for any satisfactory course of treatment. It must be encouraged and developed from the beginning and is most important in esthetic dentistry. The patient must feel at ease. To this end, a neat, well-ordered, attractive, and comfortable reception area is an obvious prerequisite (see Chapter 5 on marketing). The first visit, which may or may not involve a functional procedure, is the best time to intensify the communication process. The patient's first impression, if positive, will serve as reinforcement for subsequent treatment. If negative, it can be harmful to the atmosphere of candor and trust essential to successful esthetic treatment.

Important questions to ask

Why are they here?

There is no more important information than why the patient came to see you. This is not to be confused with your patient's major complaint. Rather, why are they at your office instead of another? And why did they leave another office (or offices) for yours? Frequently, this information can reveal valuable insight into your patient, his or her fears, needs, desires, and expectations. These may not necessarily be related to a specific dental condition.

Who referred your new patient?

This information can be quite helpful in determining what concerns your new patient has regarding his or her dental needs. One basic problem is that many individuals choose not to disclose this information, not wanting to prejudice you in rendering your opinion. The fear is that you may "slant" your treatment plan based upon the referring patient rather than offer completely objective analysis.

Reasons for patients prefer not to disclose referral source include the following.

1. There is less chance that the dentist can estimate their financial status, which may or may not be the same as that of the referring patient.
2. The patient wants an objective, unbiased opinion.
3. They fear that you might disclose their condition or treatment to the referring patient and they don't want this information disclosed

Therefore, always respect your new patient's right of privacy, especially at first. Often, the referral source will later become known, usually through casual conversation.

Who examines the patient first: dentist or hygienist?

There is always the question of who should see the patient first—you or your hygienist. There are advantages and disadvantages to each being the first contact. (See Figure 3.3 for a typical flow of patient contacts in a practice for comprehensive dental treatment.) Even if the patient wishes an appointment only for a prophylaxis, it may be important for you to see and meet the patient first. Not only is it valuable for you to identify your new patient's primary concerns, it is also quite helpful for you to examine the patient before your hygienist alters the appearance of the mouth (Figure 3.4A). One definite advantage of this is to be able, if necessary, to place the patient in a soft tissue management program before a prophylaxis is scheduled. This can also emphasize to the patient just how essential it is to have healthy tissue before any esthetic treatment is planned (Figure 3.4B). Observe calculus, stains, and baseline oral disease in order to be of maximum help to your patient. Also, be sure to take *photographic records before a prophylaxis removes stains or other visible evidence* of just how your patient performs oral care.

What to look for

Prehygiene: look at the patient and observe the following:

1. **Stains**: what types and severity?
2. **Calculus**: how much and the length of time since the last prophylaxis.
3. **Plaque**: most patients attempt to brush their teeth as well as possible before a dental appointment, so if your patient has a great deal of plaque present it should give you a good idea of how the patient's oral hygiene is lacking.
4. **Habits**: a hygiene appointment could erase valuable evidence left by any harmful habits the patients may have. Examples are heavy smokers or coffee drinkers whose stains would be eliminated after prophylaxis. Therefore, make sure you examine any new patient before a hygiene appointment.

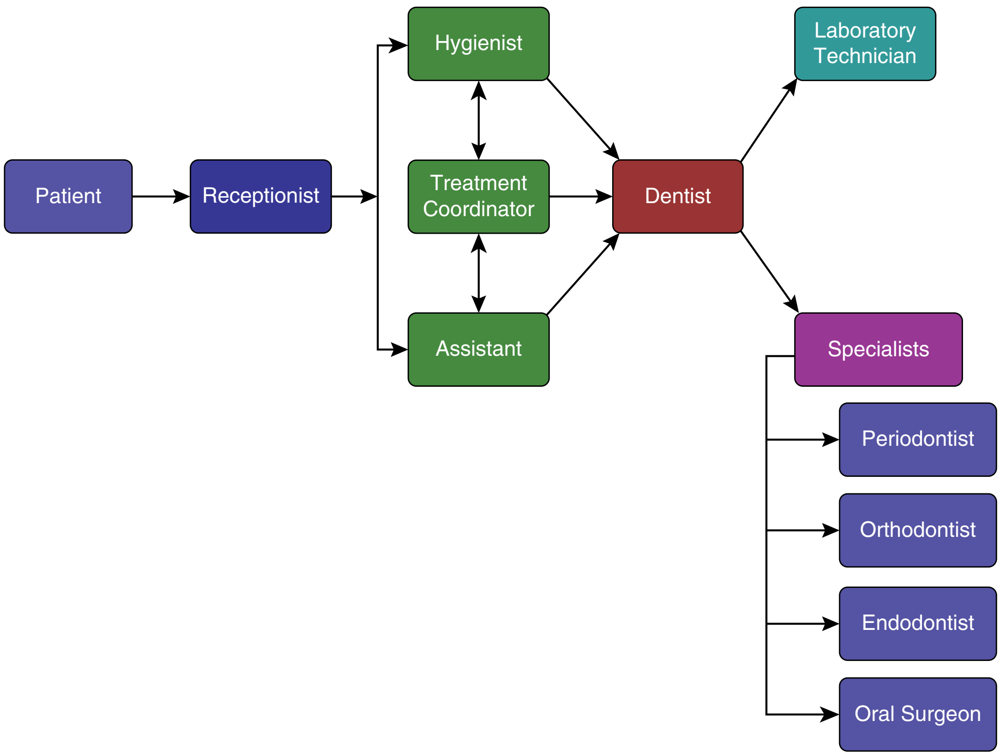


Figure 3.3 Typical sequence of patient office contacts.

Figure 3.4 **(A)** A sense of inferiority can create a depression that occasionally causes patients to become desperate about their self-image. In this case, the 28-year old woman was so ashamed of her appearance that she balked at even opening her mouth.

Figure 3.4 **(B)** The first step was soft tissue management to eliminate inflammation.

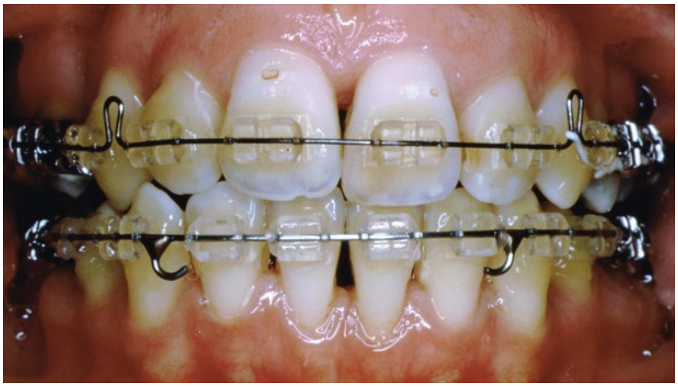


Figure 3.4 **(C)** Orthodontic treatment corrected the open bite.

Figure 3.4 **(D)** The reward of an extended consultation period to help overcome a fear of dentistry is the acceptance of combined therapy to achieve an esthetic result.

5. **Attitude**: another reason to meet the patient before the hygiene appointment is to get a better idea of the patient's personality. After a 30- to 50-minute hygiene appointment, the patient may be stressed, out of time, or even non-communicative.

Remember, you can uncover important information during this initial interview, and it is imperative to ascertain that you have sufficient information to develop a comprehensive treatment plan. The more difficult the esthetic problem, the more time is required for patient information gathering. Failure to obtain even one critical piece of patient information can make the difference between esthetic success and failure. Sources of this essential information may include the receptionist, dental assistant, hygienist, dental laboratory technician, and treatment coordinator. Although we assume that all of the above individuals have contact with the patient, valuable information can also be gained by involving your laboratory technician with the patient's esthetic concerns. In most cases, the laboratory technician will be able to tell you whether the technical problems involved can be easily overcome. This information is also essential before finalizing your patient's treatment plan because, for example, your fee and that of the technician can vary considerably based on the technical requirements involved (Figure 3.4C and D).

The role of the hygienist

The hygienist may be the second, third, or fourth member of the treatment team the patient meets. However, the hygienist usually is the first who actually performs treatment and therefore must be fully proficient in hygienic techniques and subtle investigation while maintaining a reassuring manner. Often the hygienist will develop a special relationship with your patient. This rapport can result in learning crucial information that can make your treatment a success or warn you of possible failure. The hygienist must be both inquisitive and observant enough to help discover potentially harmful habits and bring them to the attention of both the patient and you. Such habits include lip, cheek, or nail biting, chewing ice or other foreign objects, or grinding of teeth. As the teeth are being cleaned, the patient's desires in regard to esthetic treatment can and should be determined. Preliminary observations can be made concerning obvious discolorations,

Figure 3.5 **(A)** The rapport between hygienist and patient often can help uncover a patient's interest in esthetic dentistry.

necessary restoration, ill-fitting crowns, and so on. The approach can be in the form of a question, such as, "Does this concern you? If so, the doctor may be able to correct it." The possibility and applicability of esthetic treatment should be of central concern, but the concern should not manifest itself at this time as direct recommendations or specific advice to the patient. The hygienist must be alert to cues that indicate a patient's interest in esthetic dentistry. A patient who covers his or her mouth when laughing is making a wordless, vitally important statement. Lips pulled tightly over the teeth, constricted cheeks, or a tongue pressed against a diastema are subconscious signals from the patient. Directly or indirectly, they express a patient's concern for his or her appearance. The hygienist should communicate these observations to the dentist in private. Our office has found it extremely useful to have intraoral cameras available for the hygienist to utilize for each patient. I especially like to walk into the operatory to do my periodic examination only to find several pictures already up on the monitor. This means the hygienist has already informed and shown areas to the patient that she would like me to check. Even if I feel the specific problem may not need treatment at present, patients appreciate the hygienist always looking out for possible problem areas that might be a future concern (Figure 3.5A).

At the initial visit, the patient may see the dentist for a comparatively brief time. This depends upon the patient's ability and desire to spend up to several more hours for the "second visit" at the same appointment. If the patient is from out of town, it is usually advisable to plan both first and second visits at the same appointment to reduce the patient's travel time and costs. This may also be a reason to send the out-of-town patient a copy of *Change Your Smile*[2] (Figure 3.1B) in advance of the appointment since the final diagnosis may well be presented in one day.

Good rapport must be established while convincing the patient that only after a thorough study of radiographs and other diagnostic aids will treatment alternatives be suggested. In addition to a medical and dental history, thorough charting of both periodontal and general tooth conditions, diagnostic models, occlusal analysis, and digital color photographs are taken at this visit (Diagnodent, Kavo, USA). Normally, specific suggestions should be postponed until the second visit. At that time, you should examine and discuss treatment alternatives as well as the patient's own esthetic evaluation as it is revealed in the self-smile analysis unless the patient has previously completed this self-examination.

The clinical examination

Every new patient receives a clinical examination. For the patient who is primarily interested in cosmetic dentistry, an esthetic clinical evaluation is mandated. This patient may have already received a prophylaxis, radiographs, examinations, and treatment plans from several other offices. Therefore, the initial appointment with you may be specifically for an esthetic evaluation, and more time should be reserved to listen to the patient's problem and desires. The remainder of the appointment is focused on the non-esthetic but functional clinical analysis.

Patient examination

Although the entire stomatognathic system should be evaluated, there are three main components of any clinical examination:

- facial analysis
- evaluation of the teeth, occlusion, and arch arrangement
- determination of the periodontal status.

Note: for more advanced cases, 3D cone beam computed tomography (CBCT) may be performed as part of this examination. The order in which you perform these specific functions is not important, just as long as you spend sufficient time on each one. At Goldstein, Garber, and Salama, we do the facial analysis first.

Teeth and arch examination

Regardless of which chart you use, a tooth-by-tooth examination is essential to verify functional as well as esthetic limitations for the desired treatment. As basic as it may sound, there is no substitute for an extremely sharp explorer. Although some schools may be moving away from explorer use, I find it extremely helpful in verifying restoration margins and particularly subgingival crown margins.

It is virtually impossible to visually determine the soundness of each individual tooth. Saliva, plaque, and food deposits can too easily fill a defective margin and make it appear "perfect." The absence of stain around a leaking or defective margin may make it easy to overlook the necessity of including that tooth in your treatment plan. Therefore, each surface of each tooth should receive a thorough evaluation. Magnifying lenses of 2.5 diopter or greater are extremely valuable tools in being able to properly detect defective restorations as well as other defects.

There are two technologies that I have found indispensable. Both the chairside microscope and intraoral camera provide essential views for precise tooth surface exams. The microscope can provide a brilliant and clear extreme close up of tooth restoration defects. Microcracks can be so clearly seen and photographed while the patient discovers them on the chairside monitor and sees them through the stereoscopic lens. Then there is the use of the intraoral camera which will not only support your findings but also may reveal to you other deformities not seen by either the naked eye or with the aid of magnifying loops. The intraoral camera also has the ability to easily transilluminate and photographically record hidden microcracks that could easily alter your treatment plan. This photographic or video examination of the mouth can also make you aware of potential pit and fissure problems or hidden surface caries that could be overlooked in your visual examination or even missed with the explorer. I also consistently make use of a hand-held laser caries detection device (Diagnodent) to evaluate any suspicious pits and fissures (Figure 3.5B). Finally, an intraoral camera provides

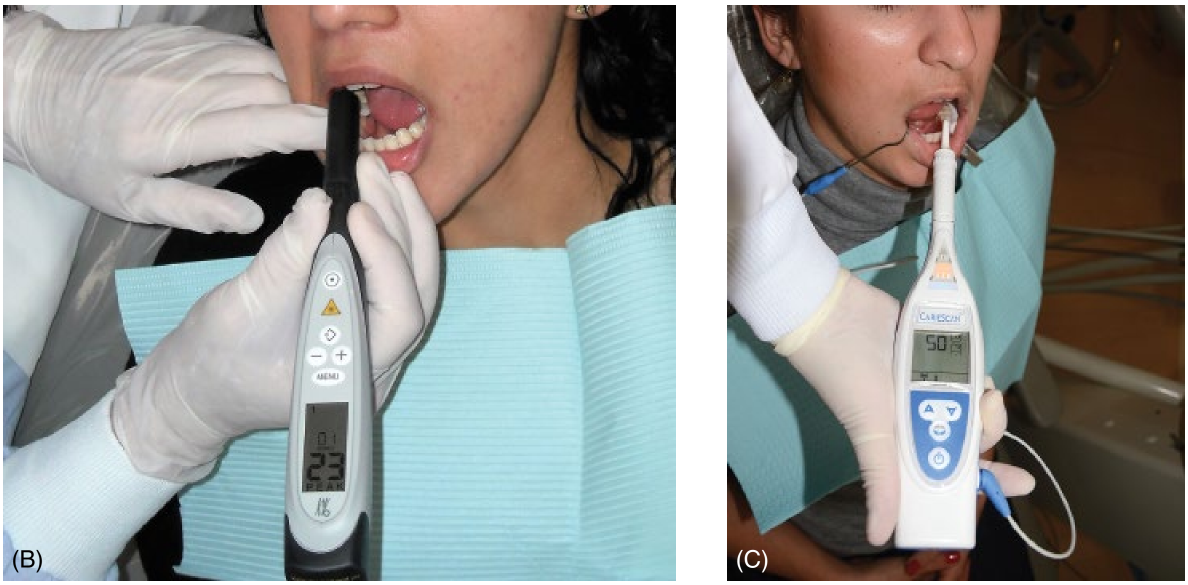


Figure 3.5 **(B and C)** Both Diagnodent (Kavo) in panel B and Cariescan (Ivoclar) in panel C are hand-held laser caries devices used to help evaluate any suspicious pits and fissures.

for easier and more accurate communication with your patient so that he or she can more readily understand the reasons for your treatment recommendations. Pay particular attention to cervical and incisal erosion as well as any large, defective restorations.

At what point do you suggest crowning versus the more conservative treatment of bonding, veneers, or porcelain inlays or onlays? Esthetically and functionally, it may be much better to conserve the labial (or lingual) enamel rather than reduce it to place a crown. This is one instance where patients should be given a choice after being informed of the advantages and disadvantages of each treatment option. Frequently, informed patients will opt for the more costly but more conservative procedure.

Arch alignment

Arch integrity should be evaluated both vertically and horizontally. Although orthodontics can correct most arch deformities, restorative treatment frequently can provide an acceptable esthetic and functional compromise. Determine the plane of occlusion and analyze just how discrepancies will affect the ability of your ceramist to create occlusal harmony. Slight irregularities in tooth-to-tooth position can make such a difference in the final arrangement that it always pays to take adequate study casts and then double-check your initial visual analysis to ensure that you can achieve the occlusal and incisal plane you wish. I have estimated that approximately 50% of my new patients over the years have had orthodontic consultations prior to arriving at a treatment plan. Years ago I coined the phrase “compromise orthodontics” whereby the teeth are moved into a better but not perfect position. This can allow a better restorative result than if the teeth were left in their original position. Now, with Invisalign so many more adults are accepting orthodontic treatment than ever before because the technique eliminates visible brackets of any kind, which can be a turn off for many adult patients.

Periodontal evaluation

Evaluation of bone support, tissue recession, tooth mobility, bleeding points, and periodontal pockets all have tremendous influence on your ability to achieve an esthetic as well as functional result (Figure 3.5C). Presence or absence of appropriate ridge tissue also can change the treatment approach. A major reason for predestined esthetic failure is a failure to realize the negative factors involved.

If your patient has a periodontal condition that you feel will not heal with routine prophylaxis treatment, you may first wish to institute soft tissue management procedures. This is especially important if the final treatment plan could vary, depending on how successful the soft tissue management therapy will be. In fact, spending extensive time establishing your patient’s entire treatment plan at this time could be counterproductive. What may appear to be the best plan of action now could be considerably altered depending on not only your therapy, but also on how well the patient follows your homecare program. The patient’s periodontal condition may well need to be reanalyzed after soft tissue management with you or your hygienist. Therefore, a consultation with the periodontist can either be at or after the initial appointment or after any disease control. One advantage in having the periodontist see the patient in this state is because he or she will be viewing the patient with the tissue in the best condition possible without a surgical or other periodontal therapy. But failure to achieve a successful esthetic and functional periodontal condition that serves as the framework for the teeth can make or break the final result.

Facial analysis

The first step in facial evaluation is to make sure you are viewing your patient at an appropriate angle. Have your patient stand or sit up in the chair with his or her gaze parallel to the floor. Then you can more easily tell if a part of the face is out of proportion. Later, computer imaging can confirm this for you. Note any facial deformities or parts of the face that stand out disproportionately (Figure 3.6).

Next view your patient’s profile at rest, smiling, and with lips closed. This view can also reveal potential esthetic problems depending upon what will eventually be planned for the patient. Also, by you viewing the profile it allows the patient to also voice any problems that he or she may want corrected. The problem may be nondental such as a nose or chin that the patient may not be happy with which can prompt you to offer possible solutions and an eventual consultation with either a plastic or oral surgeon.

Visualize your intended changes, such as increasing the interincisal distance, or shortening, widening, or narrowing the teeth. Then confirm your ideas via computer imaging. Try to see how your patient’s appearance could be improved. To do this you need to visualize an ideal facial form and identify what is lacking to make that face ideal. You may not be able to accomplish this—nor does every patient wish to be “perfect”—but for those who do, your careful evaluation can be extremely helpful. The more you do this the better you will become at helping your patients see what is needed to improve their appearance. A video camera and monitor also allow both you and your patient to see the face in two-dimensional silhouette form. By recording your patient while speaking various facial positions can be seen, thus making it easier to identify the extent of any esthetic problems.

Esthetic evaluation chart

To accurately diagnose a patient’s problems and then create the best esthetic treatment plan, an esthetic evaluation chart is helpful. It can be a simple one-page form as developed by Goldstein (Figure 3.7) or a more elaborate version. The comprehensive charts developed by Levine, Oquendo, and Dawson incorporate both esthetics and function in their evaluation criteria. There are a number of excellent esthetic evaluation forms and several of the best are presented in Appendices A, B, and C at the end of Volume 1. All critical areas of the teeth, mouth, and face are displayed in an easy-to-understand diagrammatic fashion. Whether you use one of these charts or develop one of your own, they can be valuable diagnostic tools in your treatment planning.

Transillumination

Large tooth fractures can usually be observed clinically, but most enamel microcracks are rarely seen unless the affected teeth are either transilluminated (Figure 3.8A and B) or viewed with an

Figure 3.6 Facial evaluations should be made both in person, face to face, and recorded photographically. The digital photograph provides the two-dimensional silhouette from which it is easier to determine facial deformities.

intraoral camera. Therefore, you should allow sufficient examination time to transilluminate or view each tooth and record whether there are vertical, horizontal, or diagonal, or if no microcracks are present. This will help you predict the probability of future problems.

The presence of microcracks does not mean it is necessary to bond, laminate, or otherwise restore the tooth. The greatest percentage of teeth with vertical microcracks are not restored and rarely offer problems. However, teeth with horizontal or diagonal microcracks, usually the result of substantial or unusual trauma, may warrant repair. At the very least, bonding over the microcrack, if sensitive, can be useful in reducing discomfort and help to seal the defect and hold the tooth together. Another reason for detecting microcracks is to alert the patient to the fact that these tooth defects are present. Also, advise the patient that these microcracks stain more easily than solid enamel so some dietary change may need to be suggested. For instance, heavy smokers and coffee drinkers need to know that they may have new motivation to quit or seriously reduce some of the main causes of stain.

The intraoral camera

The simplest high-tech method of documenting the presence of microcracks is the use of an intraoral camera. It allows you to show patients their microcracks enlarged on a TV monitor, and also to record the finding on either a photograph or video. Thus, the patient involved in an accident claim has tangible evidence to provide insurance companies with proof of damaged teeth.

An intraoral camera provides instant visualization of the patient's teeth in real time. It is a powerful communication tool that helps you and your patient focus on "how to treat" instead of "why treat?" In today's high-tech society, patients relate to live video images in a way they seldom do to a sketch or X-ray. Since an intraoral camera also has the ability to store the images it records, the pictures are available later to both you and your patient, to demonstrate the before- and after-treatment images (Figure 3.9A–F).

With the capability to see and record conditions such as the presence of enamel cracks, the intraoral camera has become one of the most valuable diagnostic aids in the dental operatory. It is the best tool to allow you to reveal which teeth and/or restorations are defective. In addition to showing your patient exactly why you are suggesting restorative therapy during the treatment planning stage, you can use the camera as a continuous communicator and educator during treatment. For example, you can point out actual caries under an old filling you are replacing. Since very few patients have ever seen real "decay," you are also reinforcing your credibility as an honest practitioner performing necessary procedures.

A major use of the intraoral camera in esthetic dentistry is in showing patients defective restorations. This is especially useful when discussing how defective Class II restorations might affect the color of the proposed porcelain laminates. To achieve ideal esthetics when making porcelain laminates, the teeth should be uniform in color. Thus, an old amalgam restoration that has darkly stained a part of the tooth can influence the color of the final laminate. The intraoral camera will provide convincing evidence that the offending restoration should be changed prior to laminate construction. Another reason to use some of the intraoral camera is that by recording what you find after removing an old restoration you are acknowledging any pathology present and also any potential future problem as a

Clinical Examination of Conditions Present

A Color
- Discoloration ______
- Unsightly restorations ______
- De-calcification______ Hypercalcification ______
- Caries ______
- Stains______
- Other ______

B Size and shape
- Large teeth______ Small teeth ______
- Faulty restorations______
- Attrition______ Abrasion______ Erosion ______
- Other anomalies of tooth form,size or number ______

C Arrangement
- Missing teeth______ Crossbite ______
- Chipped or fractured teeth______ Open bite ______
- Uneven incisors______ Excessive overbite ______
- Excessive uniformity______ Spaced incisors ______
- Protrusion maxillary teeth______ Crowded incisors ______
- Protrusion mandibular teeth______ Closed vertical dimension ______
- Smile line______
- Undererupted and extruded teeth ______

D Periodontal
- High lip line ______ Low lip line ______
- Inflamed gingiva______ Receding gingiva ______
- Hypertrophic gingiva______ Calculus ______
- Plaque______ Cleft ______
- Advanced bone loss ______
- Gingivitis ______
- Periodontitis______
- Other ______

E Other abnormalities ______
______

Treatment Indicated for Esthetic Improvement

- Subject needs some______ no______ elective ______
- Cosmetic contouring ______
- Orthodontia______ major______ minor ______
- Operative______
- Prosthodontia ______
- Bridgework______
- Periodontia______ SGC______ GPY______ GTY ______
- Other ______

Figure 3.7 Original esthetic evaluation chart. (Goldstein, R. Esthetics in Dentistry, Ist edition, 1976.) Although there are many newer forms available (see Appendices A–C), many of the conditions listed here are still quite relevant.

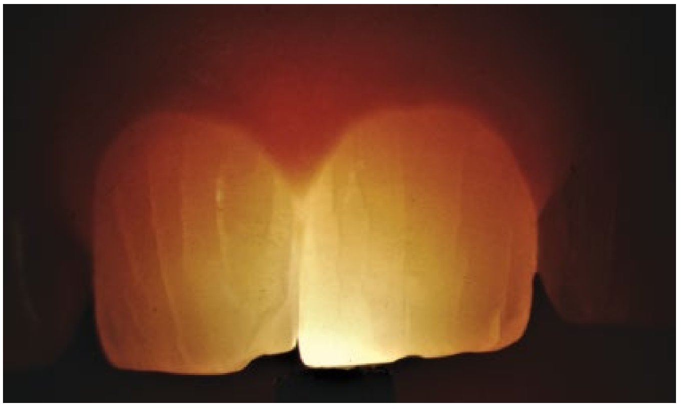


Figure 3.8 **(A)** Using an intraoral transilluminator is an excellent method of diagnosing microcracks. The intraoral camera can also record these microcracks.

Figure 3.8 **(B)** Transillumination is easily accomplished using one the many Microlux (AdDent) tips. One of the most useful ones is a vertical tip that can help visibility and measure post preparations.

Figure 3.9 **(A)** This Kodak 1600 intraoral camera has auto focus which can either be wireless or wired, and it makes it easy for both dentist and hygienist to quickly record a patient's condition including potential caries identification technology.

Figure 3.9 **(C)** Another major use of the intraoral camera is the important recording of deep microcracks along the pulpal floor. This recording will be helpful in showing your patient that the tooth was damaged prior to your restorative treatment.

result of an existing microcrack on the pulpal floor, deep decay, or other hidden problem.

The extraoral camera

Digital photography has virtually transformed diagnosis to the point that there is little excuse today for not adding digital photographs to your diagnostic records. For every new patient our dental assistant takes a complete series of extraoral photos, uploads them to the patient's photo chart, and when I come in to

Figure 3.9 **(B)** One of the major uses of the intraoral camera is to record and show your patient severe microcracks that may result in catastrophic tooth fracture. Such an example is seen in the bicuspid photograph.

Figure 3.9 **(D)** The SOPROLIFE intraoral camera not only provides visual evidence of what you see, but also quickly converts to a light-induced fluorescence evaluator to help distinguish carious from noncarious tooth structure.

see the patient for the first time the photos are already on the chairside monitor. This makes it much easier to show the patient potential problems as well as having the patient point out areas of his or her concern. We train our assistants to take good digital photos before we even see a new patient, which really helps both the patient and me look at the various photos in two dimensions. When you view your patient in the dental chair, you are seeing the patient in 3D. However, Pincus (personal communication) pointed out that when you look at a photo, you are then looking at the image in 2D which is much better to help you see silhouette form and easier to detect esthetic defects. (See Chapter 7 on practical clinical photography for instruction on views to capture.)

There are also times when you would be smart to record your patients' comments and pictures using a video camera. This can be especially important if the patient is complaining of "botched

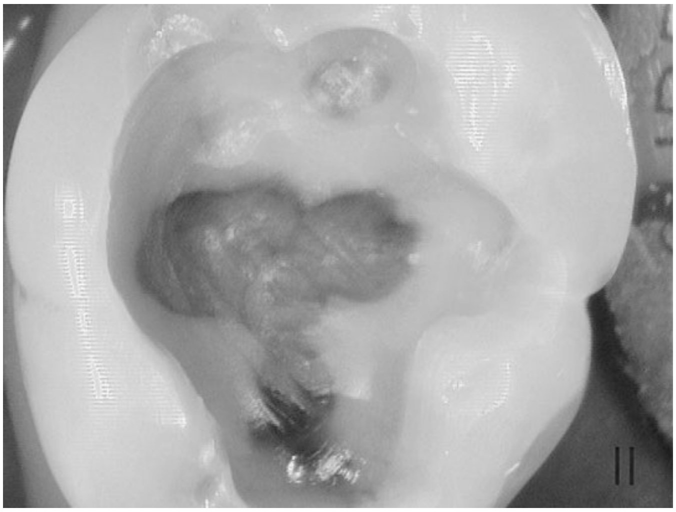


Figure 3.9 **(E)** This photo was taken after caries was thought to be removed under a defective amalgam restoration.

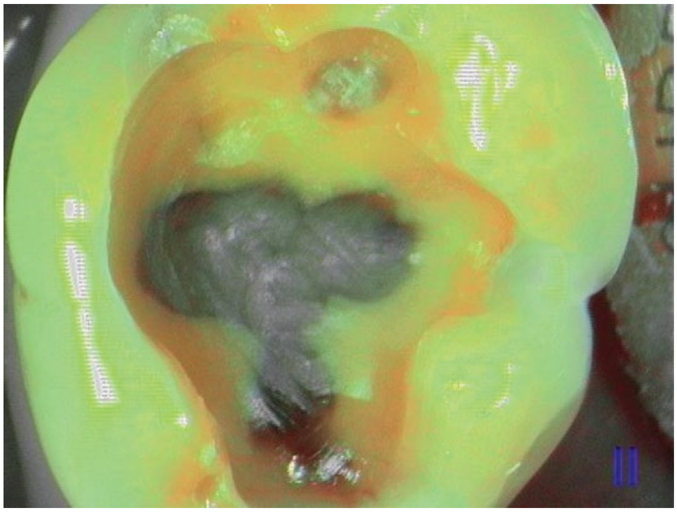


Figure 3.9 **(F)** A simple click converts to the special blue light, which reveals in red where caries was still present.

dentistry" or is so unhappy with the previous dentist that a lawsuit could be occur in the future. The better records you have of the patient's actual condition and what the patient is unhappy with the less likely you will be misquoted or misunderstood. Furthermore, your own words cannot be misconstrued by the patient. Acquiring a good, high-definition video camera is unnecessary today because a cell phone can take high-definition video with ease, so it makes little sense to not have your potentially difficult patients recorded.

A dual form of recording information will capture simultaneously the pretreatment full face and smile of the patient as well as the conversation relative to his or her perceived condition or problem. However, a panoramic film or even a CT scan may not be able to give you the detail you need for a complete diagnosis. Both an audio and video recording are extremely helpful if there is any future question about the exact condition with which the patient originally presented. Viewing the 2D full-face aspect on a TV monitor makes it easier for both you and your patient to accurately see the silhouette form. This is also true when recording the patient's right and left profiles, and close-up smiling and speaking. Most patients are amazed by what is revealed in these views. They become acutely aware that this is what everyone else sees and can be more motivated to make sure these views can eventually present them in the most flattering way possible. The result is greater potential for a more comprehensive treatment plan (Figure 3.10).

X-Rays

Although the typical full-mouth radiographic series is indispensable to patient examination, there are times when some patients will object to even digital radiation regardless that it may be 90% less than with traditional radiation techniques. In these cases, it is extremely valuable to have technology like a CBCT scan or panographic radiograph. Digital radiographs are also used to take multiple views at different angles of problem areas, and the fact that it is instantaneous can save time in diagnostic procedures. This technology is also helpful when fitting inlays, onlays, crowns, posts, and virtually all other fixed prostheses where try-in adjustments are usually necessary to obtain perfection in fit (Figure 3.11A). Patients will not object to further radiographs when they realize how little radiation the process involves. This means you can continue to fit your prosthesis and repeatedly check the margin with additional X-rays until it is perfect. A major enhanced advantage of digital radiographs is the ability to communicate information to your patient, even in color. Many patients have difficulty in seeing a problem using the typical grey scale of the X-ray (Figure 3.11B).

Occlusal analysis

Evaluating occlusion of your new patient is essential to both function and esthetic treatment planning. The simplest way to initially observe the occlusion is through accurate diagnostic casts mounted on an adjustable articulator. When this step is combined with a clinical evaluation it becomes easier to determine if orthodontic therapy needs to be a part of your treatment plan. This analysis also will help you explain why orthodontics may be an important final step in the treatment plan. You will definitely need to have clear records of your recommendations and if the patient refuses to even consider orthodontics this fact definitely must be documented and even initialed in the chart. I have had many cases of unhappy patients with compromised restorative treatments whereby the patient stated orthodontics was not offered as part of the treatment plan only to find after consulting with the previous dentist that orthodontics was indeed mentioned but not written down in the patient's chart. Consequently, regardless of a patient's preconceived notion that they would not consider orthodontics, after insisting on a joint consultation with the orthodontist, about half of these patients elect to have either ideal or compromised orthodontic treatment.

Periodontal charting

No part of the esthetic examination is more important than ascertaining the condition of your patient's supporting bone structure. The most perfect restoration in the world will fail if placed in a tooth with a weak supporting structure. Therefore, functionally, esthetically, and legally you are required to thoroughly examine

Figure 3.10 Although there are a multitude of extraoral cameras that can be used for patient photographs, a Nikon D300 with four flashes is able to provide excellent digital images.

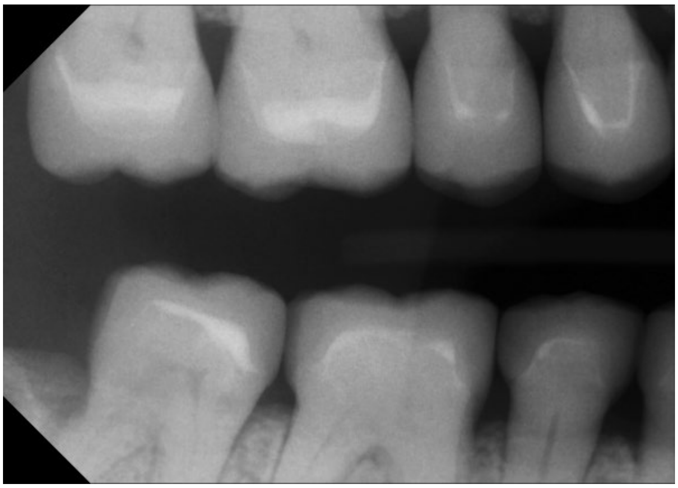


Figure 3.11 **(A)** Digital radiographs make it quick and easy to verify the interproximal fit of your prosthetic restorations before final seating.

full-mouth radiographs as well as probe teeth in six locations. This can be done with a traditional periodontal probe or an accurate 0.5-mm-increment thin colored probe (Figure 3.11C and D) (Goldstein ColorVue Probe, Hu-Friedy), where the data can be recorded electronically using a voice-activated system. One major advantage in producing a color, 8 × 10 in (20 × 25 cm) easy-to-comprehend chart to give to the patient is to make him or her feel more responsible for any diagnosed periodontal problems (Figure 3.12). It is far better to give your patients tangible evidence of their periodontal problems rather than merely verbally informing them of your findings. Voice activation makes it easy and quick for your hygienist to perform this periodontal charting on virtually every patient and also enables you to provide periodic progress charts when necessary.

Computer imaging

Used first in 1986 by plastic surgeons and the beauty industry, the computer makes it possible to digitally alter the pictures of a patient's teeth and face, and to produce a picture of how they might look after cosmetic treatment (Figure 3.13). This visual prediction of potential treatment solutions to esthetic problems offers an unparalleled method of letting you and the patient look at how your intended esthetic correction will not only change your patient's smile, but also, in many cases, his or her entire face. It also accomplishes the following:

- It lets you do a better job of treatment planning by allowing you to visualize a possible result, which can then be studied to determine its esthetic effect.

Figure 3.11 **(B)** Digital radiography makes it easy to convert black and white images to color so patients can quickly see and understand what the dentist is describing.

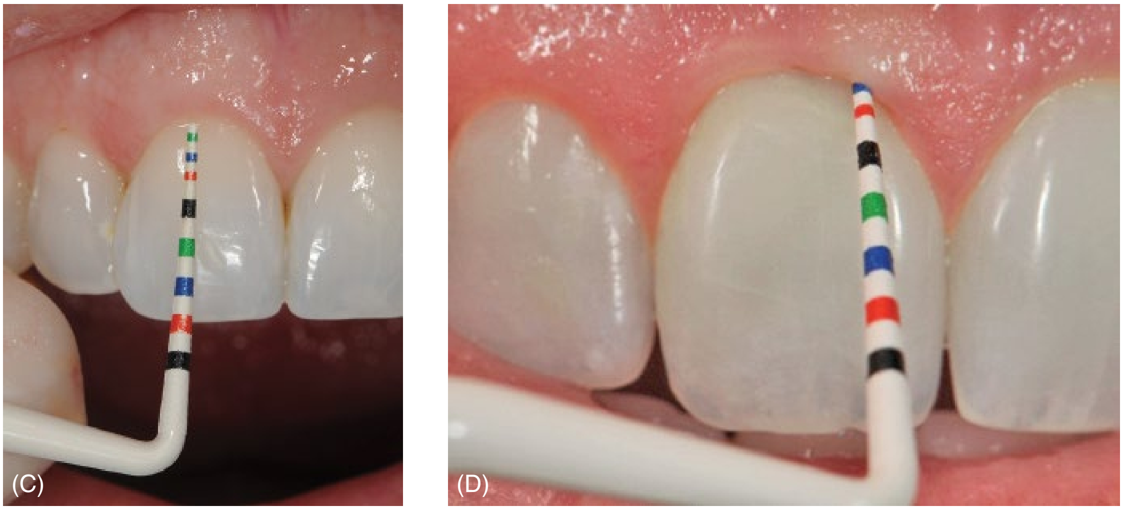


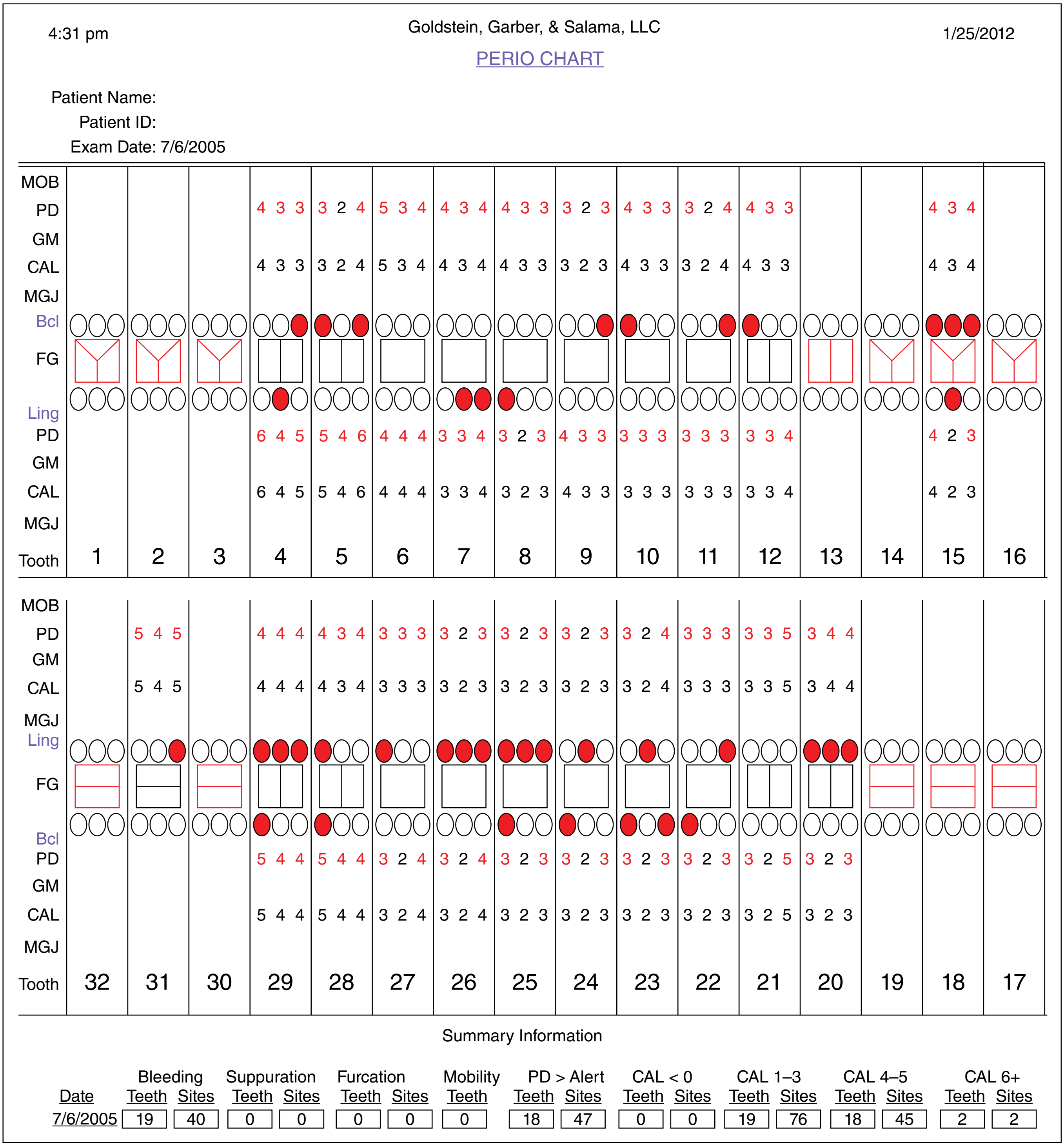
Figure 3.11 **(C and D)** The Goldstein ColorVue Probe is more comfortable than the metal probe and more precise since it measures in 0.5 mm increments up to 3 mm.

- The patient is able to view your intended correction and make suggestions on how he or she would like to see it modified.
- Based on feedback from the patient, further computer imaging allows you to show patients how they can look with any number of additional or different esthetic changes and improvements. You are therefore limited only by your creative ability.
- It increases patient motivation by demonstrating the positive aspects of an improved appearance and enhanced self-image, and reducing patient uncertainty and anxiety.
- It helps to establish the fact that your office employs state-of-the-art diagnostic and communicative tools and techniques, making a positive statement about the type of dentistry you practice. The real value in enabling a patient to see proposed changes is ensuring that both dentist and patient envision the same result. If, for any reason, they do not have the same expectations, this is the proper time to make any changes regarding results. Certainly, unmet expectations after your treatment can require either redoing or altering the correction; or even worse, they may establish a defensive position with the patient, which frequently causes a wider communication gap. At the very least, one can avoid discovery after the fact, which is expensive. Retreatment of the patient is usually done at a loss for the dental office. It does not take too many losses of this type to realize that esthetic imaging can be a valuable asset when a major esthetic correction is being planned.

There is a legitimate question raised when turning to the decision of who is to perform the imaging. Obviously, many dentists like to make their own computer changes while others prefer to have a computer imaging therapist assist in providing this service. In our office, we chose to have a talented dental assistant train to be able to make the necessary computer enhancements to both smile and face. This assistant is capable of understanding our intended changes, plus she is artistically qualified and has excellent ability to communicate with the patient. This last fact also saves the doctors considerable "explanation" time. However, the imaging therapist can be a hygienist or another person knowledgeable about dental procedures. The patient must be made to clearly understand that the image produced by the computer is only an approximation of intended results you feel he or she can reasonably attain. If you plan to give a copy of the computerized image to the patient, remember to always print, in color, a disclaimer clause on the copy. This clause may read as follows:

> This picture is for purposes of illustration only. It does not represent a guarantee of any kind.

The following is a good example of just how important computer imaging can be: a 26-year-old professional athlete was concerned about his crowded teeth (Figure 3.14A). Clinical examination revealed a high lip line with gingival tissue covering the cervical third of the teeth. This combination resulted in a disproportional smile/tooth relationship to the full face. The patient's previous dentist stressed the ideal solution of orthodontics but did not give him any alternative. The patient felt there must be an alternative, such as crowning. When verbally discussing the various options for improving his appearance, the patient could visualize how straight the teeth would look, but he had difficulty understanding the need for cosmetic periodontal therapy. Computer imaging was used to show the patient what could be expected of cosmetic periodontal surgery plus 10 porcelain veneers (Figure 3.14B, right-hand panel). When he saw the intended result through computer imaging, his immediate question was, "How fast can the treatment be accomplished?" Following cosmetic periodontal surgery, 10 porcelain veneers were inserted to achieve the look in Figure 3.14C. Computer imaging played a major role in convincing this patient of the importance of both procedures to obtain maximum esthetic results.



4:31 pm | Goldstein, Garber, & Salama, LLC | 1/25/2012

PERIO CHART

Patient Name:
Patient ID:
Exam Date: 7/6/2005

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
MOB																
PD				4 3 3	3 2 4	5 3 4	4 3 4	4 3 3	3 2 3	4 3 3	3 2 4	4 3 3			4 3 4	
GM																
CAL				4 3 3	3 2 4	5 3 4	4 3 4	4 3 3	3 2 3	4 3 3	3 2 4	4 3 3			4 3 4	
MGJ																
Bcl																
FG																
Ling																
PD				6 4 5	5 4 6	4 4 4	3 3 4	3 2 3	4 3 3	3 3 3	3 3 3	3 3 4			4 2 3	
GM																
CAL				6 4 5	5 4 6	4 4 4	3 3 4	3 2 3	4 3 3	3 3 3	3 3 3	3 3 4			4 2 3	
MGJ																
Tooth	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

	32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17
MOB																
PD		5 4 5		4 4 4	4 3 4	3 3 3	3 2 3	3 2 3	3 2 3	3 2 4	3 3 3	3 3 5	3 4 4			
GM																
CAL		5 4 5		4 4 4	4 3 4	3 3 3	3 2 3	3 2 3	3 2 3	3 2 4	3 3 3	3 3 5	3 4 4			
MGJ																
Ling																
FG																
Bcl																
PD				5 4 4	5 4 4	3 2 4	3 2 4	3 2 3	3 2 3	3 2 3	3 2 3	3 2 5	3 2 3			
GM																
CAL				5 4 4	5 4 4	3 2 4	3 2 4	3 2 3	3 2 3	3 2 3	3 2 3	3 2 5	3 2 3			
MGJ																
Tooth	32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17

Summary Information

	Bleeding		Suppuration		Furcation		Mobility	PD > Alert		CAL < 0		CAL 1–3		CAL 4–5		CAL 6+	
Date	Teeth	Sites	Teeth	Sites	Teeth	Sites	Teeth	Teeth	Sites	Teeth	Sites	Teeth	Sites	Teeth	Sites	Teeth	Sites
7/6/2005	19	40	0	0	0	0	0	18	47	0	0	19	76	18	45	2	2

Figure 3.12 A digital perio-probing chart is another essential diagnostic tool to be used in treatment. It is easy for both dentist and hygienist to read and compare results.

The major advantages of computer imaging are outlined below.

- Computer imaging demonstrates to the patient 2D views of their teeth and smile that they would not normally see (Figure 3.15).
- It provides full-face frontal and profile views that can help you and your patient visualize the effects of proposed changes to the teeth and gingival tissues on the face.
- It may indicate what not to do, and highlight undesirable results. Not infrequently, certain intraoral changes can have a detrimental effect, instead of the desired one, by being too perfect or too imperfect. Equally damaging is making teeth too light or too dark. Although not guaranteeing a perfect shade, the computer can help illustrate to the patient an acceptable, approximate shade range. A critical consideration for imaging occurs when orthodontic treatment achieves occlusal success

Figure 3.13 Although there are many ways of showing a patient the results of treatment, esthetic imaging is an excellent method of demonstrating potential results of diastema closure. A disclaimer should always appear on the photos stating: "This photo is for illustration only and does not represent a guarantee of any kind."

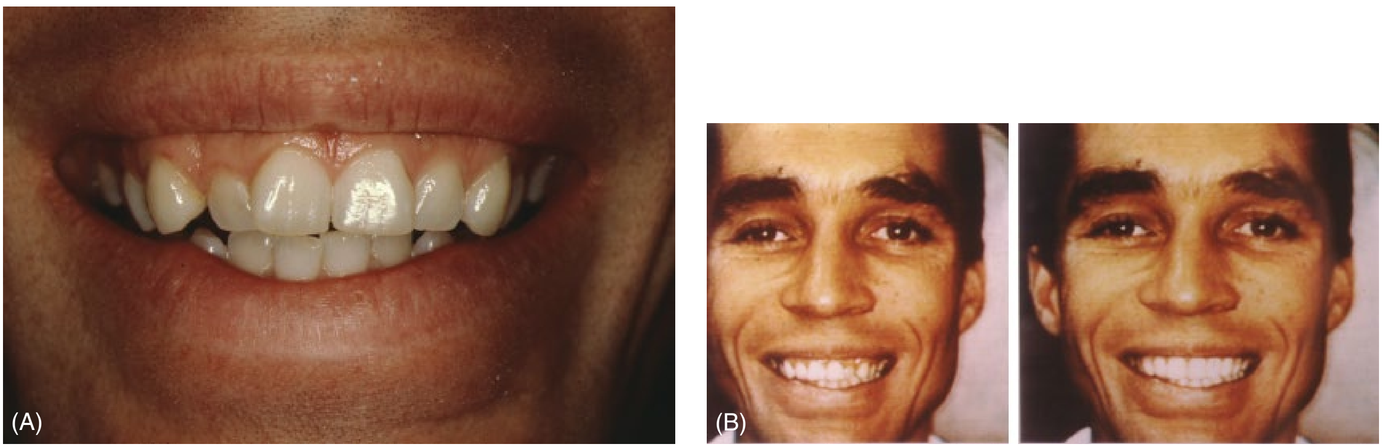


Figure 3.14 **(A and B)** Although crowded teeth caused this international tennis star to seek esthetic treatment, computer imaging indicated the need for cosmetic periodontal-gingival raising therapy for improved facial proportion. Imaging also gave him a much desired alternative to orthodontic therapy by demonstrating the proposed results using porcelain veneer restorations.

only to destroy facial balance. For example, moving anterior teeth lingually either with orthodontics or through prosthetic means may make for occlusal success, but it may cause more prominence to the patient's nose. Your patient may like his or her nose as it is. Making the proposed change could produce an esthetic disaster from the patient's point of view.

- When restorative treatment consists of bonding, veneers, or crowns, imaging can be invaluable during the try-in phase when the patient or dentist is not absolutely certain of the optimal length or width of the new restoration. Rather than blindly removing existing porcelain incisal edges on the restoration, which could ruin your esthetic result, it is easier to image your patient and make the changes on the screen. You and your patient can then come to a mutual agreement on what looks best.

Figure 3.14 **(C)** The final smile would not have been possible had this patient not been motivated to undergo both periodontal and restorative therapy after seeing the potential results via computer imaging.

- Another critical area where computer imaging can make a significant difference is in the communication between the dentist and the off-site laboratory technician. That communication is most often in the form of models, impressions, and written notes. If an actual picture reflecting what you and your patient expect is given to the laboratory technician, the probability of a successful result is greatly improved.

Trial smile

The trial smile is the very best method for both patient and dental team, including the laboratory when necessary, to view proposed esthetic changes. This extra step is essential to avoid esthetic failure. There have been many times when a patient did not initially like our plan and we were fortunate to make the necessary changes in the trial smile to obtain patient approval. Once you have that approval take alginate impressions so both you and the laboratory will have the model to use as a guide for the final restorations.

Although the subject of trial smile is dealt with extensively in Chapter 42 on temporization it should be noted here that a next or even substitute step may be a trial smile. No doubt a patient can more easily grasp the effect of lengthening the teeth with a mock-up direct composite resin applied to his or her own teeth. Nevertheless,

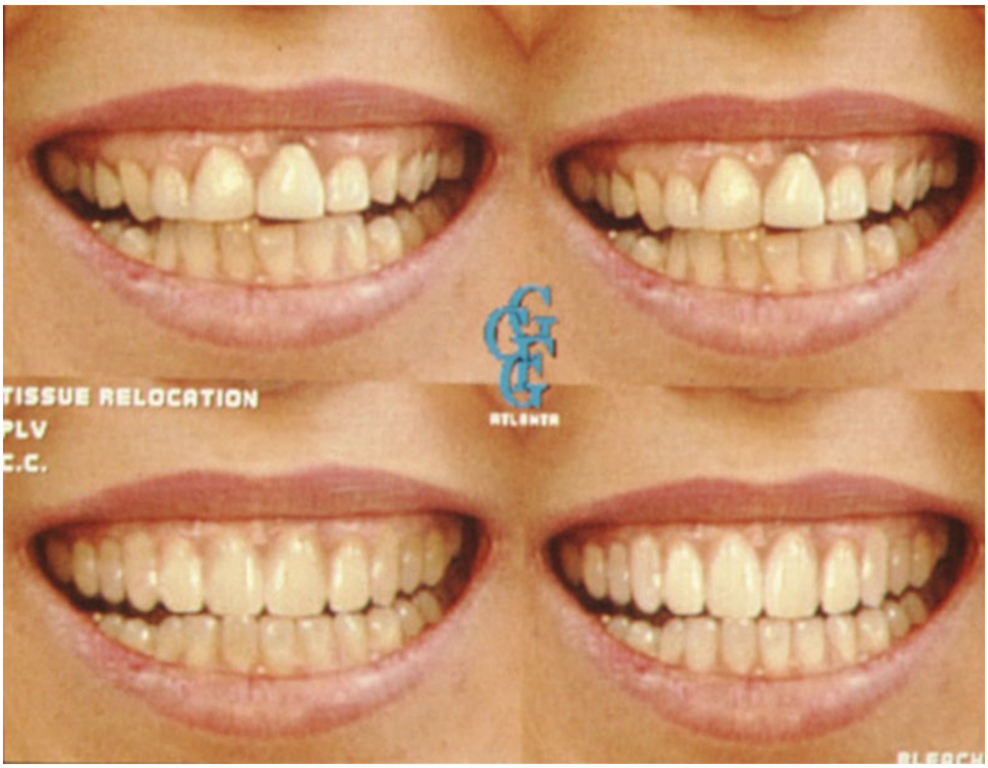


Figure 3.15 This computer imaging printout shows the importance of taking a lateral view since this aspect as seen by others is seldom observed by the patient.

looking at a 2D effect is of advantage as well. So an esthetic imaging photo of before and after plus an extraoral photo of the patient's own teeth being altered by mock-up composite (or tooth-colored wax) can help the patient make a more educated decision.

Technology and an integrated digital system

Dentistry is fast heading toward a paperless office where every conceivable record can and will be computerized. The patient's file, including all diagnostic and treatment records, can already be stored, displayed, printed, and transported electronically. One of the major advantages of this trend is that it enables you to accumulate vast amounts of knowledge about your patients and retrieve the information faster than by looking through pages of records to find, for instance, what cement you used many years ago to seat a particular crown.

State-of-the-art diagnostic procedures are now controlled by an integrated workstation. The advantage of this clinical and management-oriented system is the ability to add and retrieve information quickly and easily from multiple, flexible locations within the office. Records, X-rays, and reports are not misplaced. A patient's last X-ray and the next day's schedule should be at your fingertips while you are on the phone determining how and when to treat the patient. You may even have workstations at home for on-call situations involving any patient in your practice. This is especially valuable for multidoctor and multilocation practices. Fast and comprehensive specialty and referral consultations are easily made using modems. Third-party reimbursement is certainly faster if claims are submitted electronically, and procedure approvals can be higher with the ability to submit more in-depth documentation.

Various components of typical integrated system include:

- practice/business management system
- extraoral camera and video, with memory and printer
- intraoral camera
- digital radiography
- occlusal analysis
- voice-activated periodontal and general oral diagnostics
- caries detection analysis
- patient education and interactive video system
- esthetic imaging system
- CBCT and 3D treatment planning software.

The voice-activated charting component is actually the core of the system from a clinical perspective because it generates the basic information of the electronic chart. In addition, temporomandibular joint analysis and esthetic evaluation can be incorporated into this integrated system. The video recordings become a form of informed consent. While recording face and smile, you also capture the patient's voice stating that he or she understands what a particular procedure is and why it is being done. For the esthetic practice, this can prove to be a definite advantage, especially if a patient presents a problem after treatment. Photographic records need to be the rule rather than the exception. Recreating the circumstances of a restorative procedure takes only seconds if they are stored in the system. Three-dimensional diagnostic models and even their occlusion are possible when the principles of computer-aided design/computer-aided manufacturing (CAD/CAM) are integrated into the system.

The first visit frequently ends with the recording of the patient's images. The actual computer imaging correction often occurs after the patient leaves, either by or in consultation with the dentist. You may also consider using Digital Smile Design in treatment planning for your patient, (see Chapter 4).

Preparation for the second visit

Review of radiographs

Preliminary reading of radiographs should reveal obvious caries, periodontal disease, and evidence of abscess or other pathology. Any teeth to be considered for crowning should be examined on the radiograph to see if the pulps are large or receded, because their condition can alter treatment expectations. Teeth that have deep caries or thickened apices may sometimes require root canal therapy. It is essential to determine and treat any necessary endodontic treatment before inserting esthetic crowns. Performing an endodontic procedure on a newly cemented porcelain crown is not a pleasant task, especially given the possibility of lingual surface fracture. Therefore, interim treatment crowning for an extended period may be indicated before you insert the final restorations.

Evaluation of diagnostic models

Diagnostic models are an essential part of the treatment planning procedure. However, they must be accurate and well-made, and contain as much detail as possible. Arch relationships and tooth form, size, and arrangement should be studied. It may be necessary to consult a specialist with the diagnostic models before the patient's second visit. Several questions should be asked when reviewing the models:

1. Is repositioning needed for a proper esthetic result?
2. Can restorative dentistry alone achieve esthetic balance?
3. Are periodontal or other surgical procedures necessary for a successful restorative result?
4. Do wear facets indicate a loss of vertical dimension or any other occlusal problem? It might be necessary to wax-up an intended restoration as well as various alternatives to help the patient choose the best one. A wax-up is an important diagnostic and visual aid and enhances diagnosis and communication between the patient and dentist.

Review of medical and dental histories

The dentist should be aware of any systemic physical or mental disease. Using a history chart similar to that in Figure 3.16A and B, the dentist can learn if a patient has any of the various medical ailments that could compromise a successful esthetic result. It is

MEDICAL STATUS FORM

Name: ____________________ Birth date ________
Address: ____________________ Sex ___M ___F
____

Phones: home: ____________
work: ____________ Cell: ____________
email: ____________

The dentistry you receive has an important interrelationship with the health problems that you may have, or medications you are taking. It is imperative that you provide the following information to help us treat you as effectively and safely as possible.
Please initial that you read this paragraph: ________

Are you under a physician's care now?	( )yes ( )no	If yes, please explain: Dr. Name: Address: Telephone Number: Date of last physical exam:
Have you ever been hospitalized or had a major operation in the past five years?	( )yes ( )no	If yes, please explain:
Have you ever had a serious head or neck injury?	( )yes ( )no	If yes, please explain:
Are you taking any prescription or non-prescription medications, pills, herbal supplements, aspirin, ibuprophen, vitamin E or drugs?	( )yes ( )no	If yes, please list and explain: ____________ ____________ ____________ ____________ ____________
Are you taking or have you taken bisphosphonate for osteoporosis: such as Actonel, Boniva, Fosamax, Zometa or Aredia?	( )yes ( )no	If yes, please explain:
Have you ever been advised to take pre-medication for dental visits?	( )yes ( )no	If yes, please explain:
Have you ever had a lesion biopsied or removed from the mouth or lips?	( )yes ( )no	If yes, please explain:
Are you on a special diet?	( )yes ( )no	If yes, please explain:
Do you smoke or use tobacco?	( )yes ( )no	If yes, how much? How long?
Do you use controlled substances?	( )yes ( )no	If yes, please explain:
Do you consume alcohol?	( )yes ( )no	If yes, please explain:
Has anyone told you that you snore?	( )yes ( )no	

WOMEN:	Are you pregnant or trying to get pregnant?	( ) Yes	( ) No
	Taking oral contraceptives?	( ) Yes	( ) No
	Nursing?	( ) Yes	( ) No

DA/RDH Initials: ________
Dr. Initials: ________

Figure 3.16 **(A)** Medical history form (page 1).

important to know, for example, if the patient can tolerate sitting for extended periods during try-ins or difficult staining procedures. As an alternative, can and should conscious sedation be utilized? It is obvious that not every patient can undergo cosmetic restorative treatment. The patient's history can show if there are systemic diseases that can cause problems, particularly in combined therapy cases where orthodontics, periodontics, and full-mouth reconstruction are performed. An esthetic result that will last for any length of time is difficult to achieve if there is continual periodontal breakdown due to preexisting disease.

Are you allergic to any of the following:

☐ Aspirin ☐ Penicillin ☐ Tetracycline ☐ Erythromycin ☐ Codeine

☐ Acrylic ☐ Metal ☐ Sulfa ☐ Local Anesthetics ☐ Latex

☐ Other: ______________________ ☐ No Known Allergies

Do you have, or have you had, any of the following?

AIDS/HIV Positive	☐ yes ☐ no	Implants-Hip/Breast/knee/tooth	☐ yes ☐ no
Allergies	☐ yes ☐ no	HPV (Human Papilloma Virus)	☐ yes ☐ no
Alzheimer's Disease	☐ yes ☐ no	High Blood Pressure	☐ yes ☐ no
Anaphylaxis	☐ yes ☐ no	Hives or Rash	☐ yes ☐ no
Anemia	☐ yes ☐ no	Hypoglycemia	☐ yes ☐ no
Angina/Chest Pains	☐ yes ☐ no	Irregular Heartbeat	☐ yes ☐ no
Arthritis/Gout	☐ yes ☐ no	Kidney Problems	☐ yes ☐ no
Artificial Heart Valve	☐ yes ☐ no	Leukemia	☐ yes ☐ no
Artificial Joint	☐ yes ☐ no	Liver Disease	☐ yes ☐ no
Asthma	☐ yes ☐ no	Low Blood Pressure	☐ yes ☐ no
Blood Disease	☐ yes ☐ no	Lung Disease	☐ yes ☐ no
Blood Transfusion	☐ yes ☐ no	Mitral Valve Prolapse	☐ yes ☐ no
Bruise Easily	☐ yes ☐ no	Osteoporosis	☐ yes ☐ no
Cancer	☐ yes ☐ no	Periodontal "gum" Disease	☐ yes ☐ no
Chemotherapy	☐ yes ☐ no	Psychiatric Care	☐ yes ☐ no
Celiac Disease	☐ yes ☐ no	Radiation Treatments	☐ yes ☐ no
Congenital Heart Disorder	☐ yes ☐ no	Recent Weight Loss	☐ yes ☐ no
Convulsions	☐ yes ☐ no	Renal Dialysis	☐ yes ☐ no
Cortisone Medicine	☐ yes ☐ no	Rheumatic Fever	☐ yes ☐ no
Diabetes	☐ yes ☐ no	Rheumatism	☐ yes ☐ no
Drug Addiction	☐ yes ☐ no	Scarlet Fever	☐ yes ☐ no
Eating Disorder (Bulimia and/or Anorexia)	☐ yes ☐ no	Stomach/Intestinal Disease/Ulcers	☐ yes ☐ no
Emphysema	☐ yes ☐ no	Shortness of Breath	☐ yes ☐ no
Epilepsy or Seizures	☐ yes ☐ no	Sickle Cell Disease	☐ yes ☐ no
Excessive Bleeding	☐ yes ☐ no	Sinus Trouble	☐ yes ☐ no
Excessive Thirst	☐ yes ☐ no	Special Diet	☐ yes ☐ no
Fainting Spells/Dizziness	☐ yes ☐ no	Spina Bifida	☐ yes ☐ no
Frequent Cough	☐ yes ☐ no	Shingles/Herpes/Cold sores/Fever blisters	☐ yes ☐ no
Frequent Diarrhea	☐ yes ☐ no	Stroke	☐ yes ☐ no
Fequent Headaches	☐ yes ☐ no	Swelling of Limbs	☐ yes ☐ no
Glaucoma	☐ yes ☐ no	Thyroid Condition	☐ yes ☐ no
Heart Attack/Failure	☐ yes ☐ no	Tonsilitis	☐ yes ☐ no
Heart Murmur	☐ yes ☐ no	Tuberculosis	☐ yes ☐ no
Heart Pace Maker	☐ yes ☐ no	Tumors or Growths	☐ yes ☐ no
Heart Trouble/Disease	☐ yes ☐ no	Venereal Disease	☐ yes ☐ no
Hemophilia	☐ yes ☐ no	Yellow Jaundice	☐ yes ☐ no
Hepatitis A, B, C, D, or E	☐ yes ☐ no	Contact Lenses	☐ yes ☐ no

Have you ever had any serious illness not listed above? ( ) Yes ( ) No
If yes, please explain: ____
To the best of my knowledge, the questions on this form have been accurately answered. I understand that providing incorrect information can be dangerous to my (or patient's) health. It is my responsibility to inform the dental office of any changes in medical status.

Signature of patient, parent or guardian ____________________ date ________

DA/RDH Initials: ________
Dr. Initials: __________

Figure 3.16 **(B)** Medical history form (page 2).

The dental history can indicate the patient's familiarity with dentistry. From this, the dentist can judge how much time should be allowed for the second visit or if subsequent visits will be necessary before the final presentation. Frequently, the patient with little knowledge of dentistry will require several visits before a successful case presentation can be made. The patient's "dental IQ" indicates his or her opinion of dentists and dentistry. *The patient who is extremely critical of previous dentists may soon be critical of the current dentist.*

Preparation of a preliminary treatment plan

A preliminary treatment plan should definitely be formulated and it is also prudent to use an organized form on which to place these clinical recommendations (Figure 3.17). Although it may be revised considerably, different alternatives should be considered before the second appointment. A quadrant-by-quadrant outline of functional necessities with a separate list of esthetic options will suffice. One major consideration will be to determine what modifications may be necessary and I have found that Fradeani's Laboratory Checklist to be invaluable (Appendix C). Although the diagnosis and treatment planning phase for the treatment of esthetic dental problems can occupy a considerable amount of time, the presentation of the findings can often be better handled by a treatment coordinator skilled in the art of patient communication than by the dentist.

The role of the treatment coordinator

The ideal dental treatment coordinator is skilled in all the phases of dental practice including insurance and patient accounts, and has a good rapport with people. The treatment coordinator's job begins either when the patient telephones for information as a new patient or upon the patient's initial meeting with the dentist. The treatment coordinator needs a full and clear understanding of all phases of treatment to enable him or her to present the treatment plan to the patient in an easy-to-understand format (Figures 3.18A). After the treatment coordinator has presented a plan that is mutually acceptable to the doctor and the patient, the next step is to have your patient sign the treatment plan which should include your financial arrangements. Only then should your patient be scheduled for treatment (Figure 3.18B).

With the increasing use of auxiliary personnel, a dental treatment coordinator can be the backbone of the treatment team's communication process, providing support to the dentist, dental assistants, hygienist, receptionist, bookkeeper, and office manager alike. Your dental treatment coordinator should spend about half of the average workday dealing with treatment planning. Another third of the day will be devoted to necessary paperwork including insurance and accident cases. That leaves the balance of the day for patient problems—fees, miscommunications, and explanations of complicated dental procedures that the patient may not completely understand.

All lines of professional communication help to provide a smooth and effective treatment process for the patient. The treatment coordinator should maintain the credibility of the dentist and staff and reinforce the entire staff's dedication to ensuring the patient's faith in treatment already begun. It involves organizing and streamlining all aspects associated with patient treatment. This also requires checking the insurance and personal information that the patient provides.

Although payment for esthetic dentistry is always arranged in advance, if the treatment plan extends over considerable time a payment plan may need to be developed and explained fully to the patient. Some dentists do not want to talk about money with patients while others are perfectly comfortable doing so. If you are uncomfortable discussing fees with patients, you may too often end up giving away a good portion of your time, or working for a lower fee than you would normally charge. Therefore, for the financial health of your practice, make sure the treatment coordinator discusses fees and methods of payment with the patient.

The second appointment

In many instances, one appointment is all that is needed to diagnose, image, plan treatment, and make financial arrangements with your patient. However, more complex patient problems will usually require a second appointment.

A completed self-smile analysis form (see Figure 3.2) should be discussed with the patient before reviewing the radiographs with the dentist. With a thorough analysis, useful conclusions can be made about the patient's attitude toward his or her esthetic problems. The smile analysis provides information helpful to understanding the patients' attitudes, which should never be ignored. Patients may ask the impossible or make statements that point to more profound wishes and attitudes. Hear not only what a patient says but also what he or she means. If the planned esthetic treatment is simple, present the final treatment plan soon after the self-smile analysis has been discussed. For the patient with a difficult tooth problem (repositioning or periodontal involvement), consultation with a specialist should be arranged.

Consulting a specialist

Too often a dentist, anxious to begin treatment, fails to stress the importance of the patient consulting with a specialist. So many more patients will opt for full or minor orthodontics now if the procedure can be accomplished without brackets. Fortunately, invisible means of repositioning teeth through a series of transparent matrices, such as Clear Correct or Invisalign, have solved this problem. I also suggest using the term "repositioning" instead of "orthodontics," as it can elicit a more receptive patient response. Dentists often do not emphasize the functional objectives of tooth repositioning, and consequently may not motivate patients to seek orthodontic treatment that might be highly beneficial to their periodontal health. It is often a more conservative treatment option.

In most instances when there are difficult spaces to restore, even a minor orthodontic intervention can make a tremendous difference in the final result. It is important to let the patient know what options he or she has and the degree of excellence

Treatment Planning Worksheet

Ronald E. Goldstein, DDS

Patient: ______________________ Date: ____________

Dr. ____________ TC: ____________ RDH: ____________ DA: ____________

8	9
7	10
6	11
5	12
4	13
3	14
2	15
1	16
RIGHT	LEFT
32	17
31	18
30	19
29	20
28	21
27	22
26	23
25	24

Cosmetic Contouring:

U___ L___

Nightguard

U___ L___

Conv. ___

NTI ___

Bleaching:

U___ L___

H ___ O ___ C ___

Hygiene: Panx ___

FMX ___

BWX ___

Probe ___

Phases of Treatment:

1. ______________________
2. ______________________
3. ______________________
4. ______________________
5. ______________________

Other Consult Needed:

1. ______________________
2. ______________________
3. ______________________
4. ______________________
5. ______________________

FORMS/REG sheet revised

Figure 3.17 There are many digital diagnostic and treatment forms but this simple chart allows easy listing of proposed treatment for each tooth.

Figure 3.18 **(A)** It is essential that the dentist meets with the treatment coordinator, making sure all aspects of treatment and fees are correct before presenting the final treatment plan to the patient.

Figure 3.18 **(B)** The treatment coordinator presents the final treatment plan and answers all questions, including about financial arrangements, before the patient signs the treatment form.

that could be obtained with or without orthodontic treatment. A "compromised" esthetic result can be achieved with limited conservative orthodontics.

The next most important specialty to consider is periodontics. The control and correction of bone loss that could complicate the diagnosis or compromise the treatment results are obvious reasons to refer to a periodontist. In addition, the patient's soft tissue needs to be observed during maximum smiling. Could tissue repositioning help create a more favorable tooth size relative to the patient's face or smile? Would ridge augmentation help make a more realistic result? These, plus other questions regarding where and what type of margins to create, are typical problems that could be more successfully solved with the aid of a periodontist skilled in cosmetic surgical techniques. Thickening of the

Figure 3.19 The best interdisciplinary consultation is accomplished when all the various specialists gather in the operatory with the patient to discuss a comprehensive treatment approach. This often must take place late in the afternoon or after hours so that all can attend.

periodontal gingival biotype to preserve marginal soft tissue levels and color is critical when performing all forms of cosmetic restorative dentistry. Connective tissue crafting is often requested.

A major problem with specialist consultation is communication between the general dentist and specialists. The typical method is referring and then expecting a letter in return. What this misses is "group thinking," which can be extremely beneficial especially in complex cases. I have always tried to get the various specialists in the operatory together with me so that interdisciplinary thinking among all of us can arrive at the ideal and even compromised plan. Although the various specialists happen to be in our office now, many years ago I would arrange the patient's appointments at

If the above is not feasible then I suggest creating a high-tech network with your main referral sources so that you can both discuss and review the patient's records at the same time. Video conferencing and eventually simultaneous holographic consultation will be routine in both medical and dental practices. Digital photos, radiographs, and Skype can work just as well today.

5:00 pm and have the various specialists come to my office to first review the records, X-rays, mounted models, and photographs and then all of us see the patient at the same time. This procedure always resulted in an appreciative patient as well as clear sequence of therapy and detailed treatment planning (Figure 3.19).

When there are questionable areas regarding periapical pathology, such as in teeth with deep, old restorations or periapical thickening, an endodontic consultation is in order. Previously placed ill-fitting crowns or endodontically questionable teeth could also seriously compromise the esthetic result unless you treat these areas, if necessary, before you begin.

Finally, oral surgery must be considered when facial deformities could also complicate maximum esthetic results. This may involve scheduling a consultation with a plastic surgeon as well, if needed. The best way to communicate the advantages of obtaining specialty consultations is to let your patient know that you work with an excellent team consisting of orthodontists, periodontists, plastic surgeons, endodontists, and oral surgeons, and that your interest is in obtaining the best possible result based on their desires or preconceived images. You also need to stress that you are treating him or her as a whole person, not just treating the teeth. Finally, make sure you help your patient visualize the various options available. Eventually holographic group consultations will be possible and economically feasible especially when it is impractical to have all the specialists in one place at the same time.

The final patient presentation

The final case presentation should be a carefully prepared, easily understood treatment plan. Visual aids, before-and-after photographs, slides, models, intra- and extraoral video and computer imaging, and examples of the procedures should be used to assist in communicating the possibilities and limitations of esthetic treatment. Many patients would also like to see your treatment results on other patients if possible. There are four basic methods for helping patients visualize your suggested solutions for their individual esthetic problems.

Figure 3.20 **(A)** Even with computer imaging it is helpful for patients to be able to see how changes will affect their speaking ability and the appearance of their lip line. This patient was unhappy with his smile and wanted longer teeth.

Figure 3.20 **(B)** Tooth-colored wax applied to the central incisors showed the patient how the final restorations would correct his problem.

Figure 3.20 **(C)** Visualizing the improvement motivated this patient to obtain esthetic correction with fixed ceramic restorations.

1. **Soft, tooth-colored wax or composite resin applied directly in the mouth**: the advantages to this technique (Figure 3.20A–C) are as follows:
   - it is the least costly for the patient
   - it is the quickest method
   - it is especially useful in space or diastema problems.
2. **A waxed study model**: when the potential solution to an esthetic problem requires extensive tooth preparation, this method can be effective for those patients who are used to visualizing plans, such as an architectural blueprint (Figure 3.21). The waxed model is also important from a diagnostic standpoint when your patient has a space problem. By preparing the teeth, then waxing them, you can determine if there is too much or too little space for normal-sized tooth

Figure 3.21 Creating waxed models of the available choices helps the patient understand the treatment options and enhances the dentist's diagnostic ability.

replacement. This allows you to adjust the treatment plan as necessary to make certain you can create an adequate esthetic restoration.

3. **Esthetic imaging**: as previously stated, esthetic imaging may be the best method to help your patient visualize your intended corrections (see Figure 3.13). The printouts and the image on the monitor can be effective communication tools. This method also allows you to easily alter your treatment plan to reflect various compromises. Rarely will it be necessary for your patient to return for further imaging if you have thought of possible options in advance. It is also effective to show your patient the various choices, since most people will opt for the best look, provided they can find a way to afford the correction. For patients with complex problems, the combination of computer imaging and waxed diagnostic models will be the best choice for complete visualization.
4. **Trial smile**: by far, a trial smile is the very best method of assuring that your patient will be happy with your final result. There are several methods of accomplishing this procedure; most of them require a good wax-up of the intended result. Next, a silicone matrix can be made of the wax-up which can then be applied directly in the mouth with either acrylic or composite resin. Also, consider using Snap-On Smile (DenMat) for a longer lasting trial smile (Figure 3.22A–E). The same procedure can be done by making the final restoration in the laboratory instead of directly in the patient's mouth. It all depends on the size and position of the teeth. Naturally not all restorative or orthodontic problems can be translated into a trial smile over the natural teeth. In these cases, either direct bonding or esthetic imaging may suffice. Trial smile may indeed have to wait until the temporary stage in certain instances and this will be covered in Chapter 42 on esthetic temporization.

CBCT and 3D planning software

The role of the CBCT unit and 3D planning software has been established as an indispensable part of ideal diagnostic evaluations and treatment planning. The ability to see the relationship of the patient's bone, soft tissue, and vital anatomy in relation to their existing or planned implants, grafting, and restoration is critical to avoiding error.

Today, we have the ability to interact with digital and optical files simultaneously and use Dual Scan protocols, stitching the model images to the CBCT images of the patient and allowing for optimal treatment planning accuracy for surgeon and restorative dentist.

The ability to evaluate pathology of the jaws and teeth as well as the quality and quantity of bone available for implant placement allows us to execute our treatment with safety, precision, and esthetics in mind.

Often, we can plan the cases on these 3D software applications using simulated implant libraries and transfer this information into surgical guides for the implant surgeon to mimic what was planned digitally. Additionally, this information can be used to create stereolithographic models of the patient's jaws for further evaluation.

Figure 3.22 **(A)** This patient had an extremely difficult malocclusion requiring orthodontic therapy.

Figure 3.22 **(B)** A removable appliance (Snap-On Smile) was made to create a realistic trial smile that he could wear and visualize the result of his treatment outcome.

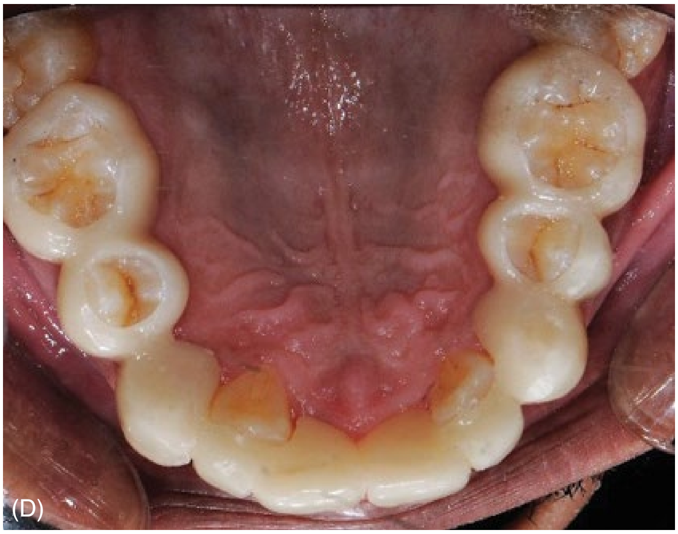


Figure 3.22 **(C and D)** Note in this occlusal photo how the appliance attaches to the teeth.

Figure 3.22 **(E)** The patient was pleased with his trial smile which allowed him to experience the reaction of family and friends to his new look.

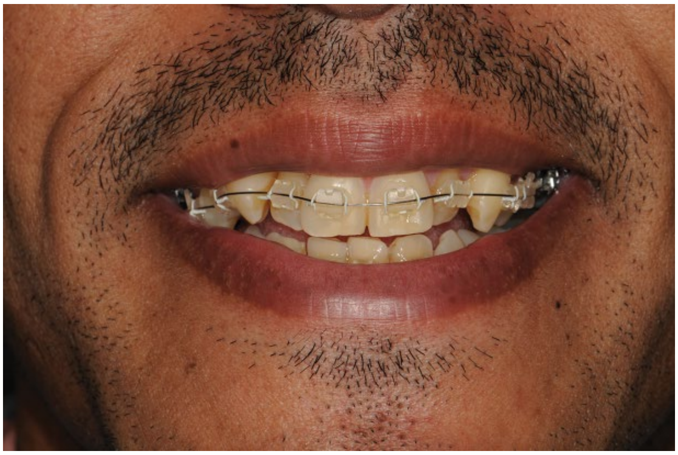


Figure 3.22 **(F)** The removable appliance was motivating enough for the patient to undergo orthodontic therapy 3 years later.

From a restorative perspective, abutments can be selected from these libraries and a provisional restoration can be designed and fabricated based upon these 3D plans using 3D printing technologies.

The future is upon us and looks bright indeed regarding the implementation of all these new digital technologies.

Problem patients: when not to treat … but refer

It is impossible for any one dentist, regardless of how capable he or she is, to satisfy every patient's esthetic needs. Most new patients are on their best behavior during the initial interview session. That is why it takes a skillful dentist and staff, as well as extra time, to ascertain what kind of patient is presenting to your office. Your goal is to determine who should be the patient you refer to another colleague. There is an entire chapter devoted to this subject, Chapter 2, which you and your clinical personnel should read and digest for a better understanding of patients and how to manage them. Nevertheless, to help with your decision of whether or not to treat certain patients, the following patient-type categories can be incorporated into your treatment philosophy.

The purpose of classifying potential problem patients here is not to dissuade you from treating them. Rather, it is to make you and your staff more aware of the potential consequences of treating certain types of patients. You and your staff should now be able to recognize better a potential problem before it happens. The treatment sequence outlined in Figure 3.3 is extremely important in this regard. The chain of people who can give you information as to the patient's personality is the receptionist, the assistant/hygienist, and then the treatment coordinator. Be sure to use the input from these key staff members before you elect to take up a patient's esthetic treatment. Should you decide to treat a problem patient, be sure to adjust your fees accordingly.

Remember, it is not enough to just cover the cost of treatment of such patients. If you elect to dedicate the extra time, effort, and above all, stress (not only yours but also that of your staff and perhaps even your family), you are entitled to a reasonable profit for doing so. Your staff and family expect and deserve it as well. The greater is the difficulty, time, and effort required, the greater is the multiple of one's routine fee. In the past 54 years many of the perceived "difficult" patients who elected not to proceed with my proposed treatment due to the increased fee have gone elsewhere for treatment—only to come back years later, still not happy. Now they will have to spend even more money to have their treatment redone. Incidentally, if you misjudged the patient the first time by referring when, perhaps, they might have been a perfectly acceptable patient, do not make the mistake of underestimating the amount of time, stress, and costs involved in redoing that patient's case.

The perfectionist

This patient has the highest standard of esthetic excellence. Unless you are willing to spend an inordinate amount of diagnostic and treatment time with this patient, you are much better off, emotionally and financially, making an early decision to refer this patient. Deciding to treat this type of patient may mean charging two, three, or even four times your normal fee in order to cover the extra time, stress, laboratory and office costs, and extended warranty for this patient. Offices that elect to do this should also consider the probability of having to redo the treatment several times in an attempt to satisfy this patient's esthetic and functional demands. Will it be worth it and can your office afford this type of expense? Too often, dentists find that treating these patients costs them so much they would have paid another dentist double the amount after they have failed in their attempts to satisfy the patient. Although many of us may enjoy a challenge, the question is, can your office afford the risk of taking on such a challenge?

The poor communicator

These are the patients who cannot communicate what they want because they do not themselves know what they want. They may show you a picture of exactly what they desire, but when they eventually see it in their mouth they may be terribly disappointed. Even study models with wax-ups may look good to these patients, but that approval may be of no benefit when the final restoration is in their mouth. What can be most frustrating is to show this type of patient a computer image of his or her enhanced smile, which may be enthusiastically received but, amazingly, not appreciated when tried in. The problem is, these people really do not know what they want when it comes to their own appearance. Typically, they have difficulty making up their minds in other areas of their lives as well. They may be constantly redecorating their homes, apartments, or offices. They may be frequently frustrated with their hairstyles and constantly changing their barber or hairstylist in an attempt to find that "perfect" style. The real problem here is identifying these types of patients before agreeing to treat them. This is one of the hardest categories to identify because, at first glance, these people seem so easy to please. You may be tempted to proceed with treatment too hastily only to find that you, in fact, are now treating the type of patient you may have wished you had referred. One important clue to help you recognize this patient type is that he or she presents to you in the middle of treatment from another office. Frequently, that dentist may have redone their treatment many times before the patient sought another opinion. If this is the situation, carefully analyze the treatment with which the patient presents. Has it been done poorly? Is it esthetically inferior? Frequently, the patient will state "I hear you're the best." Although we all like to think we can do something better, "better" may, however, be just another failure to this problem patient. And the sad situation is that few, if any, practitioners may be able to satisfy this patient. Frequently, the root of the problem is psychological. The patient may not truly know what he or she wants. Other times he or she is looking for your esthetic dentistry to solve a problem that only a psychologist or psychiatrist can solve.

High expectations/limited budget

There is nothing wrong with patients who are limited in the amount of money they can invest in their dental treatment. In fact, this may make up the majority of your patients. However, proceed cautiously with the budget-conscious patient who has extremely high esthetic expectations. Rather than having a dissatisfied patient, you are much better off explaining that because they may not be able to afford the ideal or recommended treatment due to the great amount of time, cost, and so on involved, they need to compromise. If this is the case you will need extensive documentation and informed consent forms signed before beginning any therapy.

The "wrinkle patient"

These patients are afraid of looking old. They expect esthetic dentistry to make them look young again, expecting you to get rid of their wrinkles by "plumping out" the restorations. Unfortunately, your dentistry may not be able to accomplish this esthetically, which can make for patient dissatisfaction.

The other type of patient in this category is the one who claims that wrinkles appeared after the esthetic treatment. This is one of the situations where the before full-face photograph is essential. It is advised that these photographs be taken with and without makeup. Ask the patient to remove all makeup, thus allowing you to more accurately see facial characteristics, which will help you in your diagnosis and treatment. Then point out every wrinkle and/or other facial deformities that are not likely to change. However, be quick to point out to this type of patient that you work with an excellent team which includes a plastic surgeon, and that, following your dental treatment, the plastic surgeon may be able to improve that condition if they desire. Follow this suggestion with a recommendation for a consultation with a plastic or oral surgeon during your diagnostic stage—never after your treatment is complete. Make sure to document the recommendation so that you will not be taking responsibility for something you cannot control.

The uncooperative patient

This is another potential problem patient that can be overlooked if your diagnostic time is too short. Frequently, this patient presents with poor dentistry or no restorative dentistry at all. Hygiene is either nonexistent or inadequate at best. They will vociferously complain about a previous dentist and staff. The major problem with these patients is they will not accept responsibility for any of their problems or faults. A typical response of a patient with extremely worn teeth may be, "I never grind my teeth," and he or she may become agitated at you for even suggesting it. Or, "I brush my teeth six times a day," despite the extensive presence of plaque indicating less than adequate homecare. These patients are frequently so abusive to everyone in your office, including you, that your staff will agree that no fee you may charge is worth the aggravation of treating this type of patient. This is certainly one time when a consultation with your staff about accepting this patient for treatment in your practice would be extremely beneficial. If you do decide to accept this patient, you should consider substantially increasing your fee. A doubling, tripling, or more might be appropriate.

How to treat problem patients … and keep your staff sane

There are several precautions to take if you elect to treat problem patients.

1. **Be prepared to spend much more time in diagnosis.** The best way to handle patients who have difficulty communicating what they want is to schedule several diagnostic sessions. Use different approaches to attempt to understand what your patient visualizes as a final result. It is essential for your patient to understand that this is "their" problem, and you will try to help correct it. The only time you can accomplish this is during the diagnostic stage. This diagnostic phase must be considered as a period of discovery not only of the intraoral condition but also of the patient's psychological and visual concept of self-image. If your patient refuses to admit a problem, it would be wise for you to avoid accepting any treatment liability. If you proceed with treating such a problem patient, *it is essential that you and the patient sign a limited treatment liability agreement* which outlines exactly the specific treatment and specific time period of treatment, including posttreatment care.
2. **You should never proceed with your treatment plan until both you and your patient have a thorough understanding of what your treatment will be.** Make sure your treatment coordinator has your patient sign a consent form, following an oral presentation of recommended treatment, that all options were presented and that the patient understands the options and agrees with the treatment. Next, follow up with a detailed treatment letter listing any exceptions or potential problems that could be encountered.
3. **When treating problem patients, consider treatment in phases or sequential therapy.** The advantage of treating problem patients in phases is that you never proceed to the next phase until the patient is pleased with the current phase of treatment. The following is an example of how this may occur.
    - **First phase**: diagnosis and treatment planning. This may consist of soft tissue management, all diagnostic tests and records, specialist referrals, and appropriate endodontic and periodontic therapy. Salivary diagnostics and genetic testing for periodontal disease and susceptibility may also be considered.
    - **Second phase**: treatment splinting and/or bleaching. This is the time to redo and alter, as necessary, treatment crowns or bridges until your patient is esthetically pleased and signs your release to proceed to phase 3. If a problem patient says, "I like them just the way they are except I want this tooth built out a little more," you

should not proceed to the next phase of treatment. Make the necessary changes and let the patient live with the changed restoration for at least another week to make sure no other exceptions arise. The patient must be pleased with the appearance of the treatment splints; otherwise he or she may well be dissatisfied with the final restoration, stating, "I thought it would be different!" It also means using a capable laboratory to make well-shaded and proportioned acrylic temporaries, which becomes the trial smile.

- **Third phase**: placement of final restorations. Your treatment should virtually duplicate the temporaries. Take either a very good alginate or, even better, a vinyl polysiloxane impression to accurately record just how your patient wishes to look. When all is done, the patient should be satisfied with the esthetic treatment you have painstakingly performed.

4. **Make sure your fee is adjusted appropriately.** You should apportion your fee to the various phases after determining your expenses and desired profit in each phase of treatment. The fact that your increased fee may be considerably higher than that of other colleagues should play no role in setting your fee. Your attitude should be, if the patient does not understand your special abilities and the extra effort you will expend in helping to solve his or her problem, you are better off letting another dentist suffer the consequences, including the financial loss, in dealing with this type of problem patient. In the final analysis, you should thoroughly consider all of the problems associated with each patient, whether a difficult clinical or emotional issue, or both. In some cases an astute staff member may sense that you cannot satisfy a particular patient. In all cases, be upfront and honest about your decision that this patient may be better treated by another dentist. Issues of patient abandonment do not apply if you decide to not treat during the diagnostic phase and before any treatment has begun.
5. **Pay particular attention to your treatment warranty and make sure the patient knows exactly what work and how long the guarantee covers.**

Continuous communication

Treatment planning is not complete until the patient makes a final decision about accepting treatment. However, follow-through by the treatment coordinator is necessary throughout your patient's treatment. Any proposed changes to your treatment plan must involve your treatment coordinator. In fact, if your proposed changes affect your fee, then be certain to have the new case fee verified with the patient by the treatment coordinator prior to your beginning the altered treatment procedures.

How esthetic procedures differ from ordinary dental procedures should be explained. The patient must understand that esthetic dentistry may be time-consuming and, unlike routine procedures, does not always produce immediate results. Differences such as time involved for extra try-ins, treatment plans that require chairside carving and shaping of temporaries, staining of porcelain at the chair side, and the dentist's time and expertise should all be discussed. The patient must be convinced and satisfied that any additional time necessary for better esthetic results is worth the investment.

Dentists should be aware that patients are often completely unfamiliar with esthetic dentistry and are reluctant or unable to ask the important and relevant questions about the procedures. The limitations of esthetic dentistry should also be explained to the patient. While esthetic treatment can produce dramatic improvements, it cannot do everything. If compromise is necessary, say so. It becomes the dentist's responsibility, therefore, to see that all doubts and questions are cleared away during the final case presentation. You must be careful not to impose your own esthetic notions on the patient. Superior knowledge and training make dentists the arbiters of what is practical and workable; they do not give him or her any precedence in matters of esthetic preference.

Esthetic treatment demands personal communication between patient and dentist that must continue throughout treatment. Be an acute observer, a precise listener, and an understanding interpreter. Always remember that good communication can make it possible to change an insecure frown into an assured smile.

Cost of treatment

One of the biggest stumbling blocks to offering quality esthetic dentistry is the mistaken belief that your patients will be reluctant to pay for it. One of my former patients was a bricklayer dissatisfied with his smile. He came to the appointment rather poorly dressed and not well-groomed. I spent a considerable amount of time trying to educate him as to why the best esthetic dentistry might cost more. I gave him three alternative choices for different qualities of esthetic treatment and thoroughly explained the differences among the three. He eventually chose the best and most costly quality dental service. My father believed I had spent too much time with someone who did not appear to be interested in such a high-quality procedure. However, this taught me (and my father) never to judge someone by first appearance.

This is not to say you should spend the same amount of time with every patient. It becomes obvious that not everyone will be receptive to learning the differences between quality and average treatment. In the final analysis, it will be up to you to determine if the patient who is not interested in understanding the differences will be the patient you wish to treat. Generally, these patients are shoppers who will base their decision on price only.

The different classifications of patients will have different motivations and expectations for esthetic dentistry. Some are influenced more by the life expectancy of the restoration while others care more about the esthetic result.

Almost every patient wants to know, "How much is it going to cost?," even before visiting the dental office. In fact, some patients, the price shoppers, will call to request prices before deciding to make an appointment. These people are usually driven primarily by price, and yet still may have a high esthetic dental need. Probably the most difficult task most dentists face is answering the fee question. Your fee should reflect the quality of care your office provides and should not be presented with apology. If the patient views the treatment as a need and is aware of the benefits of that treatment, he or she will usually consent to the proposed treatment plan, provided finances are not a problem. I also recommend that your potential patients read, *Change Your Smile*,[2] specifically the postscripts on page 54 regarding fees.

The patient will usually feel more at ease with a third party, the treatment coordinator, and thus more comfortable voicing questions about fees at this time. If necessary, a compromise or a different treatment alternative can be introduced when there is genuine dissatisfaction or a problem with a patient's ability to pay. If this situation occurs, it is often helpful for the treatment coordinator to suggest, "Let me speak with the doctor and see if some compromise treatment can be arranged." You may then choose to alter the terms, the total fee, or suggest alternative treatment plans. The amount of a fee is not as important as how your patient perceives it. A company president may reject even moderately priced dentistry, whereas the president's secretary may accept the same treatment plan and fee if he or she realizes the need and finds a way to prioritize the expense. One of the most important components of any case presentation is showing your patients the difference between ordinary and exceptional esthetic dentistry. For instance, show the difference between a regular porcelain crown and one of inlaid porcelain. Show the difference in an extracted tooth that has routine bonding versus one with characterized bonding. Always have two types of laminates: one with opaque monochromatic porcelain and one with color and artifacts built in. And, remember, not every patient wants or appreciates the difference. Patient feedback helps you know who your patient is and how to approach your esthetic dentistry treatment plan to gain acceptance.

Many dentists have little awareness of the factors upon which they should base their fees for esthetic dentistry. Therefore, they feel inadequate or unable to properly define and, unfortunately, even defend their fees. One thing should be made clear from the outset. Most patient insurance policies do *not* appropriately cover fees for esthetic dentistry. So how should fees be determined? The following are key factors that should be considered when you establish your fees for esthetic dentistry.

Training and technical skill

This consists not only of your educational background but also the amount of time and money you invest in brief and/or extensive courses, web-based distance learning, educational videos, reading books, magazines, and newsletters (including the volumes of information you receive from dental suppliers and manufacturers). Do not forget all those dental meetings you have attended—not only the cost of the meeting but the cost of lost income and the time away from your family and personal life. The website www.dentalxp.com is an excellent adjunct site to any education you may be receiving. Practitioners with more experience and higher level of skill should charge higher fees than someone just graduating from school. Fees should reflect your training, years of experience, and technical skill.

Time and complexity of procedure

The amount of time necessary for a procedure is just part of the fee formula. Consider the extra time you may need to spend with certain demanding patients. How much extra time will you allow for patients who ask a lot of questions? Time should cover diagnosing, planning, accomplishing the procedure, redoing, repairs, and postoperative visits. Is a crown just a crown? Is it just as difficult to do a crown on a right central incisor as it is to do one on a bicuspid? Or how about a "hidden" second molar? Laminating or crowning a single tooth to match an adjacent tooth is many times more difficult a procedure to accomplish than if you crown or laminate two or four teeth. More advanced clinical and laboratory skills are needed for the former. Is it not considerably easier to match a maxillary first or second molar to another one than to perfectly match one central incisor to another? In fact, if you are treating a single tooth, your cost per tooth is considerably more than that for doing six or eight teeth. Consequently, there is a significant difference in your cost, depending upon which procedure you are doing.

Artistic skill/patient requirements

Patients vary. Some truly do not care what your result looks like, just as long as it fits. Others may not seem to care—until he or she goes home and looks closely in the mirror. *Always give a patient a mirror and have him or her hold it at arm's length because that is the perspective from which other people will observe*. However, if your office has a good lighted area to place a nice wall-mounted mirror then this will suffice (Figure 3.23). The patient who holds the mirror very close requires something different of us; he or she is usually the perfectionist and you may need to adjust your fee accordingly. Another important consideration is your artistic ability. It is accepted, often expected, in every profession and culture to pay more for the best. We pay more for the best sculptures, artwork, photographs, ceramics, jewelry, and all types of other things that require artistic skill. We refer to our profession as "the art and science of dentistry." The science is well understood, but the art has been ignored for too long. You deserve to be compensated based in part on your artistic skill.

Overhead

Your overhead is based on so many factors, including where you are geographically, rent, upkeep, materials, and most of all staff salons. Laboratory fees, if any, must be considered, as well as the quality of the laboratory, the materials, and the equipment that you use. Does your office employ the latest in high-tech equipment? All of these things benefit the patient but cost money. If your office is a state-of-the-art facility, then it should be

Figure 3.23 This wall-mounted mirror is perfect for patients to be able to see their smile and face the way others will be looking at them.

differentiated from the offices that appear outdated and are, in fact, furnished with antiquated equipment.

Warranty

What do you guarantee? Are you giving a minimal or extended warranty? Is it 3 months, 6 months, or 1 year? For how many months will you render free aftercare and for how many years will you provide service at a reduced fee and at what percent discount? Are your patients told to wear a protective appliance? Do they or will they wear it? They may have accidents, caries, periodontal conditions, tooth loss, or root fracture; are you guaranteeing your treatment against all those things? You prescribe home care; are they going to do all that you expect? Your warranty must point out the circumstances under which you will guarantee your dental treatment. Are you guaranteeing that if your patient bites into a candied apple your laminate will not break? If eating habits are expected to change after you insert your ceramic crowns or laminates, then this, too, must be stressed and put into your warranty. The best car manufacturer may not honor its warranty if the owner does not fulfill the agreement—changing oil and allowing the dealer to perform necessary maintenance. Are you prepared to honor your warranty for patients who do not come in for routine prophylaxis and clinical examination? Certainly, damage caused by neglect can be costly. A well-constructed warranty and fee structure can help to protect you against patient-neglect situations.

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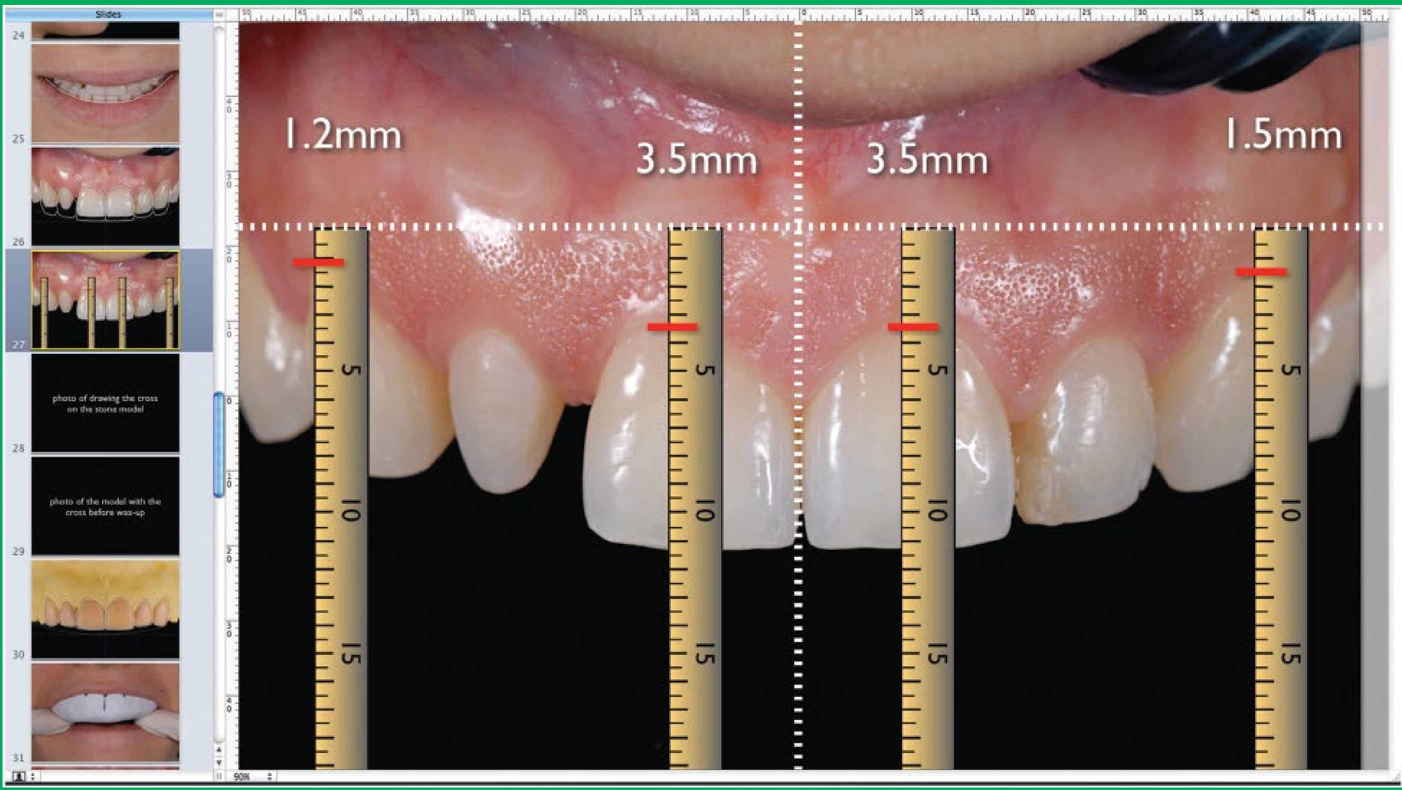

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Chapter 4 Digital Smile Design: A Digital Tool for Esthetic Evaluation, Team Communication, and Patient Management

Christian Coachman, DDS, CDT, Marcelo Calamita, DDS, MS, PhD, and Andrea Ricci, DDS

Chapter Outline

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Excellence will never be achieved by chance, but by using a consistent systematic approach for diagnosis, communication, treatment planning, and, eventually, execution. The incorporation of protocols and checklists[1–7] for quality control and information management will guarantee that every critical point is performed effectively, double checked, and communicated correctly.

In order to obtain predictable and consistent treatment outcomes, the design of the restorative treatment should be clearly defined at an earlier stage. This data must guide the succeeding phases of the rehabilitation,[8] scientifically integrating all of the patient's needs and desires and the functional, structural, and biological specifics into the esthetic treatment design. It works as a frame of reference for the treatment that will be performed.[9,10] However, many of these pieces of information may not be taken into consideration if their real meaning is not transferred in an adequate way to the design of the restorations.

The Digital Smile Design (DSD) is a practical multiuse clinical tool with relevant advantages: it can strengthen esthetic diagnostic abilities, improve the communication between team members, create predictable systems throughout the treatment phases, enhance the patient's education and motivation, and increase the effectiveness of case presentation. It is an effective digital treatment protocol which utilizes 2D clinical and lab images of the patient and the proposed treatment plan including planes of reference, facial and dental midlines, incisal edge position, lip dynamics, basic tooth arrangement, and the incisal plane.

Ronald E. Goldstein's Esthetics in Dentistry, Third Edition. Edited by Ronald E. Goldstein, Stephen J. Chu, Ernesto A. Lee, and Christian F.J. Stappert.

Digitally drawing reference lines and shapes over the patient's photo, following a predetermined sequence, allows the team to better evaluate the esthetic relation between the teeth, the gingiva, the smile, and the face. DSD is an extraordinary multi-purpose tool that can be utilized by all team members to better understand, visualize, and implement the treatment plan. As the use of the DSD can make the diagnosis more effective and the treatment planning more consistent, the effort required to implement it will be rewarded, making the treatment sequence more logical and straightforward, saving time and materials and reducing the costs during the treatment.

Advantages of Digital Smile Design

Accurate esthetic analysis

The DSD allows a careful esthetic analysis of the patient's facial and dental features and a gradual discovery of many critical factors that might have been overlooked during the clinical, photographic, or study models evaluation. The drawing of reference lines and shapes over extra- and intraoral digital photographs performed in presentation software such as Keynote (Apple iWork) or MS Powerpoint (Microsoft Office), following a predetermined sequence, will enhance the diagnostic vision. It also helps the team to assess and understand limitations and risk factors such as asymmetries, disharmonies, and violations of esthetic principles, adding critical data to the process of treatment planning.[1] Choosing the appropriate technique is easier once the problem has been identified and the solution clearly visualized.

Increased communication among the interdisciplinary team

The main goal of the DSD protocol is to simplify communication, transferring key information from the patient's face to the working cast, and to the final restoration.

The DSD protocol provides effective communication between the interdisciplinary team members, including the dental technician. Team members can identify and highlight discrepancies in soft- or hard-tissue morphology, discussing over high-quality images on the computer screen the best possible solutions for the case. Every team member can add information directly on the slides, in writing or using voice-over, simplifying the process even more. All team members can access this information whenever necessary—"in the cloud"—changing or adding new elements during the diagnostic and treatment phases.

Traditionally, the dental technician has implemented the smile design with the restorative wax-up. He or she creates shapes and arrangements in accordance with restricted information, following instructions and guidelines provided by the dentist in writing or by phone. In many cases the technician is not given enough information to utilize his or her skills to their maximum potential and the opportunity to produce a restoration that will truly satisfy the patient is missed.

When the treatment coordinator or another member of the restorative team who has developed a personal relationship with the patient takes the responsibility for the smile design, the results are likely to be superior. This individual has the ability to communicate the patient's personal preferences and/or morphopsychological features to the laboratory technician, providing information which can elevate the quality of the restoration from one that is adequate to one that is viewed by the patient as exceptional.[7,8,11]

With this valuable information in hand and from the 2D DSD, the dental technician will be able to develop a 3D wax-up more efficiently, focusing on developing anatomical features within the parameters provided, such as planes of reference, facial and dental midlines, recommended incisal edge position, lip dynamics, basic tooth arrangement, and the incisal plane.

Transferring this information from the wax-up to the "test-drive" phase is achieved through a mock-up or a provisional restoration.[4,6,12] The design of the definitive esthetic restorations should be developed and tested as soon as possible, guiding the treatment sequence to a predetermined esthetic result. Efficient treatment planning results in the entire treatment team being able to better identify the challenges they will face and will help expedite the time to initiate and ultimately complete treatment.[8]

Feedback at each phase of treatment

The DSD allows a precise reevaluation of the results obtained in every phase of the treatment. The sequence of the treatment is organized on the slides with the photos, videos, reports, graphics, and drawings, making this analysis simple and effective. At any time any team member can access the slide presentation and check what was done until that moment. With the Digital Ruler, with which drawings and reference lines are created, it is possible to perform simple comparisons between the before and after pictures, determining if they are in accordance with the original planning, or if any other adjunctive procedures are necessary to improve the outcome. The dental technician also gains feedback related to tooth shape, arrangement, and color so that final refinements can be made. This constant double-checking of information ensures that a higher-quality product will be delivered from the laboratory and also provides a great learning tool for the entire interdisciplinary team.

This process also becomes a very useful library of treatment procedures that can be used in many different ways. Going back to "old" cases and understanding visually how they were performed is effective as a learning experience.

Patient understanding and marketing tool

The DSD is an important marketing tool to motivate the patient, making him or her understand the issues and treatment options, compare before and after pictures, and value all the work that was done. Moreover, the fact of creating slides about the treatments performed generates a personal library of clinical cases that can be shared with other patients and colleagues, and the most appropriate cases can be further transformed into interesting slideshows of one's work.

Dynamic and effective treatment planning presentation

The DSD makes the treatment planning presentation more effective and clear because it allows patients to see and better understand the combined multiple factors that are responsible for their oral-facial issues. The case presentation will be more effective and dynamic for these patients since the problem list will be superimposed over their own photographs, increasing the understanding, trust, and acceptance of the proposed plan. The clinician can express the severity of the case, introduce strategies in treatment, discuss the prognosis, and make case management recommendations.[1] It also can be used for medico-legal purposes, registering the improvements that were achieved and the reasons for each one of the decisions made during the treatment.

Educational tool

The DSD can increase the impact of the presentations because it adds visual elements into the slides that will improve the educational aspects of the lecture. The audience can understand better the issues that were previously highlighted and the presenter can minimize the use of the laser pointer.

Digital Smile Design workflow

The DSD protocol is performed by the authors using Keynote; however, other similar software such as MS PowerPoint can also be used with minor adjustments in the technique. Keynote allows simple manipulation of the digital images and the addition of lines, shapes, drawings, and measurements over the clinical and laboratory images. The main steps of the DSD are described and illustrated below.

In order to begin the process, three basic photos are necessary: full-face at rest, full-face with wide smile and teeth apart, and retracted photo of the upper arch with teeth apart. A short video is also recommended capturing the following lip positions: at rest, wide smile, stretched from a frontal view, 45°, and profile. On this video a few basic questions can be asked of the patient to explain their main concerns, needs, and expectations. Then, the photos and videos are downloaded and inserted on the slide presentation (Figure 4.1).

1. **The cross**: two lines must be placed on the center of the slide, forming a cross (Figure 4.2). The full-face photo with the teeth apart should be positioned behind the cross.

Figure 4.1 Pre-operation photo.

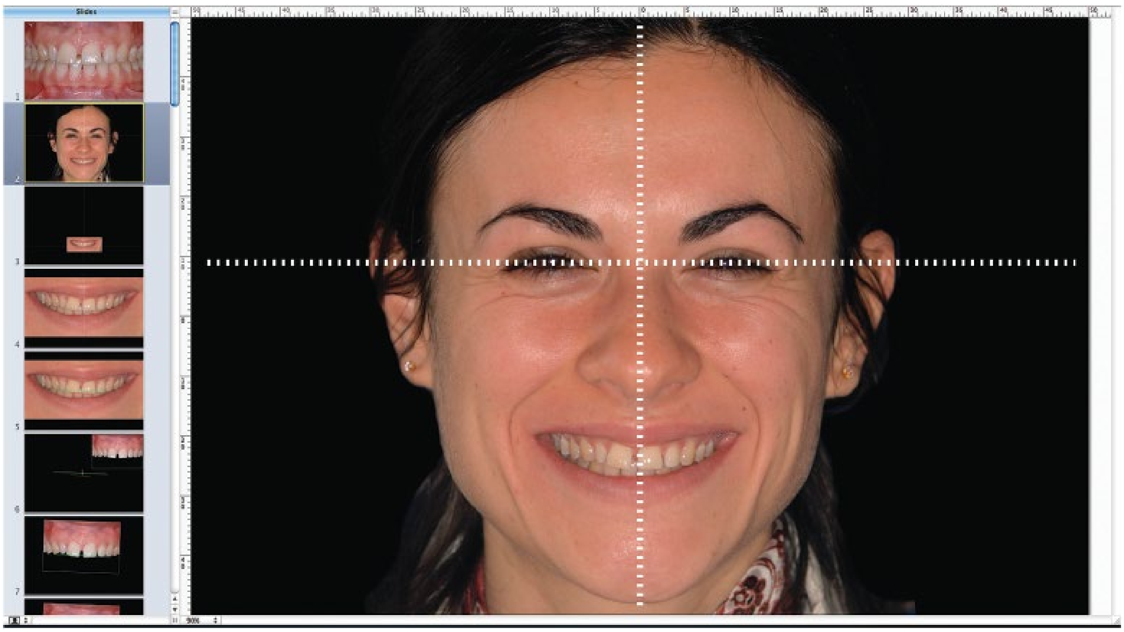

Figure 4.2 The DSD protocol can be utilized on the Keynote software or MS PowerPoint using the Digital Face Bow procedure. The face photo is placed on the slide to start the DSD sequence and is adjusted behind the two white dotted lines (the cross), determining visually the ideal facial midline and horizontal reference.

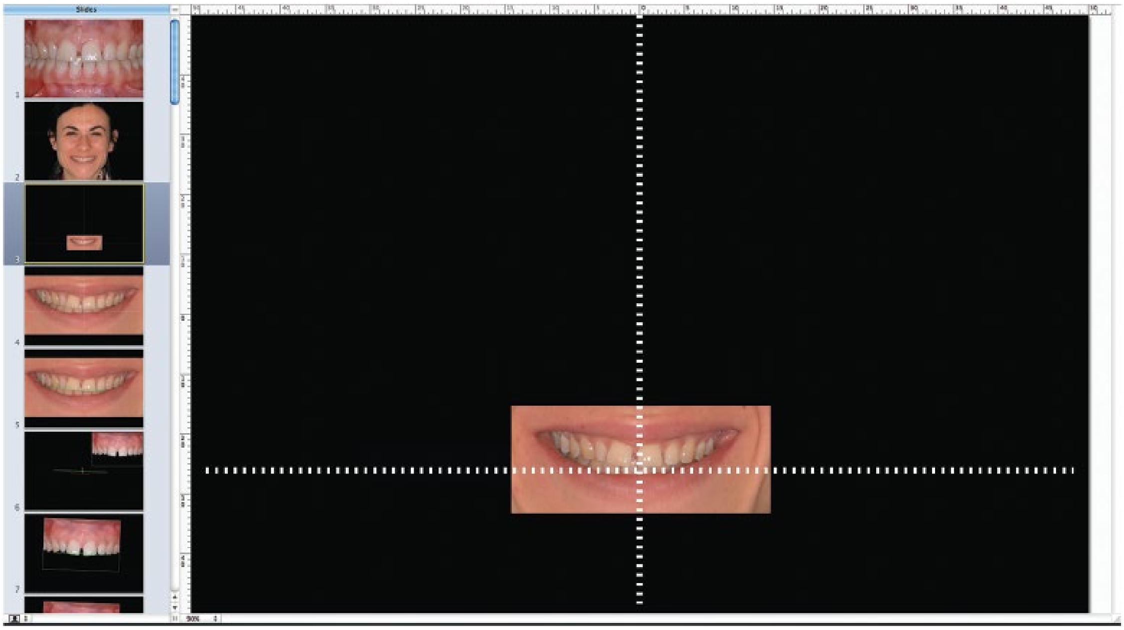

Figure 4.3 The horizontal line is moved to the mouth area and the face photo is cropped showing only the overall smile.

2. **Digital facebow**: relating the full-face smile image to the horizontal reference line is the most important step in the smile design process. The interpupillary line should be the first reference to establish the horizontal plane, but it should not be the only one. It is also necessary to analyze the face as a whole and then determine the best horizontal reference that creates harmony. After determining the horizontal reference line, it is time to outline the facial midline according to facial features like the glabella, nose, and chin (Figure 4.2).
3. **Smile analysis**: dragging the horizontal line over the mouth will allow an initial evaluation between the relation of the facial lines and the smile. It is possible to evaluate midline and occlusal plane shifting and/or canting (Figure 4.3).
4. **Smile Simulation**: simulations can be done to fix incisal edge position, canting, shifting, tooth proportion, and soft tissue architecture (Figure 4.4).

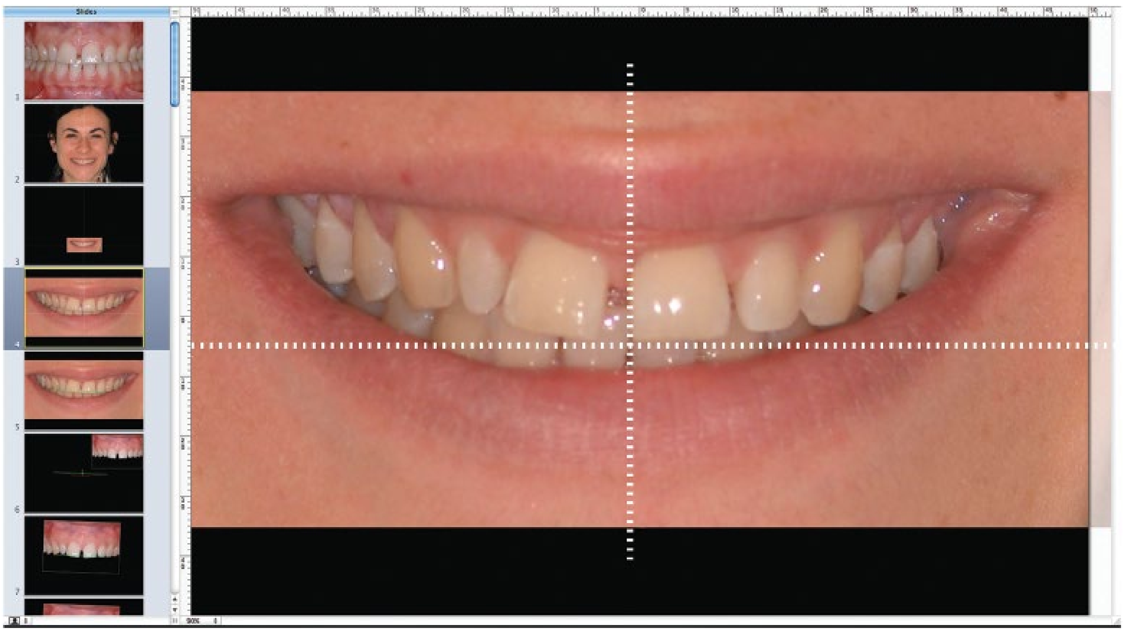

Figure 4.4 The smile and cross are enlarged to fill the whole slide.

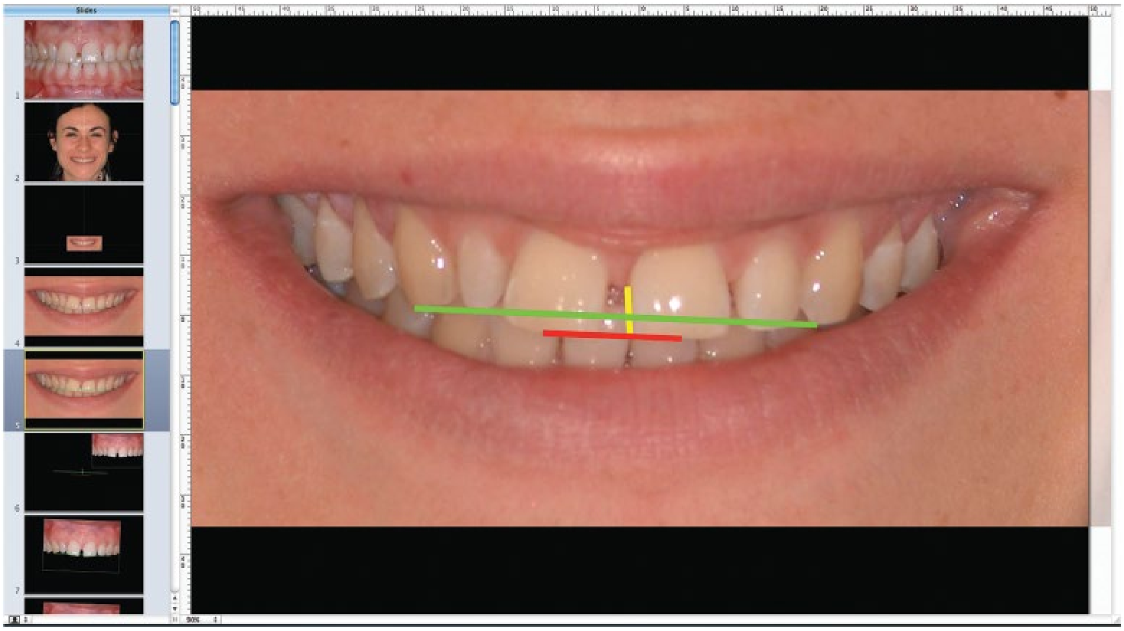

Figure 4.5 Three transferring lines are created. Green line: cuspid tips. Red line: incisal edge of the centrals. Yellow line: mesial of the central incisor.

5. **Transference from the face to intraoral**: in order to analyze the intraoral photo in accordance to the facial references one needs to transfer the cross to the retracted photo using three transferring lines drawn over the smile photo (Figure 4.5):

   Line 1: from the cusp tip of one canine to the tip of the contralateral canine.

   Line 2: from the middle of the incisal edge of one central to the middle of the incisal edge of the other central.

   Line 3: over the dental midline, from the tip of the papilla to the incisal embrasure.

   Thus, four features on the photo should be calibrated: size, canting, incisal edge position, and midline position. Line 1 guides the two first aspects (size and canting); line 2 guides the incisal edge position, and line 3 guides the midline position (Figure 4.6).
6. **Measuring tooth proportion**: measuring the width/length proportion of the central by placing a rectangle over the

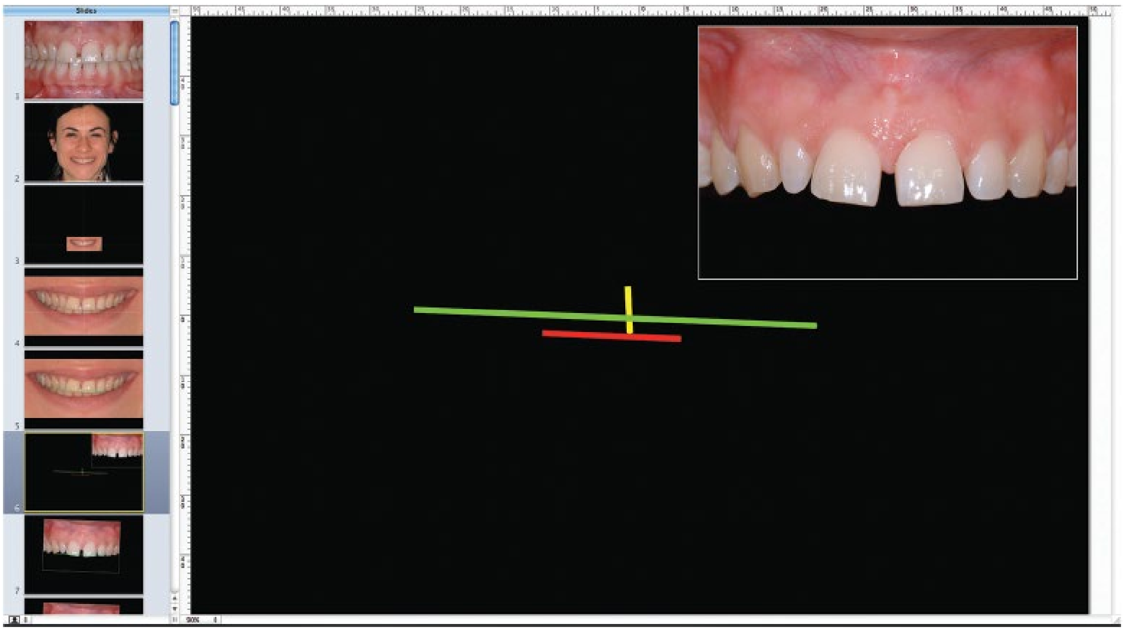

Figure 4.6 The three lines will be used to calibrate the intraoral photo to the facial cross.

edges of the central (Figure 4.7) is an effective way to start understanding what needs to be performed when it comes to redesigning a smile. The other analysis that should be performed is to compare the actual proportion of the patient's central in relation to ideal proportions according to the literature[2–8] (Figure 4.8).

7. **Tooth outline**: from this point on, all the drawings may be customized, depending on the case, on what you want to visualize and what you want to communicate with the team, technician, and the patient. One can draw the teeth outlines over the photo or copy and paste a pre-made outline from a personal library. The selection of the shape of the teeth will depend on other factors such as: the morphopsychological interview, patient's desires, facial features, and esthetic expectations[11,13] (Figures 4.9 and 4.10).

8. **White and pink esthetic evaluation**: after having all the lines and drawings performed according to the facial lines and the smile line, one can have a clear understanding about all the esthetic issues involving the upper arch such as tooth proportion, interdental relationship, relationship between the teeth and the smile line, discrepancy between facial and dental midline, midline and occlusal plane canting, soft

Figure 4.7 The first step to calibrate the intraoral photo is to adjust the size and inclination of the photo so that the cusp tips are touching the ends of the green line, exactly as performed on the facial photo.

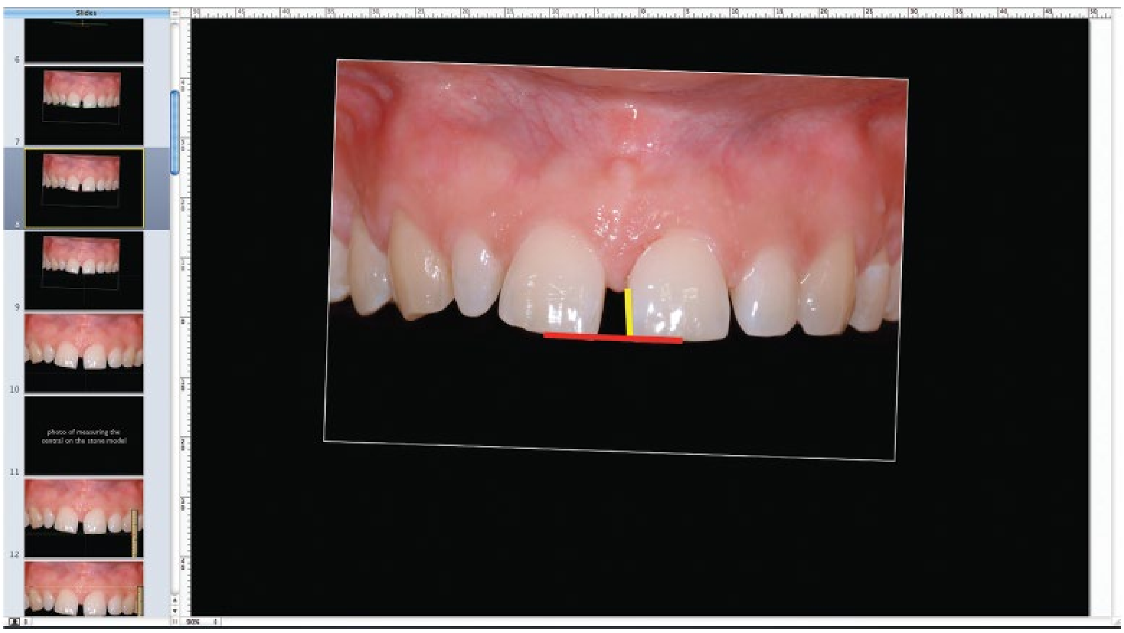

Figure 4.8 Step 2 is to move the photo so that the incisal edges and mid line are touching the lines, exactly as performed on the face photo.

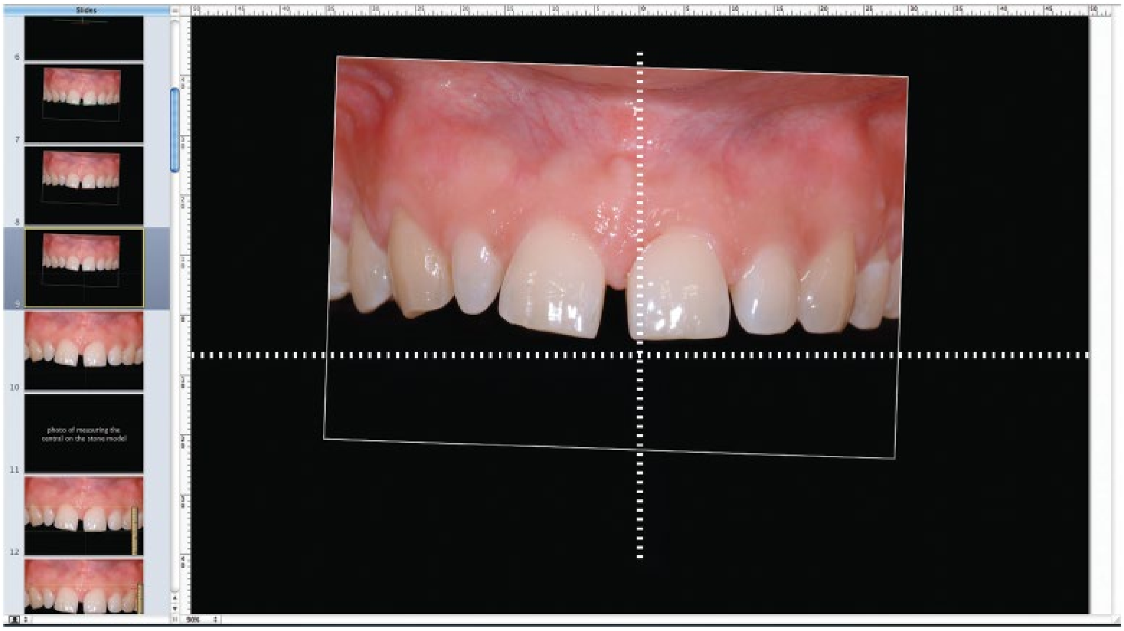

Figure 4.9 The dotted white lines are reintroduced into the slide and now the intraoral photo is calibrated with the facial cross.

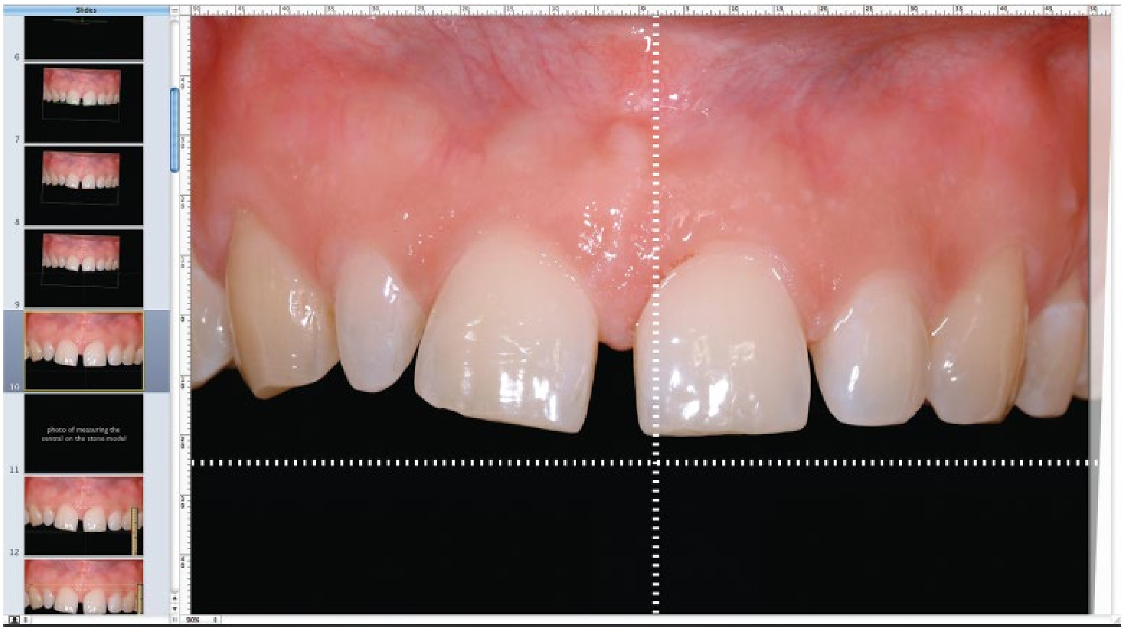

Figure 4.10 The lines and photo are positioned and stretched to fill in the whole slide, improving the visualization of the relation between teeth, soft tissues, and the facial cross.

tissue disharmony, relationship between soft tissue and teeth, papillae heights, gingival margin levels, incisal edge design, tooth axis, and so on (Figure 4.11).

9. **Digital Ruler calibration over the intraoral photo**: after all the lines are placed and drawings made, one can proceed with the calibration of the Digital Ruler over the intraoral photo by measuring the real length of one central incisor on the model (Figure 4.12) and transferring this measure to the computer (Figure 4.13). Once the Digital Ruler is calibrated one can start making any kind of measurements over the anterior area of the image (Figure 4.14).
10. **Transferring the cross from digital to the model**: the first step is to digitally move the horizontal line over the intraoral photo and place it above the gingival margin of the six anterior teeth. With the Digital Ruler the distance is measured between the horizontal line and the gingival margin of each tooth and these sizes are written down on the slide (Figure 4.15). These measurements are transferred to the

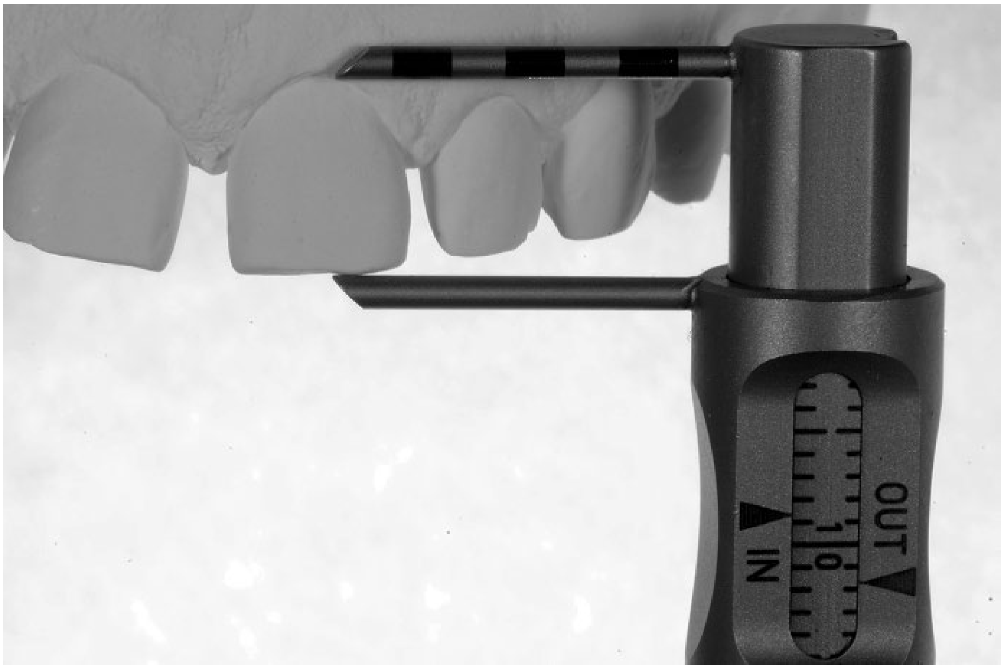

Figure 4.11 With a caliper measure the real length of the central incisor on the stone model (8 mm). This measurement will be used to calibrate the Digital Ruler.

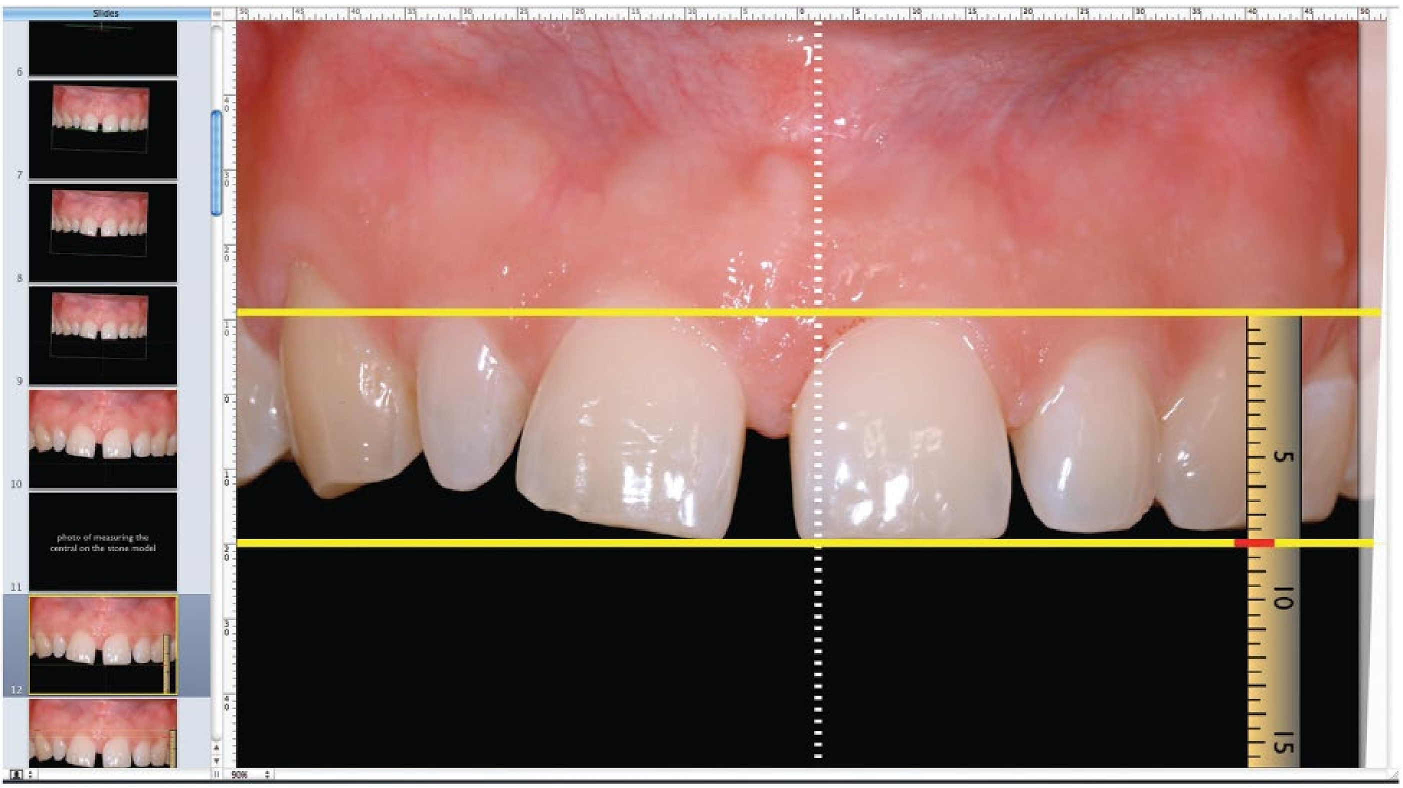

Figure 4.12 Using the computer again, the Digital Ruler is dragged onto the slide and calibrated according to the 8 mm measurement obtained. The zero on the ruler is placed on one of the yellow horizontal lines and then the ruler is stretched or reduced until the #8 reaches the other yellow line.

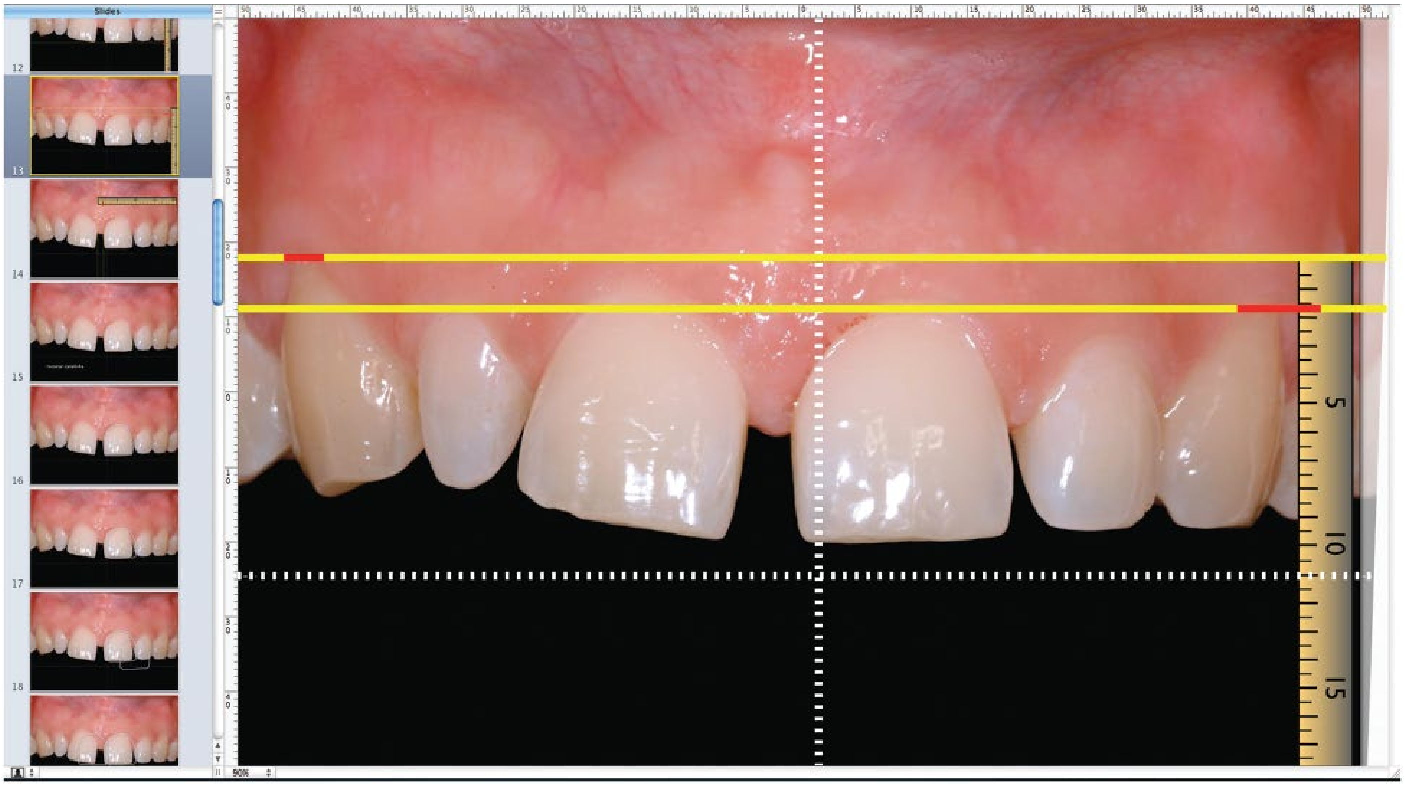

Figure 4.13 After calibration, measurements can be performed on top of the photo on the anterior area. For example, the discrepancy between the heights of the cervical of the cuspids is 1.7 mm.

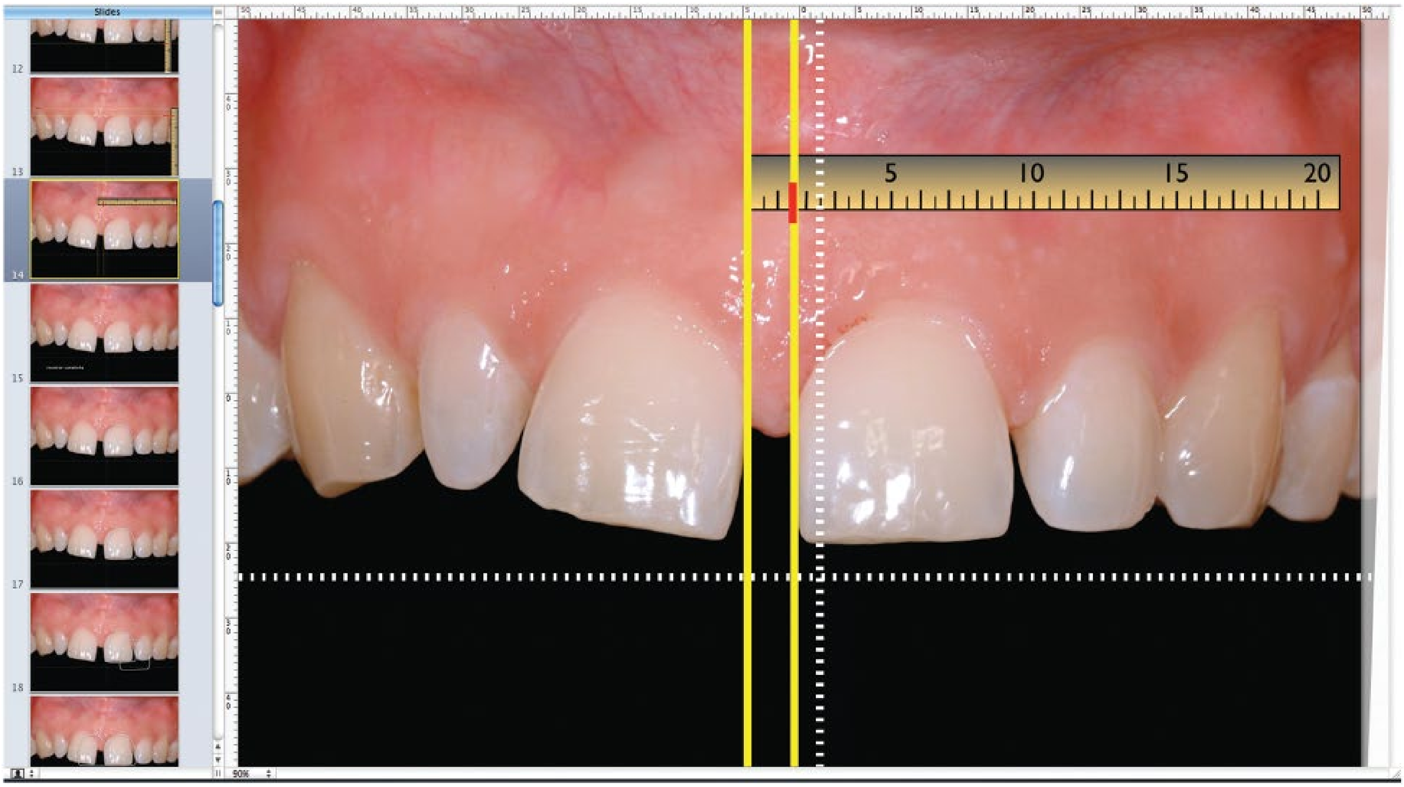

Figure 4.14 Measure the diastema, 1.5 mm.

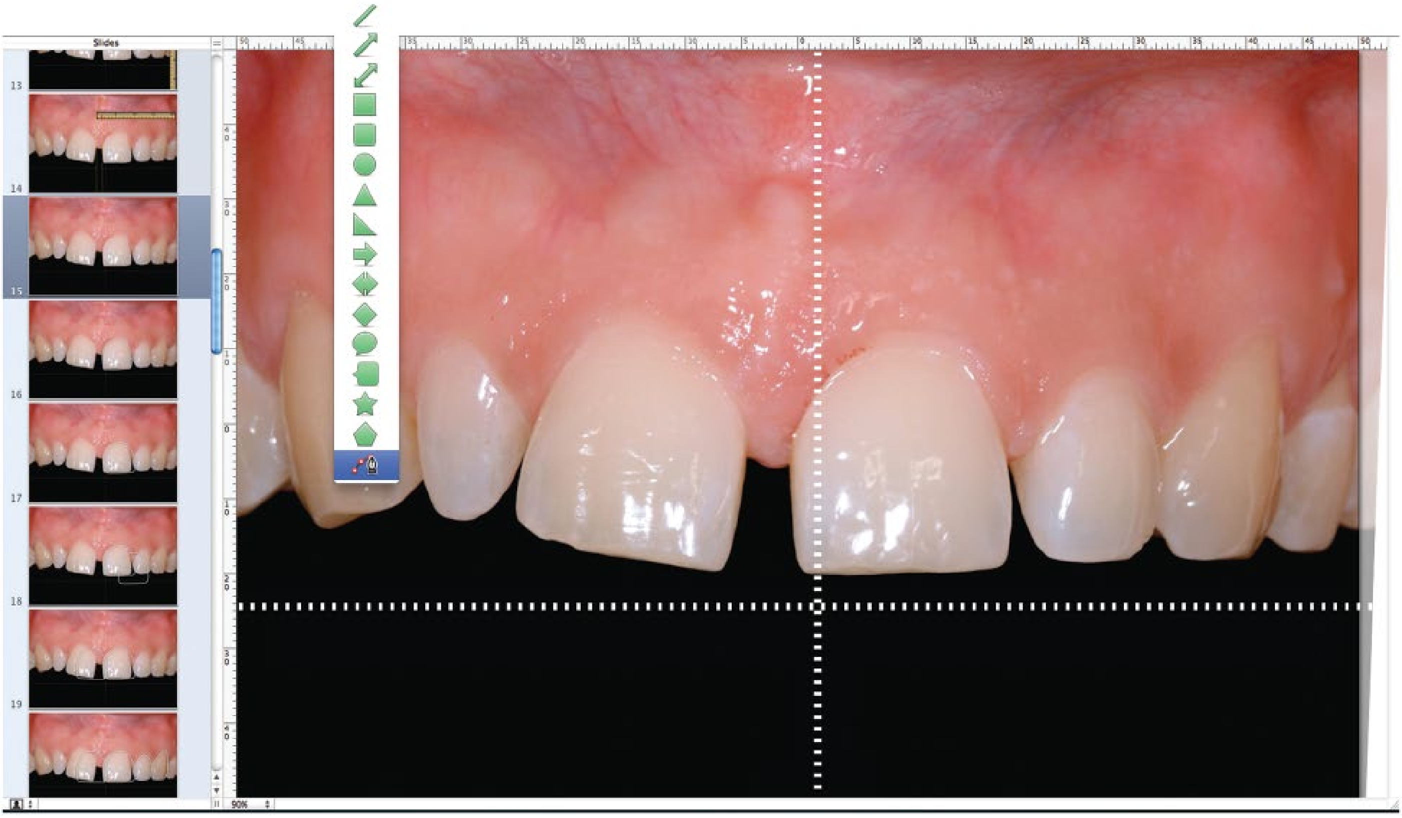

Figure 4.15 Make the digital drawings over the photo on the slide with the drawing tool.

model with the aid of a caliper, marking on the model with a pencil the same exact distances above the gingival margins that are shown on the computer and connecting the dots that creates a horizontal line above the teeth. The next step is to transfer the vertical midline, perpendicular to the horizontal line. One should measure the distance between the dental midline and the facial midline at the incisal edge level on the computer and then transfer this mark to the model with the caliper (Figure 4.16). After drawing the cross on the model (Figure 4.17) it is possible to transfer the information digitally planned, such as crown lengthening, incisal edge reduction, root coverage, and so on. At this point all the information necessary to the technician to develop a precise and useful wax-up is on the slides and on the model, guiding him or her to best perform this procedure (Figure 4.18).

The guided diagnostic wax-up is integrated with the patient's facial features and emotional needs. It is an important reference for the following surgical, orthodontic, and restorative procedures. Several guides can be produced over this wax-up to control the procedures as surgical stents, orthodontic guides, implant guides, crown lengthening guides, tooth preparation guides, and so on. The next important step is to evaluate the precision of the DSD and the wax-up performing a "test drive" (Figure 4.19). It can be a mock-up or a provisional, depending on the case. After the patient's approval of the "test drive," one can plan and adapt all the following procedures to achieve the desired result. The tooth preparation should be minimally invasive allowing just enough clearance to create proper ceramic restorations (Figure 4.20). The fabrication of the final restorations should be a controlled process with very little final adjustments (Figure 4.21), and the final result should be completely integrated, exceeding the patient's expectations (Figures 4.22 and 4.23).

The DSD is a practical multiuse tool with clinically relevant advantages: it can strengthen esthetic diagnostic abilities, improve the communication between team members, create predictable systems throughout the treatment phases, enhance the patient's education and motivation, and increase the effectiveness of case presentation. The drawing of reference lines and shapes over the patient's photo, following a predetermined sequence, allows the team to better evaluate the esthetic relation between the teeth, the gingiva, the smile, and the face.[14]

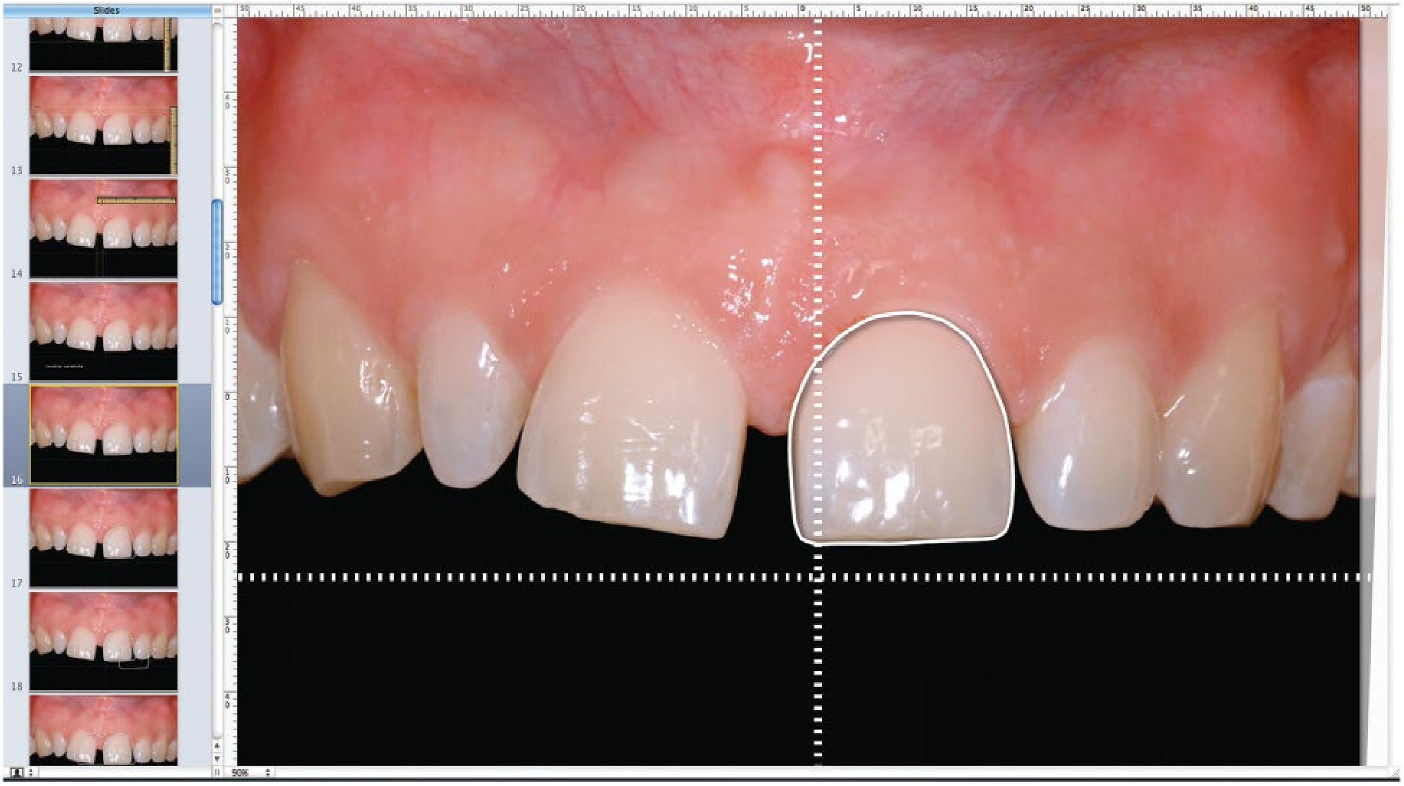

Figure 4.16 Draw the central incisor.

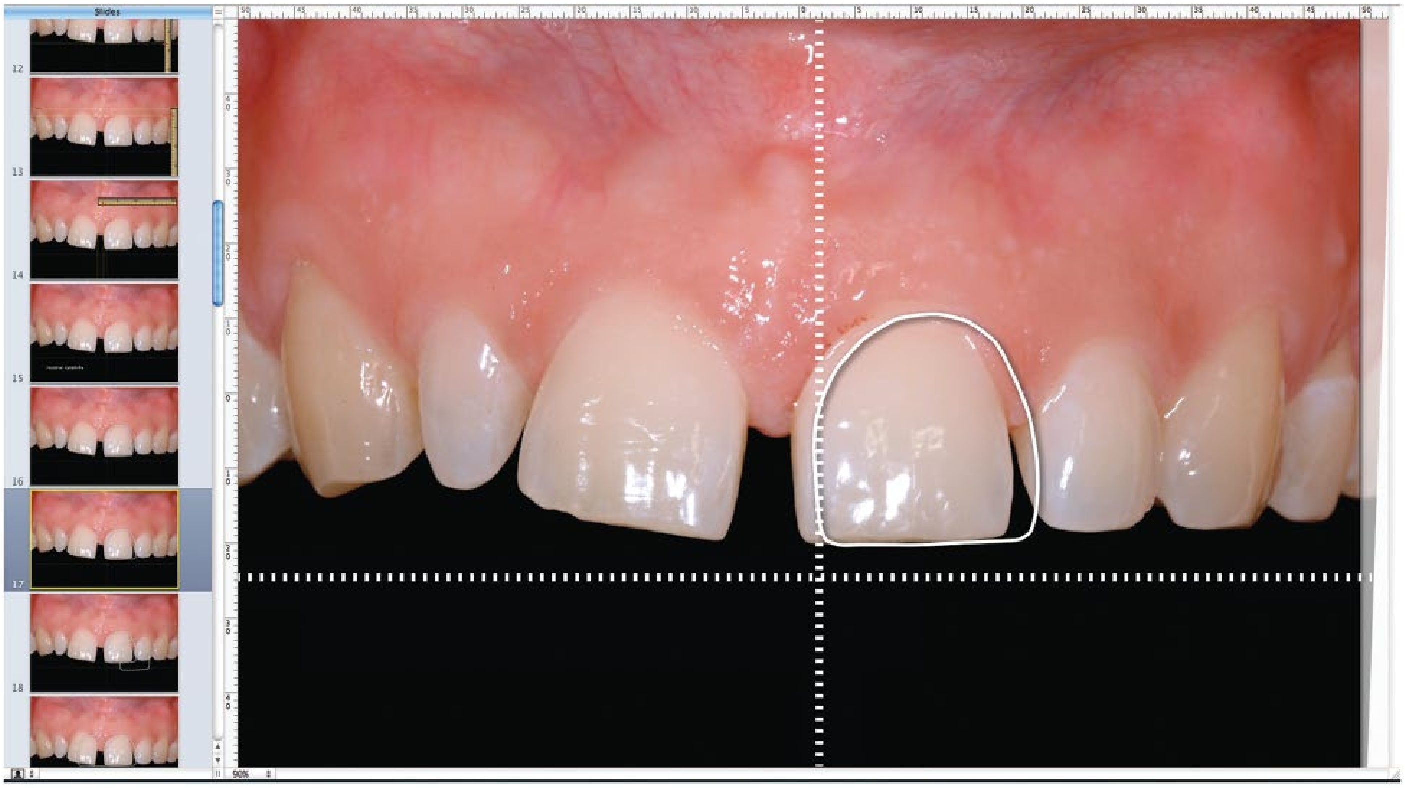

Figure 4.17 The Digital Mock-Up. Move the central distally to remove the distal diastema and to improve the match between dental and facial midline.

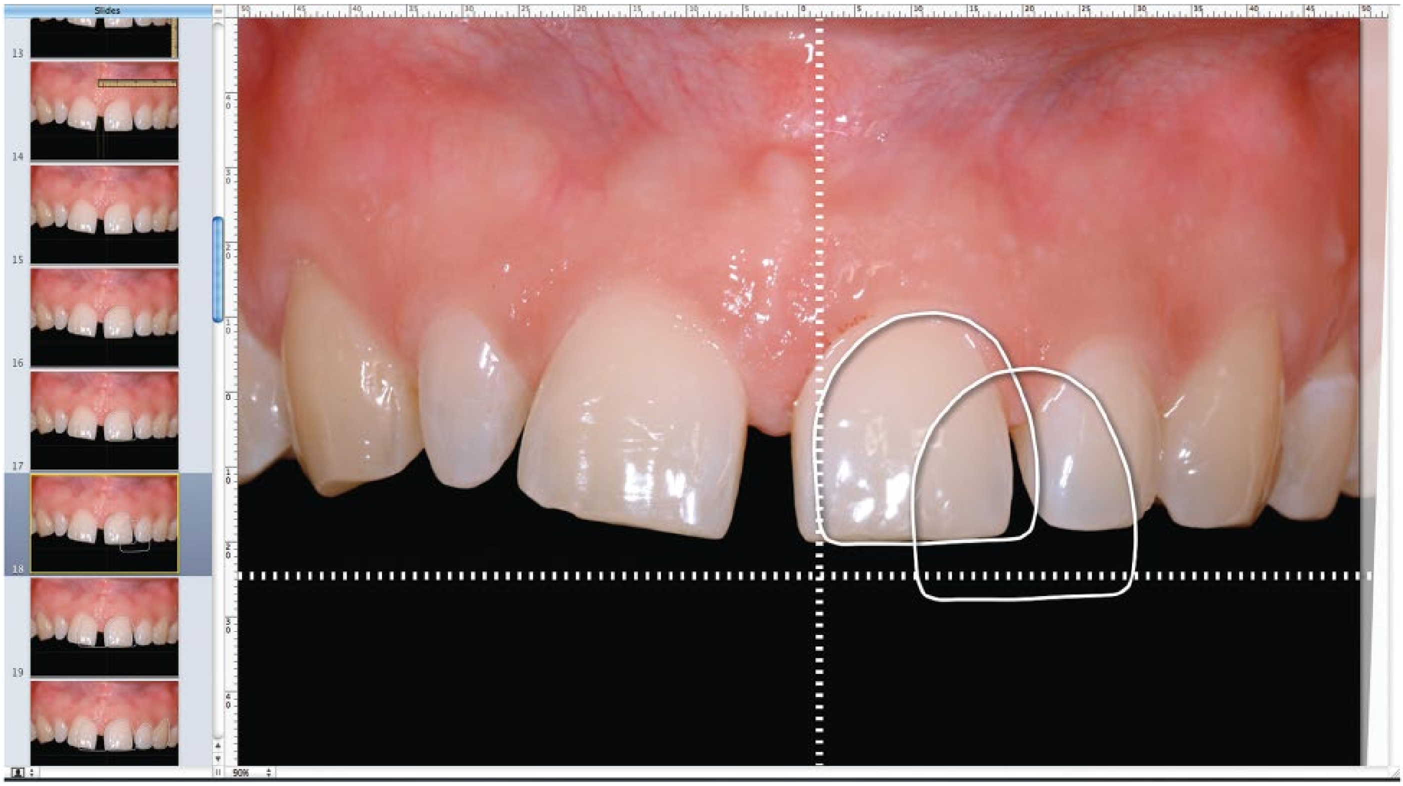

Figure 4.18 Duplicate the drawing of the central.

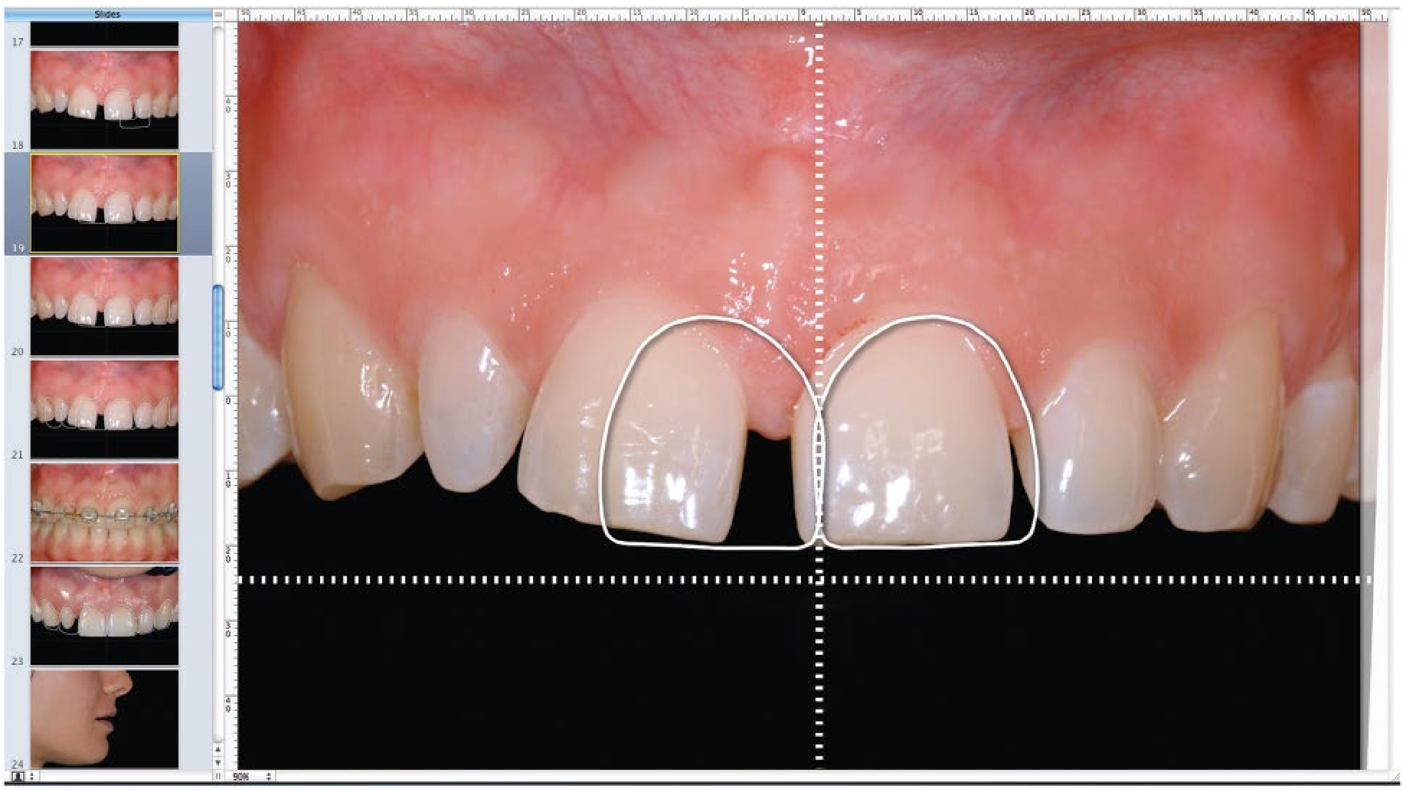

Figure 4.19 Flip the drawing and position it symmetrically to the other central. One can immediately visualize the difference between the actual and ideal position of the right central.

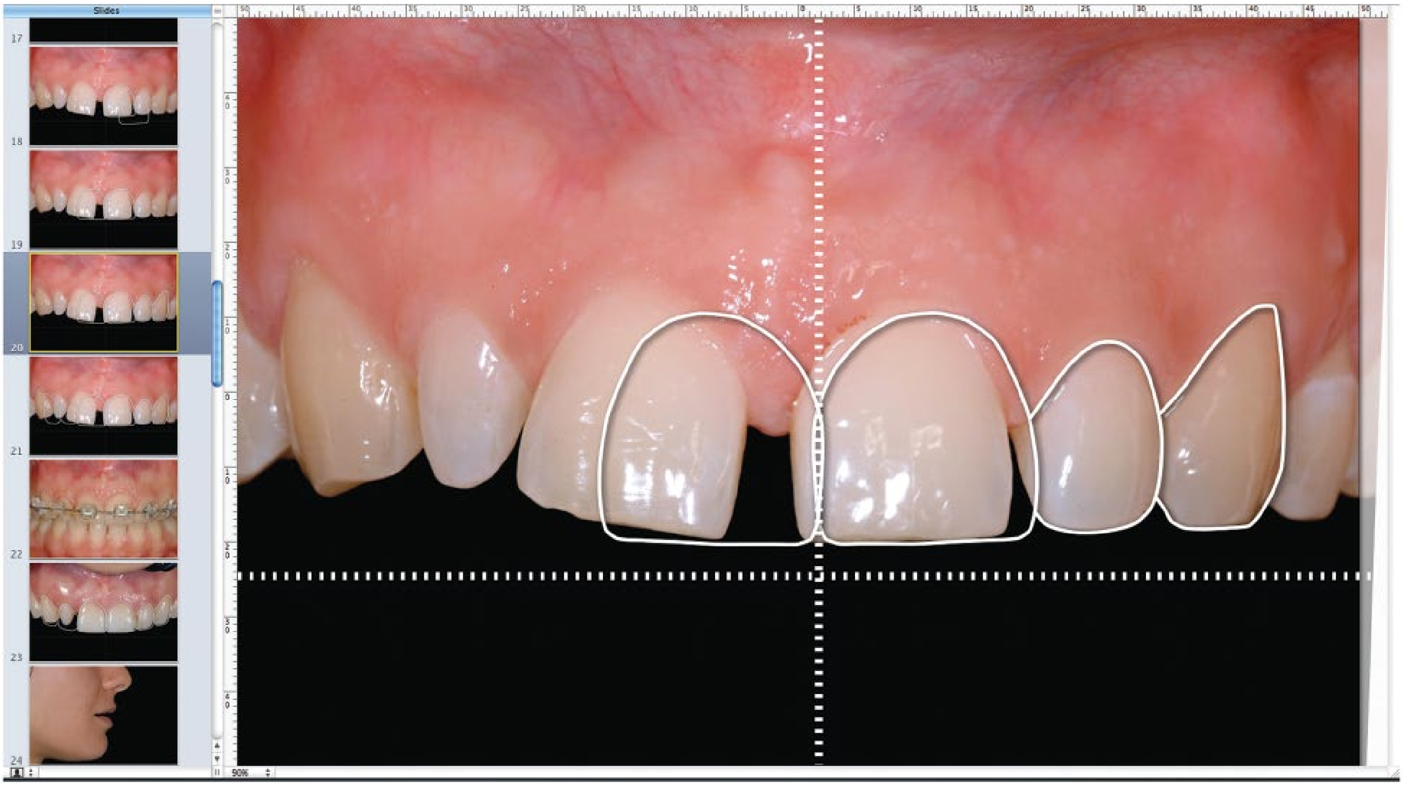

Figure 4.20 Draw the left lateral and cuspid to serve as a reference for the ideal position of the contralateral teeth.

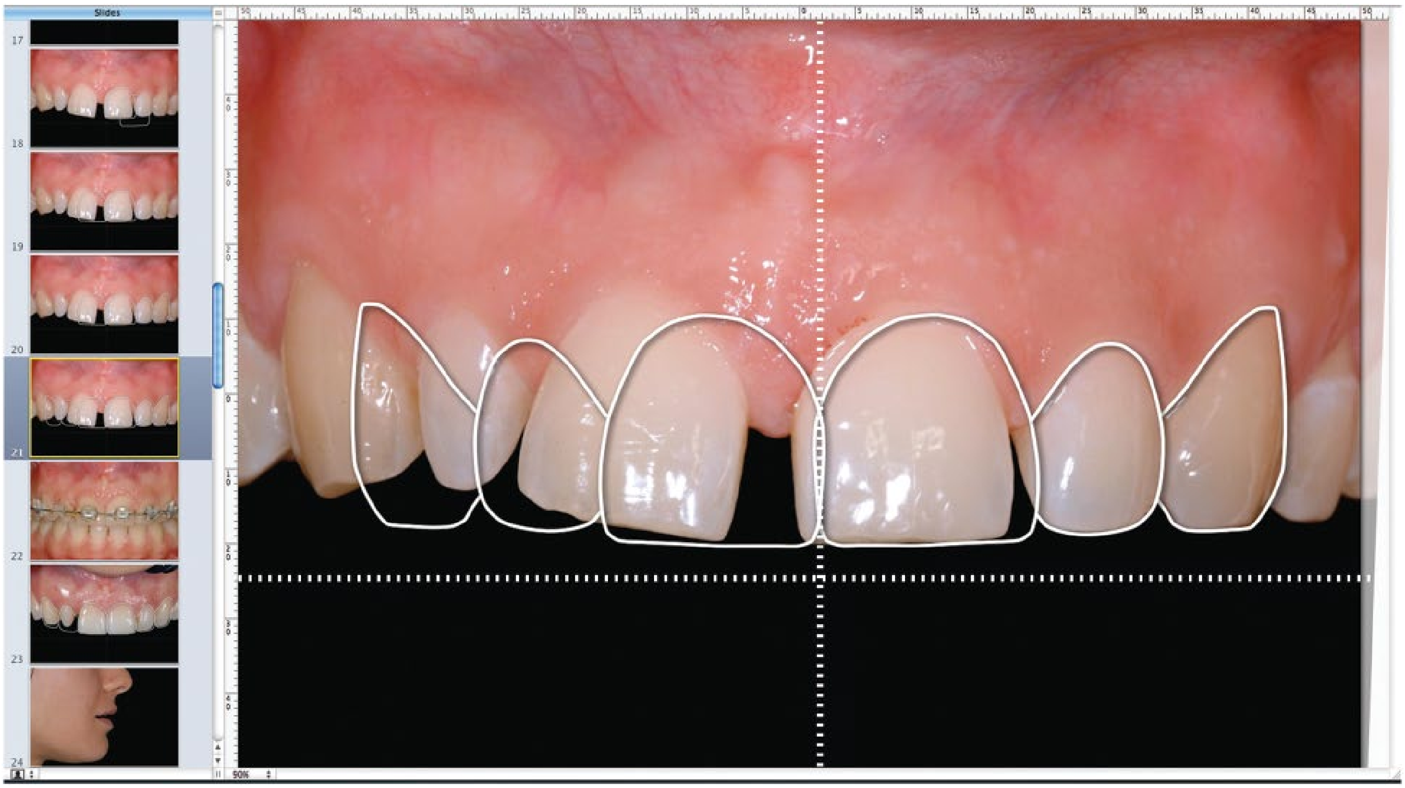

Figure 4.21 Flip and position the lateral and cuspid drawings symmetically in order to visualize the discrepancy between actual and ideal position of the six anterior teeth. This can demonstrate to the orthodontist the movements required as well as showing the patient the necessity of orthodontics to allow for minimally invasive preparations for veneers.

Figure 4.22 Situation after orthodontics.

Figure 4.23 **(A)** The effectiveness of ortho treatment can be visualized by superimposing the digital planning drawings over the post treatment photo. This helps demonstrate any further corrections needed.

Figure 4.23 **(B)** Planning the restorative procedures. Photo protocol for smile analysis after ortho.

Figure 4.24 The profile photo is also important to help analyze the buccal/palatal position of the centrals in relation with the lips.

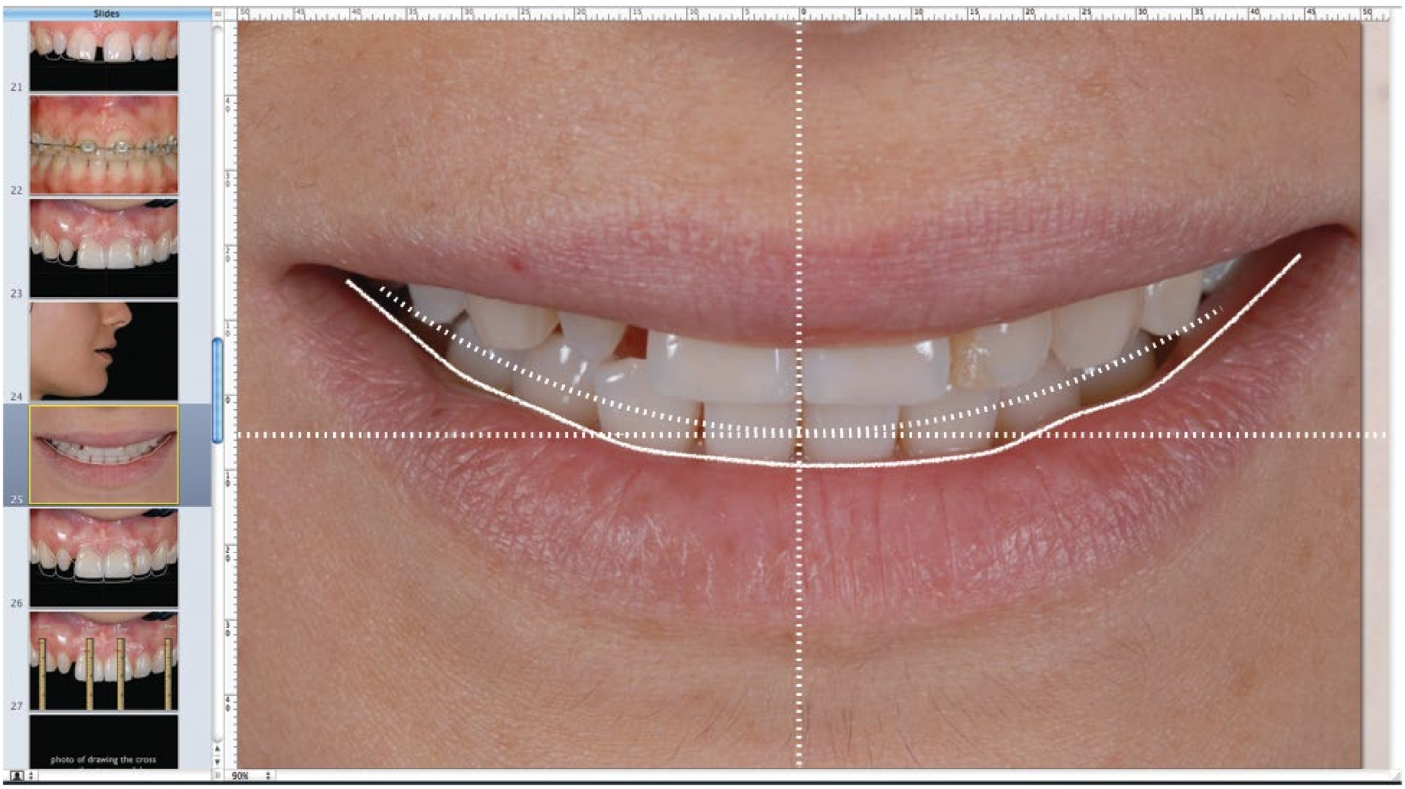

Figure 4.25 Digital planning for the restorative procedures. Analyzing the relation between the length of the anteriors and the lips. The first guess about how much one can lengthen the anteriors (curved dotted line).

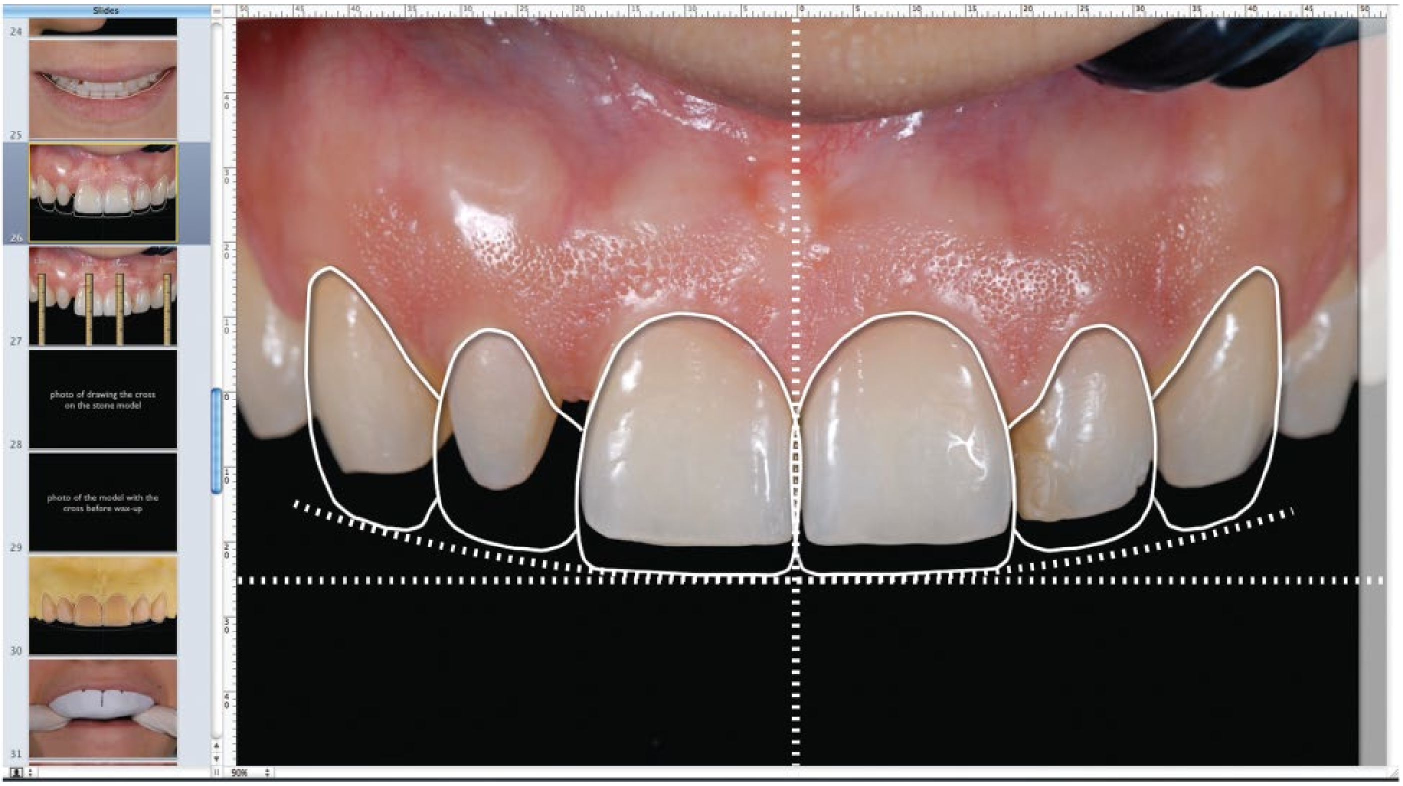

Figure 4.26 **(A)** Digital Mock-Up, giving an idea about ideal tooth design. One can visualize the relation between ideal design, actual tooth position, and soft tissues.

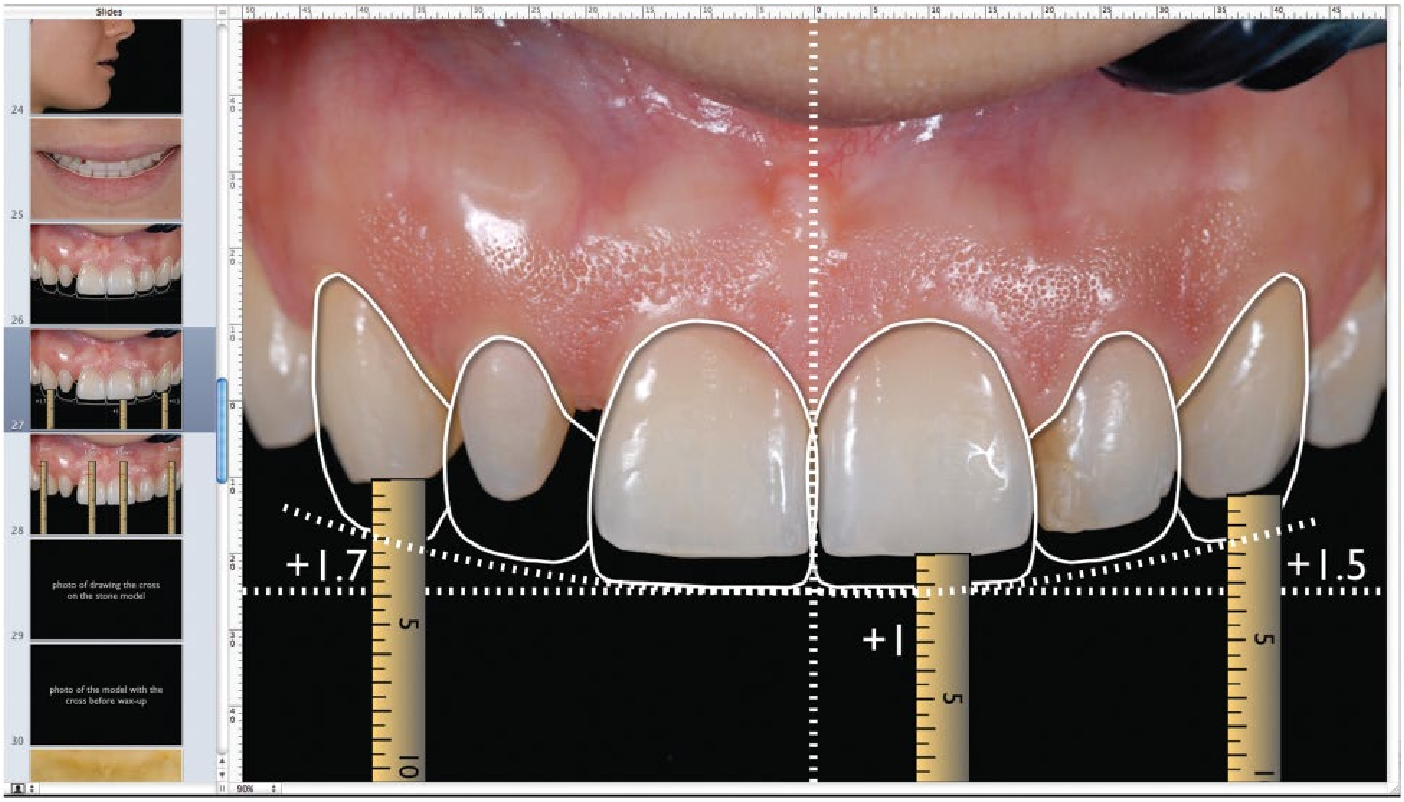

Figure 4.26 **(B)** Again, utilizing the Digital Ruler after calibration measurements are made that will be transferred to the diagnostic wax-up. For example, the amount of lengthening: 1.7 mm on right cuspid, 1 mm on left central, and 1.5 mm on left cuspid.

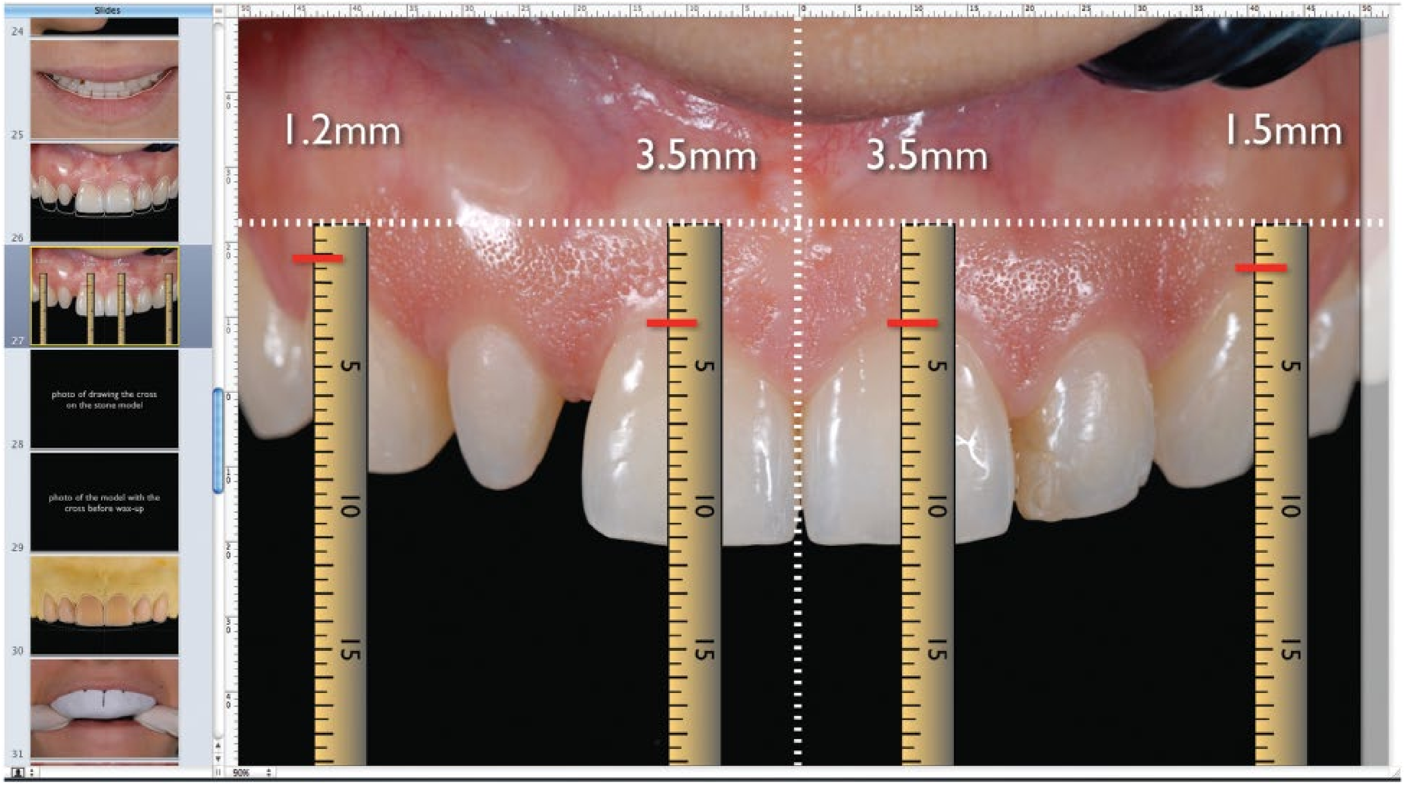

Figure 4.27 One of the main steps of the DSD technique, transferring the cross from the computer to the model to allow for a diagnostic wax-up that is integrated with the patient's face. The horizontal dotted line is placed above the teeth and the distances from the line to the cervical of the centrals and cuspids are measured.

Figure 4.28 Transferring the cross to the model. The measurements made on the computer from the horizontal line to the cervical of the teeth are marked on the model by using a caliper. Then the four marks are connected creating the horizontal reference on the model.

Figure 4.29 The vertical line can also be transferred from digital to the model. Now the model has the references for the wax-up to be developed without missing the midline and the occlusal plane.

Figure 4.31 The wax-up is transferred to the mouth to create a mock-up by utilizing a silicone index (Matrix Form 60-Anaxdent).

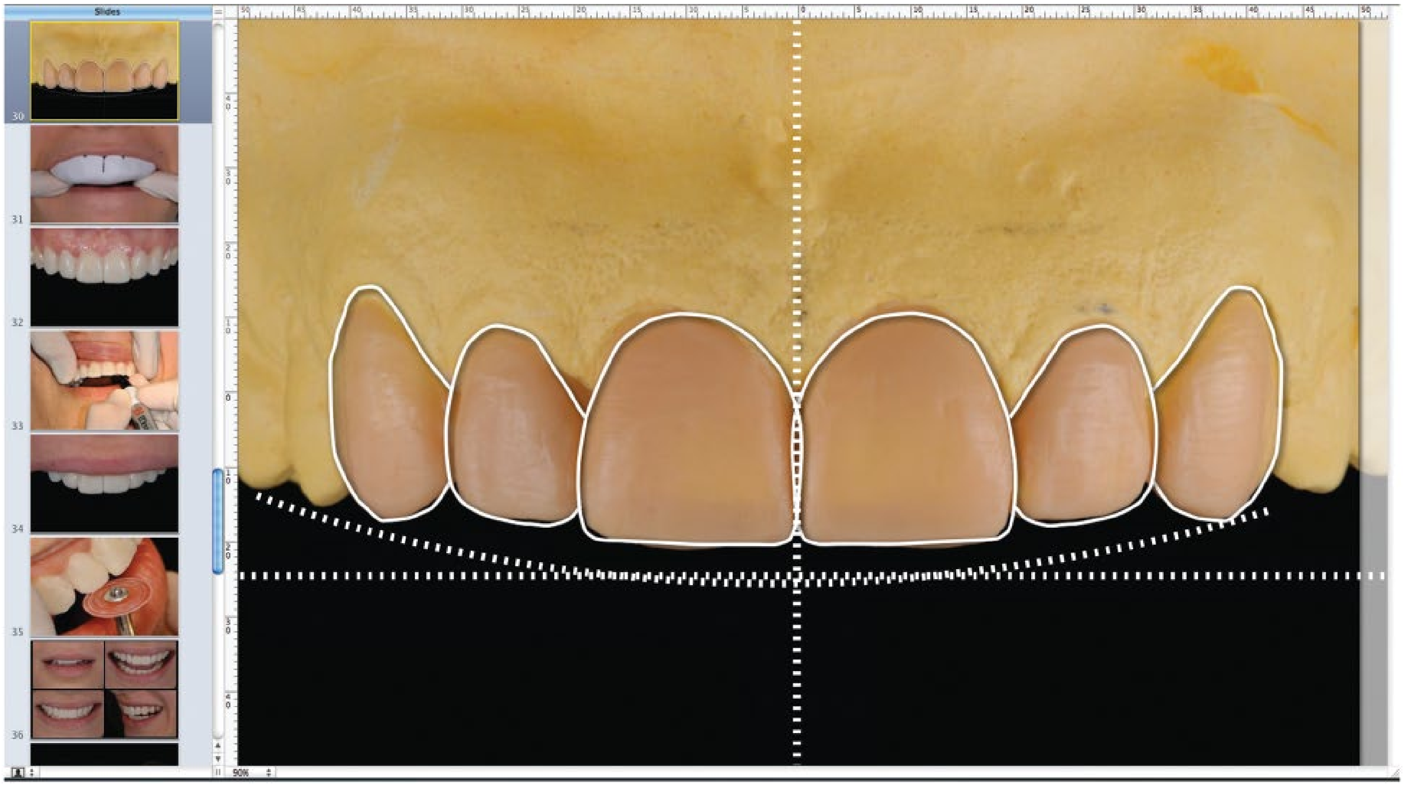

Figure 4.30 Guided diagnostic wax-up, guided by the digital planning and in harmony with the facial cross.

Figure 4.32 The mock-up made with a bis-acryl type of material.

Figure 4.33 If the mock-up seems a little long, a permanent black marker can be used to create the illusion of shorter teeth before actually shortening them.

Figure 4.34 The smile with the simulation of shorter teeth on the left side.

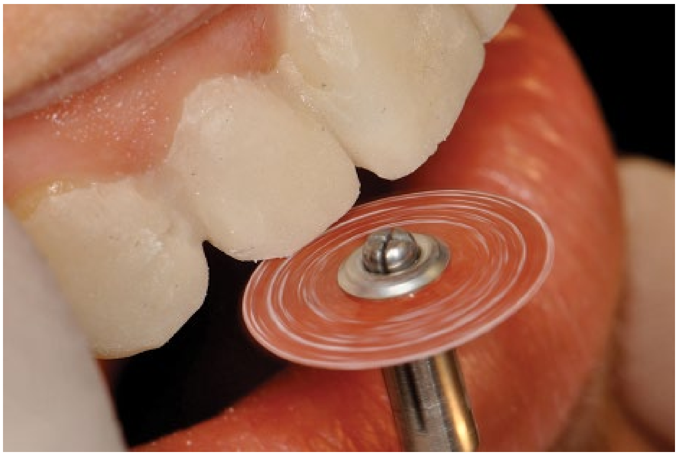

Figure 4.35 Shortening the mock-up with a sand disk.

Figure 4.36 Photographic analysis of the mock-up. These photos will be nicely displayed on the slides and presented to the patient.

Figure 4.37 The smile design should always be presented to the patient by images and videos rather than by the mirror.

Figure 4.38 Before and after the mock-up.

Figure 4.39 These casual photos of the mock-up help stimulate, motivate, and engage the patient.

Figure 4.40 Presenting the smile design with just the mirror is not effective in presenting all the possibilities to the patient.

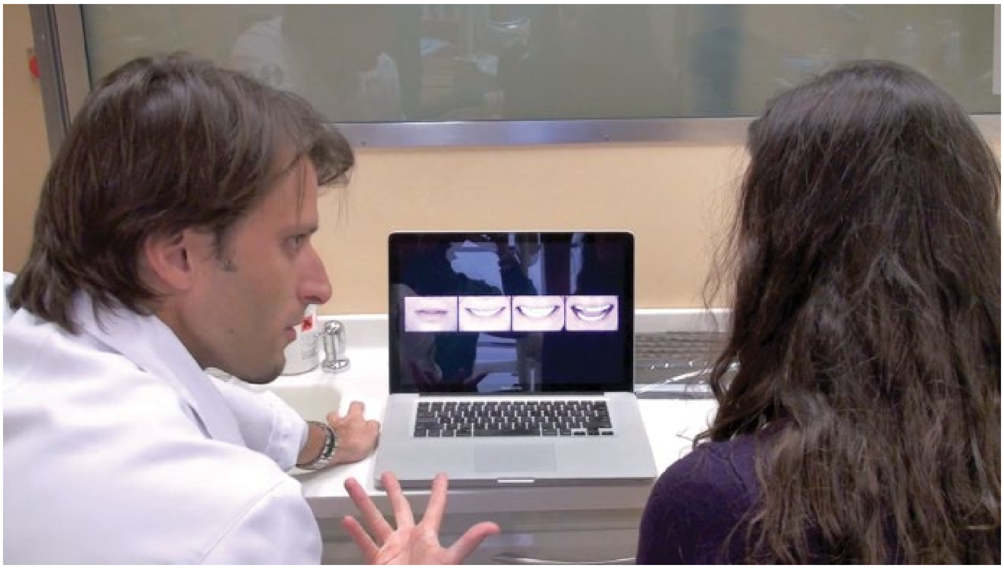

Figure 4.41 The photos and videos allow the patient to see the changed smile from all angles in order to fully understand the integration of the smile design to their face.

Figure 4.42 After the smile design project is approved by the team and the patient, the clinical procedures can be planned as tooth preparation. The tooth preparation will be as minimally invasive as possible if one knows exactly the final ideal forms.

Figure 4.44 A very important analysis is done when comparing the preps with the silicone index that shows the ideal buccal position according to the mock-up.

Figure 4.43 Finishing the tooth preparation. One can notice an almost prepless situation.

Figure 4.45 Impression.

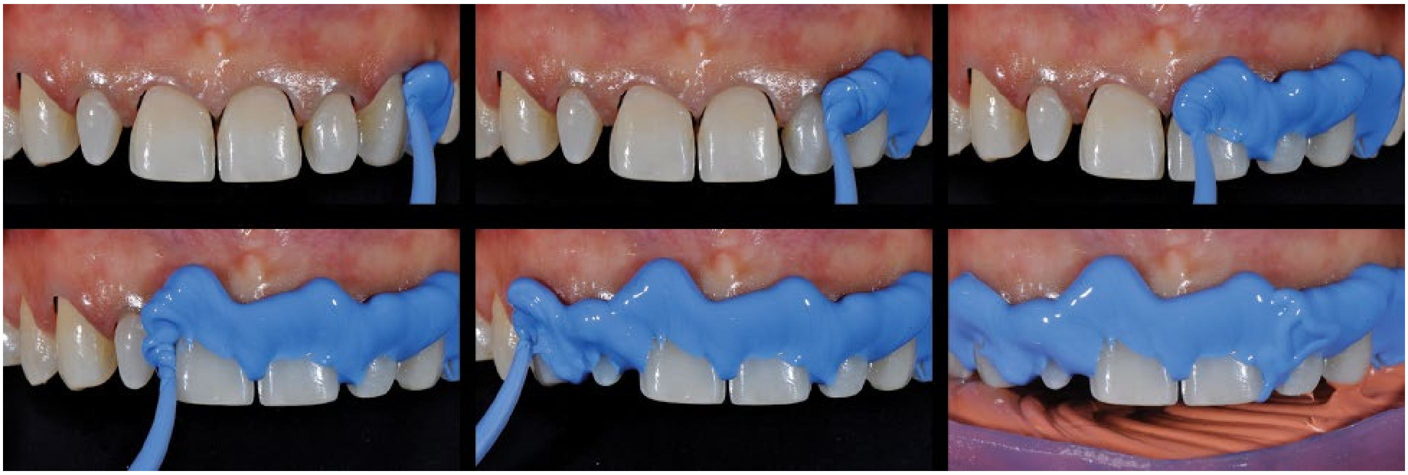

Figure 4.46 Impression.

Figure 4.47 Monolithic ceramic veneers (Emax LT BL4).

Figure 4.50 A video of the try-in allows the dentist and the patient to evaluate in all the details the integration between the veneers, the smile, and the face, allowing for final adjustments before final cementation.

Figure 4.48 The veneers in position with try-in paste (Variolink Try-in paste).

Figure 4.51 Bonding procedures.

Figure 4.49 Variolink Try-in paste and shade guide.

Figure 4.52 Bonding procedures.

Figure 4.53 Immediately after cementation showing a very good soft tissue condition.

Figure 4.54 Smile integration.

Figure 4.55 Final face photos.

Figure 4.56 It is important to present the patient with a before and after comparison slide to demonstrate the overall value and improvement to his or her smile.

Figure 4.57 Post-op after 1 year.

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Chapter 5 Esthetics in Dentistry Marketing

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Why is marketing such an important strategy for cosmetic dentistry? Consider these facts:

- There are more than 77 million baby boomers in the United States.[1]
- Millions of people have watched TV makeover shows.
- Nearly 14 million cosmetic surgery procedures were performed in 2016.[2]
- Eighty percent of people are not happy with their smiles.[3]
- More than $16 billion is spent annually on smile enhancements in the United States.[4]

[1] From US Department of Labor report, "Aging Baby Boomers in a New Workforce Development System," Available at: http://www.doleta.gov/Seniors/other_docs/AgingBoomers.pdf.

[2] American Society for Aesthetic Plastic Surgery. Available at: https://www.surgery.org/sites/default/files/ASAPS-Stats2016.pdf.

[3] American Academy of Periodontology. Available at: http://www.perio.org/consumer/smile.htm.

[4] The Doctor Weighs In. Available at: https://thedoctorweighsin.com/the-multi-billion-dollar-demand-for-cosmetic-dentistry/.

For the foreseeable future, cosmetic dentistry will be a vibrant industry with a growing patient base, especially with more and more baby boomers and members of generation X trying to hold on to their youthful appearance. However, this does not mean that every cosmetic practice will automatically experience significant growth. To fully realize esthetic production, practices must become very proactive in their marketing initiatives. To achieve the highest level of success, esthetic practices need to promote their services through internal and external marketing. These two systems are necessary to attract new patients, retain current patients, boost esthetic case acceptance, and drive practice growth. With the right mix of internal and marketing strategies, a practice is well positioned to continually increase esthetic treatment and production.

What is dental marketing?

Marketing is the process whereby a business promotes a product or service to its customers. In the case of dental practices, the service being provided is dental care and treatment.

Ronald E. Goldstein's Esthetics in Dentistry, Third Edition. Edited by Ronald E. Goldstein, Stephen J. Chu, Ernesto A. Lee, and Christian F.J. Stappert.

Unfortunately, marketing has often been a hit-or-miss proposition for many dental practices. This should not come as a surprise for a number of reasons:

1. Marketing can be an inexact science. In the business world, even a well-executed marketing campaign can fall flat due to poor timing, bad luck, or unforeseen circumstances.
2. Dentists receive little training on how to market their practices. Dentists learn dentistry at dental school—not how to market and manage a practice.
3. For much of the profession's history, dentists did not have to do much marketing, except for investing in attractive signage and a Yellow Pages advertisement. The marketplace has changed over time. The Internet and social media have brought a new dimension to marketing practices.
4. Marketing a dental practice and its services is very different from promoting other types of businesses. As a unique profession, dentistry requires specialized marketing techniques.
5. As the main provider of patient care and the practice leader, dentists are already extremely busy. Taking on additional marketing activities can present a significant challenge.

Like other business owners, dentists today need to engage in marketing to reach the highest levels of success. Unfortunately, marketing and dentistry have had an uneasy relationship. In past years, marketing was viewed as unethical and problematic by the majority of dentists. The rationale for this thinking was that dentistry, as a health-care profession, should not be soiled by the world of advertising. After all, this was dentistry—not something that could be packaged and sold like a used car on a late-night TV commercial. This hands-off approach to marketing essentially prevented practitioners from promoting themselves. Beginning approximately 15–20 years ago, attitudes started to change as more in the health-care industry, including hospitals and medical doctors, embraced high-impact marketing vehicles such as newspapers, radio, the Internet, and television.

Today, dental practices should model the best businesses and implement effective internal and external marketing programs. In the current marketplace, practices need to convey relevant information on specific services or opportunities to current and potential patients to market effectively. Educating patients through marketing activities benefits both the patient and the practice.

Creating a brand

A strong brand establishes positive and attractive qualities about your practice in the minds of current and potential patients. Those favorable impressions created by your brand can lead to increased case acceptance, more patient referrals, and, ultimately, greater profitability. Your brand drives your practice image. An effective brand should reflect the type of services performed in the practice. As practices add cosmetic services, many dentists fail to update their brands. The doctor may think of his or her practice as a modern cosmetic practice, but patients still perceive it as a typical general practice. As dentists begin the process of developing a brand, they need to ask the following questions to determine the practice's competitive advantages:

- What are the strengths of the practice?
- Why should patients come to this practice rather than another?
- What sets it apart from the other practices in the area?
- Do the team and the doctor currently have the necessary skills to successfully rebrand the practice?
- Are the practice's hours of operation different from other area practices? Does the practice offer more or less convenience to patients?
- What intangibles (special awards, community services, etc.) does the practice possess that will help in developing its brand?

Answering these questions will help dentists begin the process of determining the practice's brand. These differentiators will help the doctor select what elements are needed to develop the right brand for the practice.

Developing a marketing plan

The first step in designing a marketing plan is to identify the goals of the practice. One practice's goal may be to build a strong practice of 2000 active patients with an average patient production that leads to a $1.8 million per year gross revenue. Another practice may have a goal of providing primarily high-end cosmetic dentistry.

In the past 25 years, we have noted numerous practices that have launched marketing plans with a goal of simply "growing the practice." Unfortunately, that is not an effective goal because it is not specific. Details matter in marketing, just like they do in dentistry. Vague goals result in ineffective marketing strategies. Align your marketing plan with defined goals.

The following questions can help doctors develop specific marketing goals:

- Does the practice need more new patients? If so, how many per month?
- What is the average production per patient? Per new patient?
- Does the practice need more referrals? If so, how many per month?
- Does the practice have a sufficient number of new patients and referrals but need to enhance the case acceptance rate? If so, how much?
- What percentage of patients who contact the office actually make appointments?
- What cosmetic services are being utilized by current and new patients?
- What kind of cosmetic practice does the doctor want to create?

What is internal marketing?

Internal marketing refers to marketing activities that target current patients, motivating them to remain active in the practice, learn about all of the services offered, and refer others. The following recommendations are all part of a practice's internal marketing:

- Build a strong brand.
- Educate every patient about all services.
- Train the team to ask for referrals.
- Provide superior customer service.
- Stay in contact with patients to build and strengthen relationships.
- Reactivate inactive patients.

What is the most effective kind of internal marketing for the practice? Different patients respond to different types of marketing. Unfortunately, many practices take a scattershot approach to marketing rather than implementing a well-designed series of strategies that retain and attract patients. To be successful in building the patient base, internal marketing should be *ongoing*, *consistent*, and *positive*. As more dentists incorporate elective procedures into their practices, internal marketing becomes increasingly important to practice success. Whitening, porcelain laminate veneers, dental implants, and even removable appliances are all examples of services that many people desire but do not necessarily need. A practice focused on these types of value-added elective dental services is positioning itself for increased production and profit by successfully attracting the right type of patients through internal marketing. Properly implemented, internal marketing enables the practice to identify and attract new patients through specific strategies that result in referrals from existing patients. One such strategy is using appropriate scripting to ask satisfied patients to refer friends and family during checkout. In addition to bringing in more new patients, internal marketing helps the practice identify more treatment opportunities and increase case acceptance rates for active patients.

Internal marketing strategies

Internal marketing is often the most effective way for dentists to grow their practices and increase production. With their networks of family, friends, neighbors, and coworkers, current patients are an excellent source for new patient referrals. These patients know the practice and are more than happy to refer others if they have experienced superior care and exceptional customer service. By using internal marketing, dentists can generate more patient referrals, drive growth, and take their production to a higher level.

Internal marketing results in word-of-mouth advertising, which may be the most powerful form of advertising because other people (i.e., patients)—not the team or the doctor—are recommending the practice. This occurs when the level of patient care and customer service continually exceed expectations. When patients are extremely satisfied with the treatment and service, most will gladly recommend the practice to their friends and family, especially when the office asks them to do so.

Critical components to successful marketing

- Facility
- Doctor and team appearance
- Customer service
- Patient education
- Case presentation
- Patient referrals
- Patient communication

Facility

Appearance matters, especially for an esthetic practice. Patients are unlikely to accept treatment designed to make their teeth look significantly better if the office atmosphere is unattractive. Although this is true for any type of dental practice, it is especially important for practices that are promoting esthetic dentistry. An attractive office helps make patients feel comfortable during the cosmetic exam and instills confidence that the practice understands the importance of presentation. Improving the office's appearance is an effective method to add value to the practice. Patients must feel that they are in an esthetically pleasing environment, which reflects the ability of the doctor and team to provide excellent cosmetic dentistry. To achieve superior customer service, dentists and their team members need to view their practices through the eyes of their patients. How does the practice look from the outside? Is the building inviting? Is it landscaped and maintained well? Is the carpeting in the reception area in good shape? Is the furniture attractive and comfortable? Is it free and clear of clutter?

Walk through the entire office as if you were a patient and make notes about areas that need to be addressed. In addition, consider hiring an interior decorator or designer. The money spent on an interior designer is minor compared to the benefit gained by creating an attractive office that reflects your esthetic philosophy (Figure 5.1A–G).

> Remember, cosmetic dentistry is about esthetic beauty, so the office's appearance should reflect that, too!

Doctor and team appearance

Everyone in the practice should present a professional appearance. Uniforms or designated clothing should be attractive, clean, and up to date. As a health-care provider specializing in esthetics, a cosmetic practice must maintain high standards when it comes to dress and apparel. Patients have certain expectations regarding the doctor's and team's appearance, which should be professional and attractive (Figure 5.2A and B).

Figure 5.1 **(A and B)** Esthetically pleasing décor enhances the patient's perception of the dentist's esthetic taste. The presence of colorful flowers and other art décor around the office may also help to enhance your patient's confidence in your esthetic judgment.

In addition, the team should be seen as a showcase for the dentist's cosmetic skills. Consider offering staff members free or discounted cosmetic treatment, thus making them walking advertisements for the procedures the doctor wishes to promote. When patients walk in and are met by a sea of shining, beautiful smiles, the impression is quite dramatic. Even patients who have never considered cosmetic enhancement may start thinking about how much they would like a nice, bright smile after seeing the team's new and improved smiles. The issue of dress and appearance turns out to be more important than it might seem because patients decide whether to move forward with the treatment based on their perceptions of the dentist. If those impressions are negative, patients will turn down the treatment. They judge everything, including hair, nails, clothing, and posture. A neat, professional appearance is mandatory for every member of the team.

Figure 5.1 **(C)** For your reception area, in addition to news or entertainment videos, consider more personal educational programs with you as the teacher.

Figure 5.1 **(D)** Whenever possible, the entrance to patient treatment rooms should also be an attractive, pleasing, and comforting experience.

Customer service

Superior customer service occurs when every single process and system have been designed with one purpose in mind—to exceed patient expectations at every step of the way. This means that every team member has been trained with appropriate scripting, coaching, and mentoring to "wow" patients during their appointments, to create value for all practice services and procedures, and to view every interaction as an opportunity to build and strengthen a long-term practice–patient relationship.

Excellent customer service is the cornerstone of effective internal marketing. Patients love to be seen promptly, have their questions answered courteously and enthusiastically, and be treated like VIPs. Surpassing patient expectations can be difficult, but achieving the wow factor leaves an impression that stays with patients for a long time. By providing superior customer

Figure 5.1 **(E)** This dental office uses art glass so patients can relate to the doctors' esthetic taste.

Figure 5.1 **(G)** This unique Lalique crystal bowl has a double meaning. In addition to its beauty, the fluorescence in this bowl can help patients visualize the artistry and fluorescence that will be used in creating their ceramic restorations.

Figure 5.1 **(F)** Custom art glass flowers were designed so patients sitting in the dental chair can see the different colored petals.

service, dentists will motivate more patients to recommend their practice, which leads to more new patients and increased production (Figure 5.3A).

What are some essential features of customer service that can be applied to every patient? The following factors can help practices achieve outstanding customer service:

- All patients should be greeted enthusiastically as they enter the office. A clear script should be used to welcome patients. The scheduling coordinator should let patients know how delighted the practice is to see them.
- Make beverages available to patients. Coffee, tea, and bottled water create a warm, home-like environment. People are more comfortable when they feel that their needs are being met. A comfortable patient is more likely to be open-minded, interested in what the dentist has to say, and more willing to consider different options (Figure 5.3B).
- Patients should be escorted everywhere in the office. Each team member who comes in contact with patients has a *moment of truth*—a point of contact that should always be used to enhance the practice–patient relationship. Say hello, smile, ask a personal question, and escort patients when the opportunity exists and thank them for visiting the office.
- Smiling is critical for practices determined to expand their cosmetic production. A smile conveys to the patient that the practice is glad to see them. Due to the pace of today's dental practices, dentists and team members can sometimes forget to smile. Remember, nothing welcomes patients as much as a smiling face.

Figure 5.2 **(A and B)** The color and style of doctor and staff uniforms is another aspect of the total office image. (A and B) Two examples of physician's uniforms and staff uniforms

Figure 5.3 **(A)** In addition to other amenities, patients have the luxury of watching their favorite program on the ceiling HD television, both while waiting and during treatment.

- Every time a patient visits the practice, learn at least one new thing about them. It is important that this type of information be kept in their files, so it can be referred to before the next visit. This enables the dentist and the team to strike up a conversation in a more personal way.
- Compliment patients. Who doesn't love to receive compliments? If the team is trained to provide superior customer service, they will put smiles on patients' faces and brighten their day. People like to go to a place where they are treated courteously in a positive, welcoming environment.
- Thank every patient for visiting the office. The doctor, assistant or hygienist, and front desk staff should always end conversations by thanking the patient. Let the person know that he or she is appreciated. This results in patients feeling extremely positive about the office and looking forward to their return visits.

Patient education

Practices should use a variety of patient education tools to emphasize the benefits of cosmetic dentistry, including:

- cosmetic brochures
- posters
- before-and-after photographs and digital software
- newsletters, e-newsletters, and website updates
- patient testimonials

These devices demonstrate to patients the practice's commitment to cosmetic dentistry. Even more than simple awareness, such tools define the practice as a center for cosmetic dentistry where patients can expect to receive professional,

Figure 5.3 **(B)** This office has a comfort room for patients who have extended treatment visits. While waiting for the laboratory to complete her restorations, this patient is being served lunch by one of the office's most valuable team members.

state-of-the-art care. Many patients still do not think of their dentist as a cosmetic dentist. Fortunately, every dentist has the power to change that perception. In today's world, where consumers are becoming more aware of health and beauty options, practices can take advantage of this growing trend. Many current patients would be interested in smile enhancement if—and only if—they become aware that these services are offered. When offices combine a strong practice culture, along with excellent patient education tools, the practice is on the road to developing a powerful brand. However, efforts at patient education can fall flat if patients don't experience a high level of customer service from team members (Figure 5.4A).

Patient education is critical to gaining the case acceptance needed to increase cosmetic procedures performed in the practice. However, unlike need-based dentistry, where patients are often in pain and accept treatment as a way to relieve that pain, patient education for esthetic services is a much more comprehensive process (Figure 5.4B).

The more informed patients are of the services offered, the greater the opportunities for increasing case acceptance. Many practices have also incorporated a program of giving their new patients copies of the consumer book *Change Your Smile*[1] not only to educate the patient but also to encourage more referrals.

Case presentation

Accepting treatment for esthetic dentistry is usually much more of an emotional decision than other types of traditional services. Patients will not make a decision to accept a cosmetic case based on need—they are not usually experiencing pain—but rather on the emotional feelings they get when thinking of how much better they will look and feel after a cosmetic procedure is performed. It is more of a heartfelt decision on the patient's part. The dentist's job is not to be overwhelmingly clinical during case presentation, but rather emphasize the many emotional benefits the cosmetic procedure provides. Taking time to tell patients how good they will look and feel about their smile is an effective way to increase case acceptance. Most patients are willing to learn all the ways their smile can be enhanced, especially since many patients are completely unaware of all the options available now. Motivated patients will find a way to pay the fee involved for the procedure, if the value and benefits are clearly explained. This type of presentation creates greater case acceptance that ultimately leads to increased practice profitability (Figure 5.5A). The key to showing patients the benefits of cosmetic dentistry begins with a case presentation that is both motivating and exciting. Patients want to see themselves transformed. Begin a conversation about cosmetic dentistry by asking patients questions such as:

- Are you happy with your smile?
- Is there anything about your smile that you don't like?
- Have you ever thought about whitening?
- Do you know you could have a smile like this? (Use appropriate visual aid here.)

These "conversation starters" are a great way to get patients to think about cosmetic dentistry. In addition, you may wish to consider offering a complimentary cosmetic exam to attract new patients. During the cosmetic exam, each anterior tooth should be scored against a shade guide. Patients are given an understanding of the shade guide in advance and then scored, so that they know exactly what their shade is versus what it *could* be.

There has been a shift in the consciousness of Americans based on the hundreds of millions of dollars spent on television

Figure 5.4 **(A)** A chairside computer monitor is one of the easiest ways to consistently keep your patients informed. It is also helpful for demonstrating both intra- and extra-oral pictures to your patients throughout their treatment.

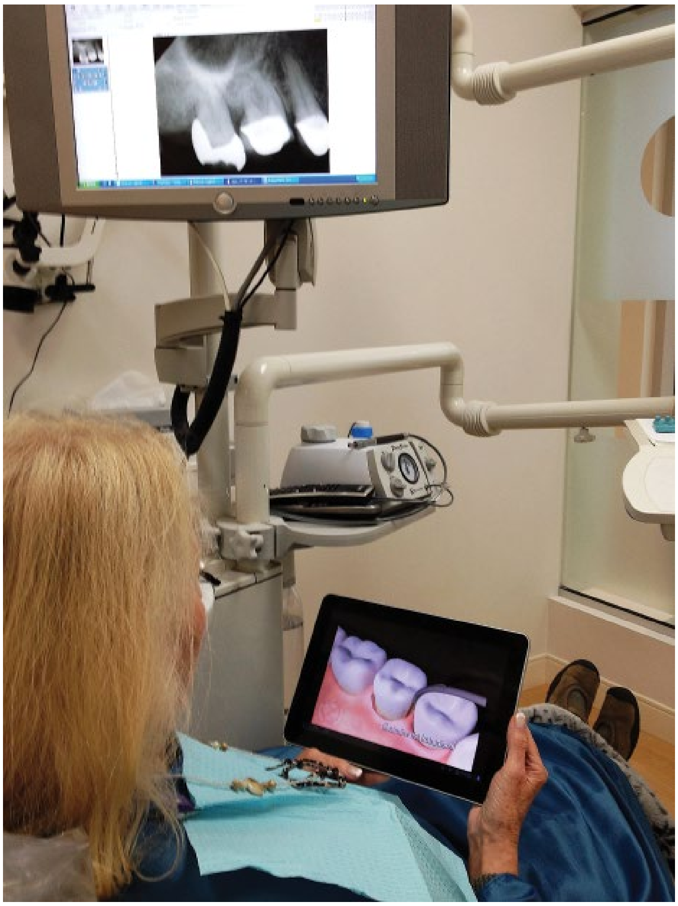

Figure 5.4 **(B)** A tablet computer is an example of how new technology can be used to easily educate your patients while in the chair. This patient is viewing a video of a proposed laser-assisted new attachment procedure (LANAP) to help better understand the treatment.

advertising for over-the-counter whitening products and the success of “makeover” reality shows. The message is out—you can’t have a beautiful face without a beautiful smile. The result of this heightened consciousness is that more Americans are interested in cosmetic dentistry. Why wait for patients to raise the issue of cosmetic dentistry? Offering a complimentary cosmetic exam opens a dialogue with patients. Many will be unaware of all the different types of elective services currently available. By educating patients about their current cosmetic condition against the standard of a shade guide, practices create a sense of comparison for patients, which often leads to diagnosis and the presentation of treatment options (Figure 5.5B).

Cosmetic dentistry has the power to transform not only smiles but lives. And that is something most patients will be excited about, if the message is presented in the right way.

Patient referrals

One of the strongest internal marketing strategies is to actually ask patients for referrals. The staff interacts with patients at every step of the treatment process, with countless opportunities to encourage referrals. Training the dental team to ask for referrals can lead to a dramatic increase in new patients. Scripting will help the staff consistently deliver a strong marketing message. When patients remark how pleased they are with the practice, team members should be trained to respond appropriately. For instance, the script could direct staff to thank patients at the end of treatment and say, “We love having patients like you. Please tell your friends about us.” Patients are often thrilled to refer their friends and family. Anyone who refers a patient should receive a personal thank-you call from the dentist and the office manager. At their next appointment, referring patients should receive a

Figure 5.5 **(A)** Although in most instances a treatment coordinator or other team member can present the treatment plan, at times the doctor may be called upon for more detailed explanation.

thank you from at least four staff members, including front desk personnel, the assistant, the hygienist, and the doctor. Recognition and appreciation are very meaningful to all patients. To increase patient awareness, make sure the office displays signs that say, "we appreciate referrals," or "the greatest compliment you can pay our practice is to send a friend or refer a friend." If signs aren't obvious and the scripting isn't effective, people will not likely think of referring others to the practice (Figure 5.6A and B).

Patient communication

When patients refer their friends, these potential new patients will want to find out more information about the practice. That means having a professional, state-of-the-art website where people can learn more about the practice, the services offered, and the doctor's professional background. The website should be easy to navigate and highlight the quality care provided to patients, including a full list of cosmetic services.

What is external marketing?

With external marketing, the practice is communicating with people outside of the office who may not be familiar with the practice. Therein lies the challenge. The main goals of external marketing are to

- create awareness
- build a positive reputation
- attract new patients.

Figure 5.5 **(B)** Internal marketing should always be considered when planning for office décor. These colorful photographs from a renowned Brazilian photographer and artist help to show the ingredients of a beautiful smile. Reproduced with permission of Dudú Medeiros.

Figure 5.6 **(A)** The ultimate success of any marketing program is satisfied patients who are willing to refer their family and friends. This cake presented to the dental team is evidence of that satisfaction.

Figure 5.6 **(B)** The design of the cake was the creation of the patient.

Figure 5.7 **(A)** A good example of external and internal marketing is seen in this blog which was a website posting of a news clip of the practice's work with StemSave.

The two main forms of external marketing are advertising (e.g., newspaper ads, or online) and public relations. Advertising, whether in print, on the web, or by other media, can be more expensive than other forms of marketing. Of course, having a quality website is one of the most effective forms of external marketing. The practice's website is the place that new patients and potential patients will first visit. They will want to see what kinds of services are offered, where the practice is located, what patients are saying about the office, and so forth.

Public relations focuses on building the practice's reputation in the area through activities such as working with schools and local nonprofit groups. Many dentists allow tours of their offices, give presentations on good oral health at schools, and sponsor local sports teams. Some dentists write a weekly or monthly column on oral health matters for the community newspaper. Positive outreach builds goodwill with local residents and businesses. Remember, marketing—both internal and external—should be reflective of the practice's brand and image in the community (Figure 5.7A and B). A good internal marketing program will help drive external marketing success. To reach the highest levels of success, marketing must be consistent and ongoing. A hit-or-miss approach will usually lead to haphazard results. Successful practices use a variety of approaches to retain current patients and attract new patients.

External marketing strategies

How do practices attract more new patients? How much should offices invest in external marketing? What strategies—direct mail, telephone directory ads, websites, radio and television advertising, and billboards—will yield the best results? The answer is that it depends on the practice goals, budget, current patient base, location, and other factors such as demographics of the target market. External marketing, when developed as a part of an overall marketing plan, can be extremely effective. However, many external marketing efforts should be approached with caution because they can be costly and fail to generate the desired results. Yet, some newer developments in external marketing, such as social media, offer promising results for a minimal expense.

What should be the focus of community marketing and advertising campaigns? Clearly, conveying the competitive edge

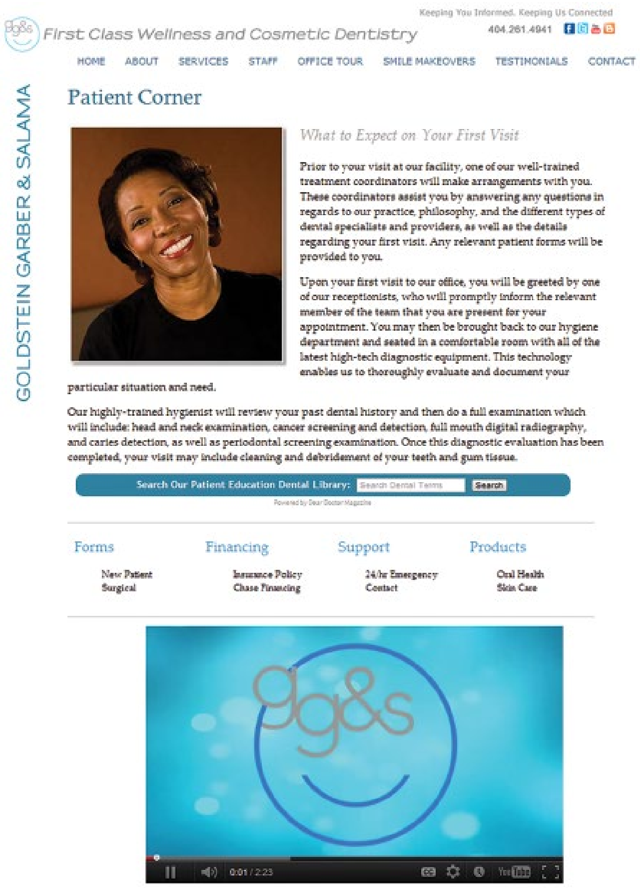

Figure 5.7 **(B)** The website should be easy to navigate and have a section for new patients and what they can expect on their first visit.

of the practice should be the primary message. There is a greater chance for positive feedback by including information about advanced technology and unique services. As a rule, advertising focused on specific esthetic services and the associated benefits is usually far more powerful than announcement-style advertising. Patients are frequently attracted by the services mentioned rather than by general information on the practice itself.

The external marketing strategies to consider include the following:

- Advertising:
  - website
  - telephone and online directories
  - television
  - radio
  - outdoor billboard advertising
  - direct mail
  - magazines/newspapers (Figure 5.8)
  - group discount shopping services.
- Public relations:
  - community relations
  - social media.

Advertising

Website and internet security

Today, your website is the first place where many new patients are introduced to your practice. Websites are a necessity, not a luxury, for most types of businesses. But simply having a website does not mean that the office will automatically derive benefits from it.

Business website design has grown increasingly more intricate and sophisticated and today's users and patients expect a well-designed interactive website. Work with professionals to design and maintain an excellent website. Update it frequently to keep it fresh. What good is a website if people don't come to visit?

The website should be easy to navigate and highlight the quality care provided to patients. It should have a section for new patients that details what they can expect on their first appointment. The website should include the following:

- dentist's biographical sketch including professional background
- what to expect on the first appointment (printable forms, description of the consultation process)
- directions to the office, hours of operation, and contact information
- virtual tour of the office
- services/procedures offered
- before-and-after treatment photos
- e-newsletter sign-up (Figure 5.9)
- contact information.

Many dentists wonder if their practice's website needs all of the latest technical security features. The answer is—absolutely yes! These days, an unsecured website is dangerous for patients, the practice, and possibly other doctors as well. For example, suppose someone hacks a practice's website. The hacker could potentially obtain sensitive patient information such as names, addresses, Social Security numbers, and perhaps even financial information. The hacker might also be able to access correspondence and treatment information that is going back and forth to other practices. Most of this activity is easily stopped through good online security.

Telephone and online directories

Today, people look for products and services much differently than 10 years ago. Although newspaper and magazine ads have their place, newer forms of media such as online directories and ads can have a much greater ability to bring patients to the practice for a lower cost.

Television commercials

Television commercials can make a powerful impression with potential patients. Unfortunately, it is also extremely expensive to produce a commercial and buy air time. Although cable TV can offer lower rates, the time slots available usually deliver fewer viewers. Something to keep in mind with commercials is that

Figure 5.8 Local magazine ads can target marketing to specific geographic areas close to your practice location.

GOLDSTEIN GARBER & SALAMA

We believe in spreading

HOPE + ❤

As cosmetic dentists, our lives revolve around our patients and the joy that their vibrant smiles bring to their lives every day. You've heard about the social effects that having an unattractive smile can have on a person but what about those who are struggling to find a reason to smile at all?

first class wellness and cosmetic dentists

The employees of Atlanta's Goldstein Garber and Salama are active volunteers at Hope and Love for Familes of Georgia, Inc., a non-profit organization founded in 2003 to offer emergency and temporary assistance to needy families that are unable to make ends meet.

Hope and Love founder Victor Ekworomadu with the team

As you can imagine, the needs this year are even greater than ever because of the current economic situation. We want to encourage and help these people get back on their feet so they can take care of their families, contribute to society, and be less dependent on the government.

"Success is not truly realized until we reach out and make a difference in the lives of the less fortunate."

Ezra Ekworomadu at a Hope and Love event at Hope Urban City Garden

Hope and Love helps families with food, clothing, school supplies, and household itmes, occassionally temporary rent and utilities. If you have made a 2012 resolution to give back or join your community, this is the perfect opportuniy. For more information visit www.hopelove.org or call 770.649.9650.

goldstein garber & salama gg&s est. 1929

HOPE LOVE

600 Galleria Parkway | Ste 800 | Atlanta, GA 30339 | 404.261.4941 | www.goldsteingarber.com

Figure 5.9 This office newsletter demonstrates that this practice is involved with local charity in the community.

viewers will be able to tell a quality commercial from a poorly produced one. If skilled professionals create it, the quality will show on the screen. Conversely, if the commercial was produced inexpensively, its limited production value will be obvious and could reflect poorly on the practice.

Radio

Although less expensive than television advertising, radio ads are only effective if the right people are listening. Too often, the only attractive rates are for time slots that have few listeners. Usually drive-time hours have many listeners but costs can be prohibitive. Keep in mind that radio is not the powerhouse it once was. With so many outlets for entertainment, far fewer people listen to radio than they did 20 or 30 years ago. The good side of this, however, is that rates can be affordable in many instances.

Outdoor billboard advertising

Billboard advertising has limited effectiveness and can be a significant expense. Only the people who happen to drive by the billboard have the chance of seeing it. Even then—how many will actually notice it? Unless the practice has created an extraordinary ad that will captivate drivers and passersby, outdoor advertising may not be the best choice of where to put the office's marketing efforts.

Direct mail

Direct mail can be effective. One study found that 66% of direct mail is opened, 82% is read for a minute or more. Further, 56% of people who responded to direct mail went online or visited the physical store and 62% who responded made a purchase. Some 84% or more said that personalization made them more likely to open direct mail.[5] Although the web continues to chip away at direct mail, these statistics show that it is far from dead. One thing to keep in mind about direct mail advertising is that a 2% open rate is considered very successful. That means most direct mail goes unread. However, that shouldn't dissuade a practice from using direct mail. There are times when direct mail is a good way to reach patients. As with any published work, make certain that what the practice sends out is professionally designed and written. The effectiveness of direct mail will be blunted by spelling mistakes or amateurishly designed pieces. When the practice is ready to mail its piece, the office should purchase an up-to-date mailing list to reach its targeted audience, whether it is by age, income, zip code, or other parameters.

Online group discount shopping services

In the past few years, we have seen an influx of online group discount shopping services such as Groupon and Living Social. Dental practices who sign up with these online shopping sites offer discounted services to attract new patients. If enough people sign up for the deal, the deal is on. The dental practice shares the revenue with the discount shopping service. The hope is that these bargain hunters will become active patients. Indicators show that the results are mixed. It is too early to conclude the true effectiveness of this type of marketing. A number of practices have found that people coming to the practice through one of these deals are only coming for their one-time discounted service. Some practices have successfully "wowed" the bargain hunter and retained them as a patient.

When considering whether to try offering this type of deal, determine whether your practice can schedule all the people who bought your deal in a timely fashion without undermining the customer service you provide to existing patients. Keep in mind that those who visit the practice with coupons in hand may be sitting in the waiting room with your patients. If they engage in a discussion, are you comfortable with your patient knowing he/she is paying substantially less for the same service? It is also important to make sure that engaging in a deal with a group shopping discount service does not violate the ethics code of your state dental association.

Public relations

Community relations

Many practices make the mistake of dashing off a "press release" to the local newspaper and expecting it to just show up in print. In truth, newspapers are deluged with press releases that are often nothing more than advertisements. A majority of the time, any press release sent to a newspaper is quickly discarded. To stand a chance of being printed, press releases should be newsworthy and should not contain language straight out of a practice's brochure.

An even better approach to getting public relations (PR) would be writing for the local community newspaper. Many smaller papers are looking for interesting content from local business people. Writing a short monthly column on oral health care for either the print or online version of a local publication is an excellent way to build the practice's brand and position the office as the leading dental care provider in the area. Another suggestion is to appear on a local radio or TV station as an oral health expert when the need arises. Getting involved in your community is also an excellent PR strategy. Sponsoring recreation league and high school teams, participating in community health fairs, and speaking at area schools are a few examples of building a strong reputation as a caring member of the community (Figure 5.9).

Social media

More and more businesses are using social media, such as Facebook, YouTube, Twitter, and LinkedIn, to strengthen customer relationships and generate customer loyalty. Social media has emerged as another powerful tool to reach current and potential patients, but that does not make it an appropriate marketing channel for all dental practices. Social media can be

[5] Forbes. Available at: https://www.forbes.com/sites/forbesagencycouncil/2017/01/10/five-ways-to-spice-up-your-direct-mail-marketing-in-2017/#5c1592f34d3e.

an incredibly useful method to reach patients, but it has to be evaluated to determine its effectiveness. Survey your patients to find out if they use social media and how often they do so. Practices that decide to utilize social media platforms should ensure that all of their marketing efforts are integrated and support one another.

If the practice decides to integrate social media in its marketing, there has to be someone in the practice—the office manager, the marketing coordinator, or another team member—to monitor traffic, update content, and respond to questions. This requires a time commitment, but the benefits can be positive in terms of outstanding patient retention.

Another avenue to consider is search engine ranking—when a "keyword" is typed in, where does your practice rank? Also, looking at positive patient feedback from sites that rate medical practices, many people check the patient reviews before going to a practice.

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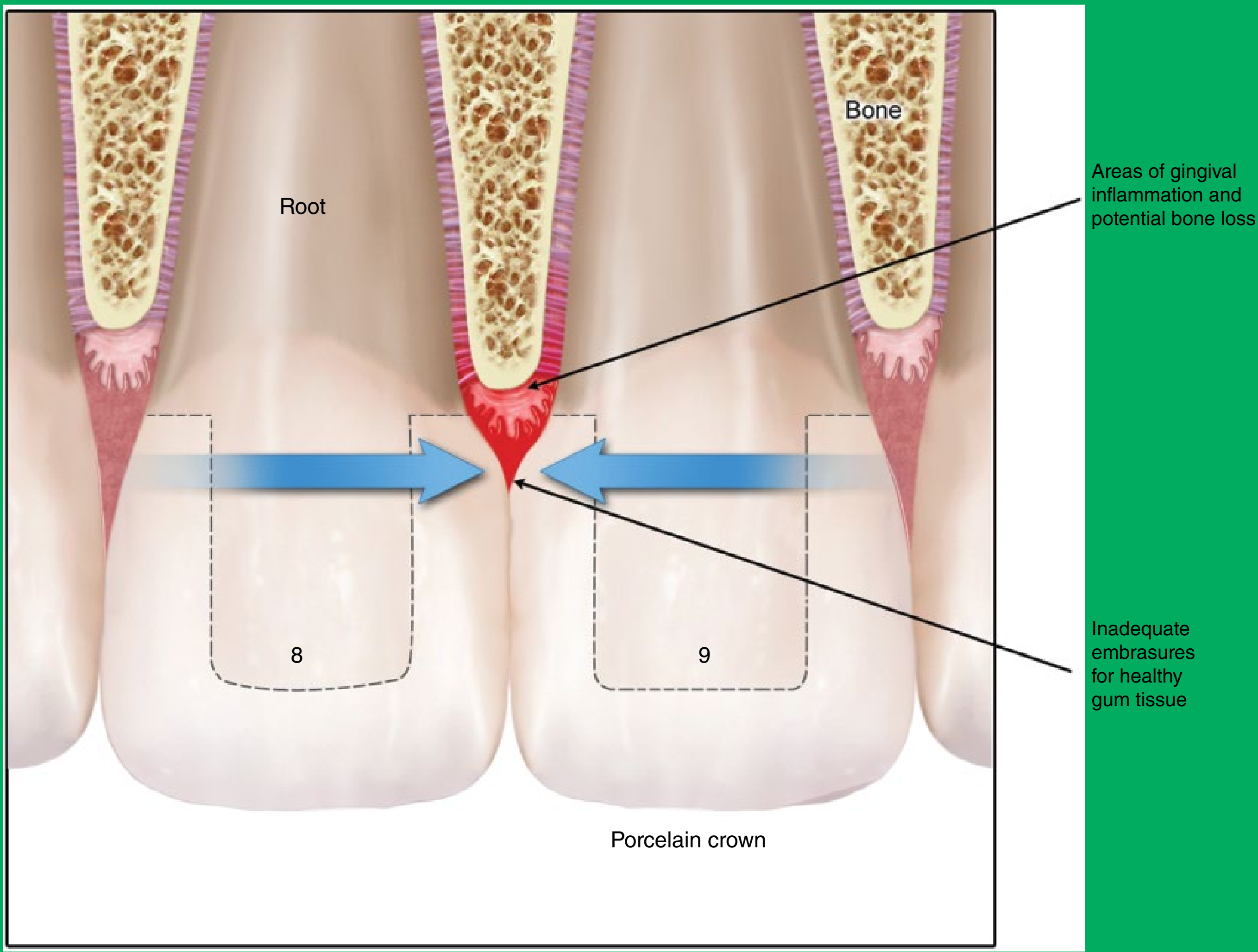
Overcontouring of crowns



Chapter 6 Legal Considerations

Edwin J. Zinman, DDS, JD

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Although it would be helpful to be able to identify a suit-prone patient and refuse treatment, this is not the reality. It is this author's experience that virtually all plaintiffs in dental negligence litigation have not previously sued a health-care professional or anyone else. Consequently, the best means to avoid malpractice suits is to adhere to the basic principles of quality care and to communicate realistic expectations to the patient. A dentist's ethical[1] and legal obligation is to always protect the patient's best interest.[2] Tort laws with potential threat of litigation spur dentists to practice safely.

To prove malpractice, a plaintiff patient must first establish the applicable standard of care. Second, the patient must prove that the defendant dentist violated this standard of care with resultant damages or injury. In a malpractice suit, each side presents expert testimony. Expert witnesses may rely on and/or consider external evidence of the standard of care, such as

Ronald E. Goldstein's Esthetics in Dentistry, Third Edition. Edited by Ronald E. Goldstein, Stephen J. Chu, Ernesto A. Lee, and Christian F.J. Stappert.

clinical practice guidelines which the various dental specialties or dental organizations promulgate.[3–5]

Dentist's legal obligation to update skills and practices

Dentists have a legal obligation to remain current through continuing education and update their armamentarium with currently accepted or proven technological advances. It might be said that a practicing dentist who graduated 20 years ago but failed to take continuing education courses possesses 1 year's experience repeated 20 times. Advances in adhesive chemistry and resin technology have expanded esthetic dentistry capabilities. Composite restorations have become an accepted material for Class III, IV, and V restorations in anterior teeth but remain questionable as a standard restoration for occlusal and proximal areas of posterior teeth with strong occlusal loading.[6] Conservative restoration preparation decreases marginal degradation and fracture associated with composites. Composite restorations are not recommended for molar teeth in which the cavity preparation exceeds two-thirds of the distance between the buccal and lingual cusps.

New high-tech devices such as Diagnodent (Kavo) help the dentist to discover if an occlusal stain is just a stain or caries. If the technology reveals there is a carious lesion present, simply sealing to entomb the decay is advisable or eliminate incipient decay with an air abrasion or burs before sealing; otherwise caries may continue to develop underneath the sealant.[7] Furthermore, if any part of the sealant breaks off or if the bond becomes detached, the caries may develop at a much more rapid rate, leading to endodontic disease.

Informed consent

Dentists have a professional and legal responsibility to provide each patient with sufficient information that enables the patient to make an informed choice decision whether to agree to a proposed treatment that poses significant potential complications. The process of the dentist providing this information and documenting the patient's agreement to the proposed treatment is known as *informed consent*. Informed consent may be oral or written, but a written consent form is more credible to a jury. Written documentation of informed consent also avoids the perils of a conflict between dentist and patient regarding who said what and when.

Any unconsented procedure performed on a patient constitutes battery, which may subject the dentist to punitive damages for unauthorized touching. Consent may be explicit—that is, the patient stating "I accept"—or implied by the patient's tacit approval of the dentist's treatment plan following the dentist's explanation of proposed therapy.

The purpose of informed consent is not simply to satisfy legal requirements, rather the informed consent process should aid the patient to understand why a particular treatment plan is recommended and the essential elements of proposed treatment.

Procedures that pose virtually no risk or significant adverse effects do not require informed consent; for example, repair of a chipped composite in a nonmarginal area. Dentists should not rely on consent obtained by the referring dentist. It is the treating dentist's responsibility to obtain adequate informed consent.

Informed consent, a legal doctrine, requires the dentist to provide adequate disclosure of benefits versus risks of procedures and reasonable alternative therapies.[8,9] This is so the patient is fully advised of the nature of the suggested treatment and inherent nonnegligent potential complications. Although the procedure may be performed with the highest degree of dental practice and care, the dentist may still be found negligent for inadequate disclosure of inherently unavoidable potential risks of treatment, which are known to the dentist but which the lay patient does not know or suspect. Although a patient consents to a treatment, that consent is voidable if their decision was made without adequate information regarding reasonable risks or complications.

Disclosure of potential risks and complications

Informed consent includes advising a patient of the pros and cons of proposed treatment and treatment alternative benefits and risks. It is permissible to inform the patient of the dentist's recommended treatment among various treatment options. Ultimately the patient decides among various proposed treatment options or can refuse all.

The principal potential complications and risk of proposed treatment should be disclosed to the patient. In some states, practitioners are not liable for failing to disclose potential risks or complications if the community practice was to not disclose these risks or complications.[10]

Many courts reject the proposition that the scope of disclosure obligations is determined exclusively by community practice. Instead, a patient has a right to be informed of available options and the complications of each option, regardless of community disclosure practices.[9]

This "objective" standard has been adopted in a majority of states in the United States.[11–15] In these states, a court will determine whether a particular disclosure should have been made based on the court's own assessment of whether the information might have affected the patient's willingness to undergo the procedure. Sufficient information to allow an informed choice must be disclosed. However, disclosure of an extremely remote risk is not required. It is not required to give a lengthy discourse on all conceivable complications if the potential is very remote. When in doubt, a dentist should disclose a particular treatment risk. Consent to negligent care is legally voidable.[16]

Disclosure of alternative treatments

Disclosure should be made of alternative procedures and likely results of these alternative procedures. Reasonable alternative procedures should be disclosed even if the dentist does not perform them. The patient should understand why the dentist has recommended a particular treatment in preference to potential alternatives. For instance, if your patient has crowded teeth but states he or she does not want orthodontic treatment, you are still obligated to state the reasons that orthodontic treatment would be the ideal preferred treatment plan as the best way to correct the malalignment. State the advantages of orthodontic treatment such as less expense over patient's lifetime, less invasive treatment, and likely elimination of root canal risks resulting from esthetic restoration preparations.

A patient should not be asked to consent to negligent care nor should the dentist provide it if the esthetic compromise exceeds the reasonable functional capabilities of restorative materials. Bleaching or bonding vital teeth is an accepted treatment for stained teeth. The esthetic utilizations of porcelain laminates include covering tetracycline staining and recreating physiological contours of teeth.[17]

Failure to offer the alternatives of bonding, bleaching, or porcelain laminates instead of full coverage crowning, if feasible, violates the doctrine of informed consent. This is because complete crowning can result in greater potential endodontic or periodontal complications.[18] Orthodontic option should be provided for diastema closure as an alternative to cosmetic restorations.

To avoid any misunderstanding, the dentist should orally describe to the patient the pros and cons of bonding. Written consent forms are strong evidence that the patient was fully advised and understood the benefits as well as the risks of bonding compared to alternative restorative procedures. In addition to a chart entry that the patient was fully advised by the dentist concerning bonding, Form 6.1 is offered as a suggested informed consent guideline form for bonding.

Informed consent requires disclosure of reasonable alternatives, which necessarily includes less invasive and reduced-risk procedures.[19,20] A reasonable dentist should always attempt to provide thin veneers in enamel. Thick veneers prepared into sensitive dentin risks endodontic complications unless tooth position contraindicates thin or no-prep veneer. Form 6.2 is an informed consent form for alteration of existing restorations. Form 6.3 is an informed consent form for approval of existing restorations.

Patient's commitment to follow-up care

The patient should be clearly advised of required follow-up care. The patient should know what subsequent actions are needed to maximize the likelihood of a successful outcome. Before authorizing a procedure, the patient should commit to performing the "required follow-up care" and acknowledge potential compromised esthetics and durability resulting from inadequate follow-up. Patient should initial the section of the informed consent form regarding the patient's obligation to achieve long-term success.

Consent forms and signatures

The state of the art in esthetic dentistry is constantly changing and improving, thus dentists should consult with a knowledgeable lawyer in their state before adopting an informed consent form. Laws vary from state to state. These forms should be reviewed periodically to assure that they reflect current laws and current practice standards.

Do not simply hand the informed consent form to the patient and ask the patient to sign. Instead, the dentist should explain to the patient in layperson's terms the material on the form. The patient should be encouraged to ask any questions and seek clarification about proposed treatment and alternative treatments. Answers should be given in understandable lay language and explained with diagrams and photos. These photos should be part of the patient's dental record with dates to document when these photos were shown and explanations given. If the patient refuses to listen or read about the possible complications and risks and alternative treatments, stating they "trust the dentist's judgment" this should be clearly noted in the patient's record. The form should note that the patient was offered the opportunity to be advised of the alternatives, benefits, complications (ABCs) but declined to be informed of these options. The patient should sign the consent form with a notation that the *patient refused to participate in the informed consent process*. The patient's signature should be witnessed by at least one person other than the dentist. The executed consent form is an integral part of the patient's record. The patient may initial each paragraph or section of the consent form, but the patient's signature on the document suffices for agreement to the whole document (see Form 6.4).

Informed consent alternatives, benefits, complications (ABCs):

- diagnosis in nontechnical terms
- recommended treatment
- alternative treatment options: clinical condition may require modification of treatment plan
- benefits of treatment (results and patient satisfaction are not guaranteed)
- potential risks and complications
- required follow-up and self-care for successful results.

Negligent customary practice

A negligent custom is not consonant with reasonable and prudent care, which the standard of practice requires. Many negligent customs, although widely practiced, are nonetheless unreasonable and therefore substandard. In other words, average customary care is below the average of reasonable care if it is not reasonable and prudent. Examples include the use of contraindicated cold sterilizing solutions to disinfect instruments[21] and unnecessary exposure of the patient to a higher dose of X-rays because newer types of X-ray, such as digital methods, are not used.[22–25] Other examples include failure to use a rubber dam for nonsurgical endodontics, omission of charting of periodontal pockets, and/or clinical attachment loss. Caries risk assessment should be included in a comprehensive exam to assess the risk of future recurrent caries causing failure, which may otherwise compromise the esthetic durability benefits of new restorations.[26,27]

A majority of dentists do not practice impression disinfection,[28] despite the US Centers for Disease Control and Prevention (CDC) recommendation. In the United States, Occupational Safety and Health Administration (OSHA) guidelines are designed to protect employees from the risk of infection transmissions by instituting controls that prevent contact with

INFORMED CONSENT TO BONDING: BENEFITS AND LIMITATIONS FOR PATIENT INFORMATION

A. Introduction

Bonding pros and cons are discussed in this form, so you may understand and appreciate the benefits as well as the limitations of bonding.

Bonding is a dental procedure which bonds plastic dental restorative materials to your teeth. Plastic bonding may last for several years but is less strong than the more durable or longer lasting restorations such as porcelain laminates or crowns (caps).

Most patients are gratified by the immediate improvement in their smile and appearance, which bonding accomplishes usually without local anesthesia. Initially, tooth surfaces which are to be "bonded" to the plastic material are prepared by etching or roughing the surfaces with a chemical. This is similar to wallpapering by first applying a chemical to prepare the wall before application of the wallpaper.

Bonding materials are applied in layers to the teeth until the desired esthetic results occurs. The bonding material is hardened by a curing process with high intensity light shielded from the patient's eyes. If the patient is esthetically displeased, bonding material may be added, removed, or recontoured to improve esthetics.

B. Alternatives

1. Crowning of teeth
   Although individuals experiences may differ markedly from statistical averages, the average bonding life expectancy before repair or replacement is required is approximately 5 to 8 years. Porcelain crowns, which require the grinding of natural tooth structure, local anesthesia, and impressions, last on the average 10 years, but may last up to 15 years. Esthetic life ranges between 5 to 15 years. Chipping or fracturing can occur with any dental material at any time after placement. However, bonding can be repaired more easily by the application of additional bonding material to the fracture site whereas crowns may require total replacement to achieve a comparable esthetic result.
2. Other Dental Materials
   Porcelain veneers are porcelain shells, which, after some minor tooth reduction, are cemented to the outside surface of teeth. Esthetic life ranges between 5 to 12 years.
3. Nontreatment
   Bonding is designed primarily for esthetic reconstruction in selected areas of the patient's mouth. Patients may also elect treatment for tooth fracture or replacement of existing restorations that are decaying or breaking down and likely to cause future decay problems. Many patients choose bonding for psychological reasons since an improved appearance may benefit the patient socially or aid career advancement.

C. Risk of Bonding

1. Staining can occur with smoking and excessive amounts of coffee and tea.
2. Durability varies but is approximately five to eight years before replacement is required.
3. Chipping or fracturing may necessitate periodic repair or replacement.

D. Consent

I have read the above informed consent document, which has legal significance. All of my questions concerning bonding have been answered by the doctor or I have no questions. I hereby consent to bonding for esthetic reasons and/or treatment of dental decay, if any exists.

Date____________________ Patient____________________ Witness____________________

Form 6-1 Informed consent for Bonding.

blood-borne pathogens. CDC provides similar infection control guidelines for blood-borne infections, which reasonably clinicians should follow carefully.[29] Impressions should be disinfected before being sent to the dental lab for prostheses although this is honored in the breach more than the observance.[30]

Composite restorations can potentially cause pulpal irritation with the acid-etch technique if the acid reaches dentin when the dentinal tubules become exposed during the procedure. Children or adults with extremely large pulp chambers are prime candidates for pulpitis. Therefore, in these instances, exposed dentin may require protection before the etchant is applied. Not all practitioners recognize or appreciate the risk of pulpal irritation resulting from microleakage or chemical irritation from poorly cured resins, but careful clinicians do.[31]

The philosophy of "extension for prevention," originally advocated by GV Black, is no longer necessary, especially utilizing conservative composite resin Class II restoration with proper home care. Moreover, no current credible evidence exists that subgingival margins prevent decay. Although subgingival margins are used in patients with a high or medium

Informed Consent Statement

Altering of Existing Restorations

Patient's Name (printed):

____

I understand that any time existing porcelain restorations are altered, the porcelain could chip and/or fracture. However it is my desire that Dr. ______________________ refinish and/or reshape the porcelain in/on my teeth in an attempt to help me obtain the functional and/or esthetic shapes I desire. In the event chipping or fracture occurs, I will not hold ____________, his staff or Legal Name of Practice liable; and it will be my personal responsibility to pay for replacement or repair as necessary.

I have also had the opportunity to ask and receive answers to all my questions regarding this treatment.

I have read the above and have discussed with Dr. _____________ and/or also his dental assistant the risks and treatment options available to me. I understand that dentistry is not an exact science and no guarantees can be made to me regarding this treatment. I hereby give my permission to proceed with alteration of my teeth and/or restorations.

Signed __________________________________ Date _____________

Witness / Dental Assistant _________________ Date _____________

Name and Address of Practice

Telephone and email address

forms/REG informed consent re altering existing restorations

Form 6-2 Informed consent altering of existing restorations.

Informed Consent Statement Regarding

Approval of Provisional Restorations ("Temporaries")

Patient name ____

Doctor ____

Dental assistant ____

This will serve to confirm that I have had the opportunity to evaluate the shape, form, size, and color of the temporary restorations that have been fabricated, and I approve of these provisional restorations and agree to proceed with fabrication of final restorations.

____

Patient date

____

Parent or guardian if patient is a minor date

____

Witness date

Name and Address of Practice

Telephone and email

forms/REG informed consent re temporaries

Form 6-3 Informed consent approval of provisional restorations.

lip line for esthetic purposes, subgingival margins can cause inflammation by shifting plaque subgingivally. However, many dentists continue to place porcelain laminates up to 0.5 mm subgingivally, although esthetics can be accomplished with porcelain margins ending at, rather than below, the free margin of the labial gingiva.[32] Excessively deep subgingival margins risk biologic width invasion that may require crown-lengthening surgery to correct.[33] This practice, however, must be balanced

ESTHETIC CONSENT TO SILVER FILLING AMALGAM REPLACEMENT WITH COMPOSITE RESIN

I consent to the removal and replacement of my existing silver amalgam fillings in teeth number__________, __________, and ___________, with new restorations consisting of ______________________.
restoration name

Doctor ________________________ has informed me of the following:
name

1. My existing amalgam fillings are sound and well functioning. If not replaced, my present amalgams will likely last a number of years.
2. Current scientific evidence has established the biologic safety of amalgams. Therefore, there is no necessity to replace my present amalgams for any medical or dental health reasons. I have been provided and read American Dental Association literature concerning amalgam safety.
3. Proposed new restorations are designed to esthetically resemble adjacent natural tooth structures. An ideal or perfect match is not guaranteed nor likely. Natural aging of adjacent tooth structure can darken or yellow over the years compared to the newly placed ceramic restorations, which may necessitate periodic replacement.
4. Replacement restorations are durable but not permanent. Plastic composite fillings may last approximately three to five years. Crowns or caps last on average between 10 and 15 years. Durability predictions represent statistical averages. Each individual's restorative longevity may vary depending upon a variety of factors, including, but not limited to each patient's intake of coffee, tobacco, and tea; oral hygiene, and frequency of professional maintenance visits.

*5. Replacement risks include, but are not limited to, root canal therapy in a small percentage of cases, pulp (nerve) exposure, cusp or enamel fracture and presence of deep stains from the older amalgam restoration being replaced.

6. Doctor has personally explained the risks and esthetic benefits of amalgam replacement, as well as the reasonable alternative of doing nothing with my present amalgams. Doctor has answered any of my questions concerning amalgam replacement.
7. I understand the above and consent to amalgam replacement solely for esthetic reasons.

Date ________________________ Patient _________________________ Witness ___________________________

Form 6-4 Consent form for replacement of amalgams.

against the risk of ending a margin at or just beneath the gingival margin where potential gingival shrinkage may allow a dark porcelain fused to metal margin to show. Porcelain veneers bonded to enamel can be durable for more than 16 years.[34] Compared to enamel bonding, dentin bonding lacks long-term durability and thus has reduced longevity. Consequently, porcelain veneer preparations, particularly in the gingival third, should avoid sensitive dentin exposure.

Another example of negligent customary substandard practice is prophylactic amalgam removal to prevent or treat systemic diseases. The mercury used in properly constructed dental amalgam restorations has not been established as a cause of any systemic diseases except in the few rare cases of mercury allergy confirmed by dermatological testing. The amalgam contains elemental mercury rather than the more toxic methyl (organic) mercury. Nine grams of mercury would have to be swallowed before the patient would suffer an acute toxic reaction. The amount of mercury vapor released from amalgam fillings in released air is far less than the accepted medically permissible dosage. The threshold limit value is 0.05 mg/m^3 of air for 8 hours a day for a total of 40 hours per week. Removal of existing amalgams contributes temporarily, but significantly, to mercury vapor in expired air; consequently, the possible exposure effects of amalgam removal, if any, prior to unnecessary replacement, mitigates against its prophylactic removal. Background mercury exposure also occurs daily from the environment and from ingested fluids.

The incidence of mercury allergy is rare, as evidenced by a Swedish study that identified only 82 cases in Sweden's entire health insurance program during a 12-year period for an incidence of 0.0012%.[31,35] If suspected, a dermatologist can verify allergy to common dental metals and also conduct blood and urine mercury testing. The American Dental Association (ADA) Mercury Testing Service recommends a thorough review of mercury hygiene habits if testing reveals levels above 50 µg of mercury per liter of urine. Prophylactic amalgam removal and replacement with composites or other restorative materials for systemic disease prevention is not scientifically justifiable. Amalgam replacement is indicated only if an existing restoration is dentally unsound or the patient requests replacement for esthetic reasons and preparations remain conservative without excessive stress-bearing occlusion. ADA Principles of Ethics and Code of Professional Conduct, revised April 2012, provides in pertinent part as follows:[36]

> 5.4.1 Dental Amalgam and other restorative Materials: Based on current scientific data, the ADA has determined that the removal of amalgam restorations from the non-allergic patient for the alleged purpose of removing toxic

Informed Consent Statement Regarding

Approval of Restorations

I approve of the color, shade, glaze, shape and size of the porcelain laminate(s) and/or crown(s) that have been fabricated for my teeth and wish to have them permanently cemented in my mouth. I approve of the restorations in every way. I understand that after they are cemented it will be impossible or difficult to change them without removal of tooth structure, damage to the restoration(s), discomfort, and additional expense. I have discussed this with Dr. John Smith and have had all my questions answered to my satisfaction prior to cementing the restorations.

____

Patient's name printed

____

Patient's signature date

____

Witness date

Name of Practice

Address of Practice

Telephone

Email

forms/REG approval of restorations

Form 6-5 Informed consent for approval of restorations.

> substances from the body, when such treatment is performed solely at the recommendation or suggestion of the dentist, is improper and unethical.

A patient consent to amalgam replacement for esthetic reasons is justified, but a systemic rationale is scientifically unjustifiable therapy. For replacement of amalgam fillings, the patient must sign a special consent form regarding amalgam replacement (see Form 6.4).

Guarantee or warranty

Esthetic dentistry is particularly vulnerable to claims of broken promises since patient expectation may not equate with dental realization, particularly if the dentist promises more than can reasonably be delivered. Dentist's statements such as "You will be as beautiful as a star" are tantamount to giving the patient a guarantee or warranty that the esthetic result will match the esthetics of a "Hollywood" smile.

The law does not require that the esthetic result match or meet the subjective and capricious esthetic standard of an *unreasonable patient* demanding esthetic perfection. The law measures an objective standard of satisfactory esthetics as judged by a *reasonable person* regardless of a patient's particular whim or perfectionistic desire. Nevertheless, *a dentist who foolishly guarantees a particular cosmetic result must satisfy the subjective esthetic whim of the patient*. Warranty, if proven, voids the usual rule of negligence law that a dentist is not a guarantor of a particular cosmetic result.[37,38]

To avoid a claim of warranty, a dentist should promise to do his or her best, even if the best may not ultimately satisfy the patient's arbitrary esthetic desire. No dentist using synthetic materials can exactly duplicate a natural tooth or cause it to age esthetically identical to the adjacent or opposing unrestored teeth. The patient should be provided a reasonable time to view the final restorations intraorally. The patient should sign the approval of restorations form prior to final cementation. See Form 6.5.

Patient esthetic perceptions

Dental esthetics is associated with a person's self-confidence. A patient's overall physical attractiveness may be correlated with career and social success.[39] Patients perceive factors that detract from an esthetic smile. However, patients are generally less critical esthetically than dentists.[40]

Some patient esthetic standards of acceptance follow:[40,41]

- A 3.0 mm maxillary midline deviation is near the threshold of esthetic acceptance. When made aware of midline deviations, patients prefer those that are coincident with each arch and the facial midline.
- Patients accept a discrepancy in gingival heights between central incisors of up to 2.0 mm, but prefer an absence of gingival height discrepancy. A 3.0 mm open embrasure (black triangle) between the maxillary central incisors is noticeable to patients. Unilateral alterations are more critical to patients than bilateral alterations.
- Gingival display esthetics is related intimately to the shape and position of the lips that frame the teeth and gingival tissues. Patients prefer no gingival display, with the upper lip height at the gingival margin of the maxillary central incisors. Patients nevertheless tolerate a range from 4.0 mm

of maxillary central incisor coverage to 3.6 mm of maxillary gingival display.

- Patients prefer smile arcs that are consonant with the contour of the lower lip rather than a "reverse" or "flat" appearance. Smile arc has a greater impact on esthetics than do buccal corridors. A flat smile arc decreases attractiveness ratings, regardless of the buccal corridors. Patients favor small or absent buccal corridors rather than broad toothy smiles. Extraction of premolars does not appear to predictably affect patients' perceptions of buccal corridors or dental esthetics. Thus, the number of teeth displayed is an important determinant in achieving dental attractiveness.

Patients have varying degrees of sensitivity to dental esthetics but with less critical requirements than dentists. Dentist's esthetics goals should conform to the patient's esthetic perceptions with pretreatment discussion in accordance with informed consent rather than blindly adhering to a dentist's ideal esthetics concept.

"I'm sorry" legal protection

Thirty-seven states in the United States have enacted "I'm sorry" laws that disallow health-care providers' apologies or statements of compassion as evidence of negligence or liability in malpractice cases. "I'm sorry" laws protect a dentist's statement conveying sympathy or compassion related to pain or suffering so that it cannot be used as evidence of admitting liability in a dental malpractice suit. These laws allow and encourage dentists to state to patients that they are sorry for an unwanted event or bad outcome without fear that these words will be construed in court as self-incrimination. The law does not apply to a statement of admitting negligence or fault that is part of or made in addition to a statement of feeling sorry for a negative outcome. In 2013, Pennsylvania was the most recent state to add "I'm sorry" legislation. Pennsylvania, Florida, and Nevada laws have mandates for written disclosures of adverse events/bad outcomes to patients and their families. Colorado is exceptional in that it also makes "admission of fault" inadmissible in the court of law. Under the Federal Rules of Evidence apologies are ordinarily admissible in civil court to prove liability. The language and scope of "I'm sorry" laws vary from state to state.[42] Thus, it is a good idea to investigate your own applicable law.

An upfront apology or expression of sympathy can relieve anger and frustration. This reduces the level of emotion and paves the way for an expedient resolution rather than lengthy and costly litigation. Patients do not usually sue because they are greedy, but instead because they want to know what went wrong and are seeking acknowledgment of the dentist's error. "I'm sorry" laws facilitate the continuation of the dentist–patient relationship following an adverse event. Concealing a mistake is a major genesis of litigation, particularly when a subsequent treating dentist reveals what the prior dentist previously concealed.

The American Medical Association Code of Medical Ethics, which sets forth the standards of professional conduct, states that when a patient suffers significant medical complications that may have resulted from the physician's mistake or judgment, the physician is ethically required to disclose to the patient all the facts necessary to ensure understanding of what has occurred. These guidelines also state that a physician's concern about legal liability that might result from full disclosure should not affect the physician's candid disclosure to the patient.[43–45]

The ADA Principles of Ethics and Code of Professional Conduct, revised April 2012, provide in pertinent parts as follows:[36]

> Section 5 Principle: Veracity ("Truthfulness"). The dentist has a duty to communicate truthfully.
>
> Dentist shall not represent the care being rendered to their patients in a false or misleading manner.
>
> Section 5.A. Representation of Care.
>
> This principle expresses the concept that professionals have a duty to be honest and trustworthy in their dealings with people. Under this principle, the dentist's primary obligations include respecting the position of trust inherent in the dentist-patient relationship, communicating truthfully and without deception, and maintaining intellectual integrity.

Prognosis and longevity

Prognostications on crown longevity should be based on average crown life expectancy rather than wishful optimism. Porcelain crown studies indicate a useful, functional life of 10 years.[46] However, esthetic longevity is less than functional longevity due to yellowing or darkening of adjacent and opposing teeth due to age and/or gingival recession over time. Esthetic crown life can range from 5 to 10 years.[47] Accordingly, the patient should be advised of this esthetic replacement expectation.

Porcelain fractures occur for many reasons, ranging from inadequate restorative preparation to extreme bruxism. If a fracture occurs, bonding repairs may be considered. Composites have a useful life of 3–8 years,[47] and so the patient should be advised.[32] Otherwise, the disappointed patient may sue, claiming a lack of informed consent and/or being warranted or promised a permanent restoration built to last an esthetic lifetime. Many dentists take advantage of the summary pages in *Change Your Smile*[47] after each esthetic treatment option outlining the advantages and disadvantages, range of restoration life expectancy, cost ranges, and maintenance required. If you give or lend this book to your patient, make a note in the chart which pages you advised the patient to read.

Try-in appointment

Consent should be obtained not only initially but also at the try-in appointment. Inquire in advance if the patient is trying to esthetically please someone else. Request that this person also be present at the try-in. Otherwise, the patient may leave appearing satisfied but quickly change his or her mind after a trusted friend or spouse criticizes the esthetics. At completion of the try-in, record in the patient's chart the patient's approval of fit, comfort,

Date	Service
3/31/2015	HX: NCR-pt has had a cold
	DX: Try-in lower partial
	TX: Tried in lower framework w/ wax bite rims. Bite adjusted in wax. Wax-up of teeth adjusted. Pt. approves shape and color of teeth and stated, "These look great. I really like them." Pt. advised teeth will be processed as he approved.
	AX: None
	CX: None
	RX: None
	FX: Rel /L partial; photos made of try-in

I accept the cosmetics, contour and position of the teeth as they appear today at the try-in visit.

Date ___________________________ Patient _________________________ Witness _______________________ Patient signature

HX: Health history
DX: Disposition—reason for this appointment
TX: Treatment narrative
AX: Anesthetic used
CX: Complications, problems, etc.
RX: Prescriptions given
FX: Follow-up—next appointment

Form 6-6 Try-in approval form.

and esthetics. Although not legally required, for difficult patients the chart entry may be initialed and witnessed on the chart itself or on a separate form (Form 6.6).

With the availability of newer materials, temporaries should not be esthetically inferior restorations. Although not as critical as the final try-in approval, the patient should see and approve the temporaries before leaving the office to avoid surprise or embarrassment when the patient views temporaries at home with their family. Whenever possible, the new concept of trial smile should be implemented. This will also help to ensure there will be less chance of misunderstanding about what you and your patient envisioned esthetically. See Chapter 3 for more information.

Complete dental records and documentation

Records "remember," but patients and dentists may forget. A patient-approved treatment plan should be signed and documented in the chart (Form 6.7). A patient follow-up letter constitutes additional documentation verifying the patient's consent to both the specific procedures and the costs of those procedures (Form 6.8). Such a letter is a permanent addendum to the patient's record, which may be introduced into evidence at trial as corroborating evidence. Juries trust written documentary evidence more than oral testimony since a short pen is more credible than a long memory, particularly if the record was made before any threat of litigation occurred. Therefore, avoid statements in the confirming letter to the patient that may imply any esthetic guarantee. For example, do not write a letter stating, "Following treatment, you will look 100% better and undoubtedly will get the sales position for which you recently interviewed." Instead, write "I will try my best to improve your smile and hope that you obtain the employment position you are seeking." The latter is a safe statement since the law obligates a dentist to always use the dentist's best clinical judgment in diagnosis and treatment.

Written records documenting clinical findings, diagnosis, treatment plan, and prognosis are the minimum that a dentist is obligated to maintain. Informed consent does not absolutely require written verification in the chart but is more credible than oral consent alone. The following statement documents that informed consent was provided if later disputed by the patient: "Patient advised on usual bonding risks including fracture, chipping and staining, and preventive maintenance measures." Video informed consent is admissible in court as part of the dentist's records (Form 6.9).

Dental records serve the following functions:

1. They document the course of the patient's dental disease and treatment (dental history, differential and final diagnosis, treatment plan, and treatment provided).
2. They document all communication among the treating dentist and other concurrent health-care providers, consultants, subsequent treating practitioners, and third-party carriers.
3. They serve as an official document in dental/legal matters (lawsuits), and, if properly maintained, will demonstrate a sound plan of dental planning and management.

Phase	Date Plan	Appt	Provider	Service		Tth	Surf	Fee	Ins.	Pat.
1	03/10/14		RG1	0925B	Lab Fee-#3&30			$1,650.00	$0.00	$1,650.00
1	03/10/14		RG1	D2392	Resin- 2 surf., post-permanent	2	DO	$782.00	$0.00	$782.00
1	03/10/14		RG1	D2740	Crown-porcelain/ceramic substr.	3		$3,295.00	$0.00	$3,295.00
1	03/10/14		RG1	D2950	Core buildup, includ any pins	3		$504.00	$0.00	$504.00
1	03/10/14		RG1	D2799	Crown-Provisional	3		$750.00	$0.00	$750.00
1	03/10/14		RG1	D2393	Resin-3 surf., post. permanent	4	MDB	$866.00	$0.00	$866.00
1	03/10/14		RG1	D2393	Resin-3 surf., post. permanent	28	MDB	$866.00	$0.00	$866.00
1	03/10/14		RG1	D2740	Crown-porcelain/ceramic substr.	30		$3,295.00	$0.00	$3,295.00
1	03/10/14		RG1	D2950	Core buildup, includ any pins	30		$504.00	$0.00	$504.00
1	03/10/14		RG1	D2799	Crown-Provisional	30		$750.00	$0.00	$750.00
					Subtotal For This Phase:			$13,262.00	$0.00	$13,262.00
2	03/10/14		RG1	0925B	Lab Fee-#19			$825.00	$0.00	$825.00
2	03/10/14		RG1	D2393	Resin-3 surf., post. permanent	12	MDB	$866.00	$0.00	$866.00
2	03/10/14		RG1	D2393	Resin-3 surf., post. permanent	15	DOB	$866.00	$0.00	$866.00
2	03/10/14		RG1	D2393	Resin-3 surf., post. permanent	18	BOL	$866.00	$0.00	$866.00
2	03/10/14		RG1	D2740	Crown-porcelain/ceramic substr.	19		$3,295.00	$0.00	$3,295.00
2	03/10/14		RG1	D2950	Core buildup, includ any pins	19		$504.00	$0.00	$504.00
2	03/10/14		RG1	D2799	Crown-Provisional	19		$750.00	$0.00	$750.00
2	03/10/14		RG1	D2393	Resin-3 surf., post. permanent	20	MDB	$866.00	$0.00	$866.00
					Subtotal For This Phase:			$8,838.00	$0.00	$8,838.00
3	03/10/14		RG1	D9940	Occlusal guard			$985.00	$0.00	$985.00
					Subtotal For This Phase:			$985.00	$0.00	$985.00
					Subtotal:			$23,085.00	$0.00	$23,085.00

Disclaimer: I realize that this is the proposed treatment plan and it may be revised due to clinical factors that may change as we progress. _____________

Total Proposed:	$23,085.00
Total Completed:	$0.00
Total Accepted:	$0.00
Proposed Insurance:	$0.00

I agree to pay 2 weeks In advance If treatment is over $3500. If treatment Is under $3500 I agree to pay for services as rendered. X______________

I understand and accept the treatment plan as proposed herein. I have had all of my questions answered and wish to begin treatment. Payment is due before services are rendered.

Patient or Guarantor's Signature ____Date________________

Form 6-7 Treatment plan approval form. Note the box in which the patient signs to acknowledge the cost of treatment and how it will be paid for.

4. The demonstrate conformity with peer review evaluation standards.
5. Photographic records documentation: with the advent of digital photography, there is little reason for not taking adequate close-up digital photographs of the patients' condition during the first appointment. This provides an excellent record of exactly how the patient appeared before any treatment is planned. Viewing these photos with the patient is more helpful than giving the patient a mirror to describe the patient's pretreatment esthetic dissatisfaction. Some patients

Date

Dear Patient:

It was a pleasure meeting you last week. As a follow-up to your initial consultation, I am enclosing a copy of the "Estimated Dental Treatment," which Dr. Ronald Goldstein recommended. Listed below is your treatment schedule.

First Appointment: The bleaching technician will perform an office bleach in your lower anteriors. A custom follow-up home bleaching appliance will be fabricated and instructions provided for further bleaching at home. During the first visit, which lasts approximately two hours, Dr. Smith will check the bleaching color achieved.

Second Appointment: All the upper teeth will be prepared for crowns (#2 through #15). A set of new temporaries or treatment splint will be constructed during this all-day visit, which includes initial cosmetic contouring or reshaping of the new crowns. Should endodontics (root canals) be required, the referred specialist or endodontist will advise you of such additional endodontic fee.

Third Appointment: Approximately two weeks later, a metal try-in appointment lasts about 21/2 hours in which the crowns' metal substructure are fit checked and then returned to the dental laboratory for porcelain baking. Final seating (cementing) visit is scheduled in two weeks.

Fourth Appointment: Final crowns are fitted and cemented in place. Cosmetic contouring on the lower anteriors is finalized and impressions for a nightguard taken. Please allow a full day for this appointment.

Follow-up Visit: Following the initial completion of your dental treatment, additional short visits are scheduled for any minor adjustments and to finalize the occlusion (bite) and check health of surrounding gum tissue.

If I can be of further assistance, please do not hesitate to call me.

Sincerely,

Form 6-8 Example of patient follow-up letter after initial consultation.

Name of Practice
Address of Practice

PERIODONTAL VIDEO INFORMED CONSENT

CERTIFICATION: I have viewed the video entitled "Periodontal Diagnosis and Treatment, Version 4.1." This video has aided my understanding of periodontal diagnosis and periodontal therapy.

John Smith, DDS, has encouraged me to ask any questions before proceeding, which I have done. Dr. Smith has answered any and all of my questions.

I agree to periodontal treatment with full and complete understanding of my options of nonsurgical, surgical care, and/or referral to a periodontist and elect;

______________________________ Non-surgical periodontal therapy only with Dr. Smith and staff

______________________________ Periodontal surgery by Dr. ____

______________________________ Non-surgical periodontal therapy, and after reevaluation, surgery as necessary by Dr. Smith

Date____________________Patient________________Witness____________________

Form 6-9 Video consent form.

may have very short memories of how they previously appeared. Pretreatment photos can save a great deal of mid- or posttreatment discussion of what the dentist may or may not have restoratively changed compared with pretreatment clinical appearances.

Chart documentation

Although patients may forget, a dental record remembers. If a dentist forgets, the dentist's records help remember. Erroneous entries should have a line drawn through the error and a corrected entry written above or below, indicating a later entry. Never block out or white out an entry so that it cannot be read, to avoid suspicion of falsified records. Entries can be made in ink, or pencil. If a pencil is used, avoid erasures which may suggest record alterations.

Spoliation is the legal tort name for altered, destroyed, or substituted dental records. In the United States, only Alabama, Alaska, Florida, Indiana, Kansas, Louisiana, Montana, New Mexico, Ohio, and West Virginia explicitly recognize an independent tort action for spoliation.[48] Nevertheless, the other states may issue evidentiary, monetary, or state board discipline for acts of spoliation.[49] Record spoliation adversely affects credibility and thus should be avoided. In Valdez v. Worth, D.DS., spoliation evidence included (a) spilled cola on the dentist's chart precluding expert questioned document examination, (b) destroyed models due to alleged mud on models from a flood, (c) defendant dentist's hygienist testified certain chart entries were added after her treatment, and (d) chart times were contrary to the plaintiff's phone records. The $641,441 crown and veneer award reflected a "pattern of prevarication" of an untruthful defendant.[50,51]

Electronic records

The Health Information Technology for Economic and Clinical Health Act of 2009 authorizes grants to promote "meaningful use" of electronic health records (EHRs). EHR systems permit computerized provider-order entry of medications to flag potential drug interactions, allergic reactions, errors, and safety alerts with respect to doses. EHRs have the potential to reduce injuries and malpractice claims.

Implementing new information systems may initially elevate, rather than decrease malpractice risks. Risk of error potentially increases during the implementation as dentists transfer from an existing familiar system to a new electronic format. Studies have documented increases in computer-related errors from incorrectly entering clinical data into the electronic record.[52] Effective training can minimize the incidence of such errors. Dentists have a duty to minimize such risks during the transition period from paper to electronic records.

EHRs hold considerable promise for preventing harmful errors and associated malpractice claims. EHRs promote complete documentation and timely access to patient information, facilitating sound treatment planning, decreasing transcription errors, and improving communication among treaters.[9,53] EHRs record all time stamps of computer data entries, called metadata. Metadata provide a permanent electronic footprint which can be used to track entry change activity. Under federal law, metadata are discoverable in civil trials.[54,55] State law, which governs most malpractice litigation, varies as to the discoverability and admissibility at trial of metadata.[56] Metadata can be used to authenticate the EHR and/or to verify that an EHR was modified at the time of treatment rather than belatedly. If the record was modified at a questionable time to deliberately alter records, metadata may prove record falsification.[54,55]

Some EHR systems prompt clinicians to document reasons for overriding clinically significant alerts. As the use of EHRS grows, failure to adopt an EHR system may constitute a deviation from the standard of care. Once a critical mass of providers adopts EHRs, other may need to follow. As the use of EHRs becomes commonplace, the legal standard of care will follow suit. Latecomers to the EHR standard may be subject to liability.

Example of chart documentation of informed consent

Date: 3/4/2015. Patient read pages concerning bonding in *Change Your Smile* (pp. 138, 145–150).[47] Patient fully understands pros and cons of partial coverage bonding and alternative of complete coverage crowning. Patient told doctor "You have answered all of my questions about bonding. I agree to bonding my upper six front teeth."

Signature at the end of chart entry by patient and witness is optimal but not mandatory. If patient does not sign, the assistant should initial to confirm what doctor told patient.

Complete dental records

A complete dental record should include the following:

- dental history to date
- medical history with current updates:
  - name and phone number of the patient's physician(s) and date of last medical examination
  - systemic diseases such as bleeding disorders, diabetes, hepatitis, rheumatic fever, and HIV
  - current drugs and dosages, length of time taken, and recent changes
  - allergies and drug sensitivities
  - cardiac abnormalities, current blood pressure, and pulse rate;
- chief complaints
- clinical examination findings
- diagnosis (including differential, if uncertain)
- treatment plan:
  - all signed consent forms and/or video consent, photographs shown to the patient during treatment explanations;
- present and/or future referrals
- progress notes
- completion notes
- cancelled or missed appointments and stated reasons
- emergency treatment
- patient concerns, dissatisfactions, and planned follow-up including potential referrals
- prescriptions (pharmacy and dental laboratory)
- financial records and ledger
- diagnostic quality radiographs.[3]

Standards of care versus reasonable patient standards

State laws vary regarding the duty of informed consent. Although each state requires that the patient be advised of the material risks of treatment, the variations among the states concern whether adequate disclosure pertains to what a reasonable patient may justifiably want to know, or what a reasonable dentist should disclose in accordance with standard of care practice.

In a lawsuit in those states that rely upon what a reasonable dentist should disclose, the duty of disclosure requires expert dentist testimony regarding the standard of practice concerning such material disclosures. On the other hand, in those states that determine informed consent from the perspective of the reasonable patient standard, it is for the jury to determine what a reasonable patient would wish to know irrespective of the customary practice of disclosure.[8] Thus, in states such as California or Wisconsin, where no expert testimony is mandated, the state would permit the jury to determine what a reasonable patient

Clinical case: Unnecessary crowning

In another example (Figure 6.1A–C), a patient alleged unnecessary crowning since he was not offered the alternative of bonding or bleaching.[59] These options should have been provided since treatment was done purely for esthetic rather than restorative reasons. Thus, even if the crowns were well constructed, the patient in such a case could still claim that he already suffered and would likely suffer future repetitive trauma from necessary crown removal, repreparation, and

Figure 6.1 **(A)** This 29-year-old man wanted esthetic treatment to lighten his natural tooth structure to match the two previously crowned left central and lateral incisors.

Figure 6.1 **(B)** After several more conservative consultations, including bonding, bleaching, and periodontal therapy, he chose a dentist who elected to crown all of his teeth. Note the extensive presence of periodontal disease.

Figure 6.1 **(C)** Unesthetic crowning. Note open margin.

replacement. Such replacement may be necessitated once every 10–15 years due to material wear but also every 5–10 years due to esthetic changes. Simple bonding or porcelain laminating with little or no tooth reduction represents a reasonable and preferred alternative in this case (Figure 6.1A–C). This case resulted in a jury verdict for $120,000, an expensive lesson for the dentist involved.

would expect the dentist to advise irrespective of how many or how few dentists do so.[8,37,57,58]

For instance, internal bleaching of nonvital teeth occasionally results in external root resorption. In the states requiring expert testimony, the patient would lose the suit unless an expert witness testified that the standard of practice among reasonably careful dentists is to advise the patient of the statistically small but recognized risk of external root resorption.

Nonnegligent risks and obligation to treat

Although a nonnegligent risk may occur despite the best of care, a dentist is nonetheless legally obligated to reasonably prevent, reduce, and subsequently minimize the risk once it becomes clinically apparent. Because external root resorption is known to be an associated risk of bleaching, the dentist should take periodic diagnostic-quality periapical radiographs to check for early root resorption and take appropriate action to arrest the condition if and when it first appears (see Figure 6.5). Calcium hydroxide therapy may remineralize bleach-associated external root resorption or arrest its progress if treated early. Also, a rubber dam can help prevent bleach injury to exposed root dentin.[60]

Bleaching precautions

- Use of rubber dam when using high-concentration bleaching solution to reduce gingival and pulpal irritation.[61]
- Minimum necessary bleaching times and temperatures to preserve pulpal vitality.[61]
- Avoidance of abrasive bleaching techniques that expose dentin, particularly in cervical areas where the enamel is thinnest. Be aware that the enamel does not actually meet the cementum in 10% of teeth.[62]
- Avoidance of cervical area bleaching of nonvital teeth. If bleaching is required, place a base over the endodontic fill to the level of the epithelial attachment, followed by placement of a calcium hydroxide paste into the canal for several days after bleaching.[63]

Orthodontic root resorption

Root resorption resulting from orthodontic treatment is another example of a nonnegligent risk of treatment being changed from merely a duty of informed consent disclosure to that of active intervention. Root shortening and its associated risk of premature loosening or loss of teeth occurs predictably with teeth that have already undergone some degree of root resorption prior to orthodontic therapy or in teeth with existing blunted roots. During orthodontic treatment, periodically the dentist should radiographically monitor the patient for development of any progressive root resorption. Once discovered, orthodontic treatment can be halted, a rest period of 3 months from active movement initiated, or the degree of attempted correction of the occlusion compromised to prevent or minimize any additional root resorption. On the other hand, Invisalign orthodontics virtually eliminate root resorption risks. Monitoring delayed eruption of permanent cuspids includes panorex and/or cone beam computed tomography (CBCT) to diagnose if ectopic canines are causing root resorption collision of adjacent laterals.

Misinformed consent

Misinformed consent is misrepresentation of treatment risks. For instance, advising a patient that full mouth extractions for implants are necessary since teeth will soon be lost anyway is a false and misleading representation if the remaining teeth are reasonably sound in tooth structure and periodontal support. Natural teeth have a longer longevity than implants.[64] Similarly, recommending prophylactic endodontics for restorative treatment is contraindicated in the absence of endodontic pathosis. However, if you anticipate likely pulp exposure, be sure to warn the patient before restoration preparation. Many clinically well-documented oral implant systems may be abandoned for the potential benefit of new, but untested devices. Some oral implant systems are introduced clinically without adequate clinical research. Implant informed consent forms should include the risk of failure, non-osseointegration, and implant segment fractures such as the screw or implant body. Advise that if the implant requires removal, a new implant replacement may be considered.

Who has responsibility for informed consent?

It is the responsibility of the dentist to obtain informed consent. An assistant may give the consent form to the patient and ask the patient to review the form. However, the dentist must personally review the relevant information with the patient and offer to answer any patient questions. Assistants may supplement information with patient discussion but not substitute entirely for the dentist's diagnosis of the informed consent's ABCs. Thus, informed discussion is a nondelegable duty, because only the dentist is licensed and possesses the educational training to respond to the patient's questions.

If the patient is a competent adult, it is enough to proceed with the patient alone. Complications arise, however, when the patient is a child, mentally incompetent, or not fluent in the dentist's own language. For patients who are minors, consent should be obtained from a parent or guardian. Generally, individuals younger than 18 years are considered minors, although, consent age law varies from state to state. Prudent practice for a teenage patient is to obtain consent from both the patient and the parent or guardian. If a family member is present during the informed consent discussion, note the name on the chart and have the family witness also sign the informed consent form as an additional witness. If the patient does not speak or understand English, or the dentist's native language, an assistant or family member who speaks this language can act as an interpreter. Consent forms translated into the patient's own language are preferable. A suggested introduction for an informed consent form is given below.

"I want you to understand not only what I plan to do, but also what follow-up care will be necessary. After I finish the explanation, I will ask you to sign a document which indicates that you agree to the proposed treatment. Sign the form only if you are comfortable with the recommended treatment and understand the alternatives, benefits and potential complications. Before signing, please feel free to ask me any questions that you have about the treatment procedure."

Patient's right of privacy and confidentiality

Dentists may use patient photos for teaching, research, or promotional materials and advertising. The Federal Health Insurance Portability and Accountability Act requires the patient's written authorization for photos to be used for any of these purposes. The patient's right of privacy and confidentiality of the dentist–patient relationship is violated unless the patient consents to disclosure and publication of patient photos.[65]

Doctor–patient relationship

Would you rather be liked or respected by patients? The typical dentist's answer to this question is "I want both! I want to be both liked and respected. In fact, I want to be loved and respected." But there are times that the patient will make a request that places you in a position of making a tough choice between being liked and respected.

Practice principles are paramount. Do not compromise the standard of care or dental care ethics. Patients who respect you as a dentist with principles will usually like the dentist for taking a firm stand. In turn, they will refer patients who appreciate a dentist who refuses to compromise quality. A patient should not be offered treatment choices that are negligently designed. On the other hand, the dentist should refuse a patient's request for negligent treatment. The patient must then respect the dentist's refusal to compromise the dentist's principles.

If patients do not respect the dentist's judgment, they will be less compliant with recommendations. A positive doctor–patient relationship is an integral part of treatment. Patients who like you will be more likely to return for recommended tests and follow your treatment recommendations. Anonymous dentist rating websites encourage disgruntled patients to post their displeasure of dentists they dislike. Patients are less likely to sue dentists whom they like. Patients who like you build rapport and trust your judgment.

Dentists should strive to base treatment planning on evidence-based science and not primarily on what is the most profitable treatment plan. When patients demand quick fixes that compromise the dentist's best judgment, the dentist should not succumb to patient-dictated substandard treatment options. The entire dental team should be educated to explain to patients why your recommended course of treatment, maintenance, and at-home regimen is the preferred option for achieving not only esthetics but also optimal dental health.

Nonconsent or consent for less invasive procedures

To avoid a patient's claim that treatment was unconsented and/or consent was given for a less invasive procedure, follow these suggested steps:

- Ask the patient to explain what procedure is being performed that day.
- Provide a mirror and ask the patient to point to which of their own teeth are being restored.
- Show the patient that their informed consent forms match exactly what the patient stated and pointed out regarding which specific teeth are being restored.
- Use demonstrative models or photos to show how the patient will appear after teeth preparation both with and without temporization.
- Ask the patient if they have any questions and answer each in lay language.
- Document in the chart: time out[66] was provided and staff witnessed.

Dentist's right to refuse treatment

A dentist has the legal right to refuse to treat anyone, except for reasons of race, religion, disability, or abandonment in midtreatment.[67] A demanding patient may attempt to convince you to treat, despite your misgivings, by appealing to your vanity. Despite the patient's praise, the patient's needs may be unique, special, or so demanding that the patient would be better served by a dentist who can spare the additional time necessary to satisfy the patient's exceptional esthetic demands. Although it might temporarily feed one's ego to hear a patient's flattery and confidence in your skills, you may be sorry when their unrealistic esthetic expectations are unmet.

Accordingly, be suspect of the patient whose dental history includes complaints that other well-qualified dentists failed to satisfy the patient's esthetic needs. Notwithstanding your exceptional reputation, skills, and experience, you will likely not succeed if other competent dentists have failed.

Patient abandonment claims

Collective dental wisdom teaches that a patient may not be satisfied with esthetic dentistry if a payment balance is still owing. Therefore, it is sound practice management and legally permissible to demand payment in full initially or before completion. However, a dentist cannot avoid completion, once begun, even though a balance is due, without risking a lawsuit for patient abandonment.

Reasonable temporization and periodic restorative maintenance until the balance is paid may represent a prudent measure to prevent a lawsuit for abandonment if the patient has temporary financial difficulties but wishes to continue treatment.

Right of a patient to choose a dentist

A patient has the right to decide on a dentist of his or her own choice. This right usually involves selecting the best available dentist skilled in cosmetic procedures. However, insurance companies and managed care plans will generally attempt to provide, instead, the most economical choice. The following case demonstrates that courts allow patients to exercise their right to select a dentist.

A 19-year-old woman was a front-seat passenger in a vehicle that was struck broadside when it turned in front of another vehicle (Figure 6.2A–F). The jury found both drivers were

Figure 6.2 **(A)** This 19-year-old accident victim presented with emergency splinting material previously applied by her attending oral surgeon.

Figure 6.2 **(B)** Displaced teeth and incisal fractures are seen after splinting material was removed.

Figure 6.2 **(C)** A recent photograph was used as a model to mold and carve the patient's teeth when rebuilding her teeth during first direct bonding stage.

Figure 6.2 **(D)** Result following the first stage of direct bonding.

Figure 6.2 **(E)** Patient's orthodontist provided a photograph of the patient following his successful orthodontic treatment only 10 months prior to the accident.

Figure 6.2 **(F)** Final picture of the patient's smile following second - stage treatment with porcelain laminate veneers.

responsible for the collision and compensated the passenger victim for her pain, suffering, and hospital and medical expenses associated with her injuries. The jury's verdict of $90,000 also compensated her for future costs associated with maintenance of her restored teeth, including periodic replacement of laminate veneers over her lifetime.

The following were legal implications from this case:

- it admitted into evidence the plaintiff's orthodontic post-treatment photographs to prove the virtually ideal esthetic condition of the patient's teeth before the accident
- it recognized the value of conservative dental treatment such as the use of porcelain laminates
- it confirmed the right of the accident victim to choose a dentist with greater expertise and higher fees than the lesser-skilled dentists in her insurance plan
- it awarded a sufficient amount of compensation to periodically re-treat or maintain restored teeth for the victim's lifetime.

Refunds

Maloccurrence does not alone prove malpractice.[37] An unsatisfactory result may on occasion occur despite the best of care. On the other hand, an untoward complication or bad result may be caused by the dentist's negligent error or omission. For example, overcontoured restorations and/or with open or submargins violate the standard of care and should be returned to the lab to be remade rather than using them in cementation. It is good patient relations to redo or correct unesthetic restorations without additional charge to a patient. For instance, chipping or fractures occurring within 1 or 2 years of completion should be considered for remake without charge. If the dentist concludes that a patient likely will not be satisfied, esthetically or otherwise, a refund is not an admission of fault. Rather, it is an admission of mutual frustration. Both dentist and patient would be better served with selection of a new dentist. A dentist is entitled to a fee for reasonable esthetic attempts to satisfy a patient. A refund and releasing the patient to another dentist might be the better choice and less expensive in the long run if you feel this patient will never be satisfied and will be constantly asking for more retreatments.

Settlement offers are usually inadmissible in court,[68] whereas admissions of fault are admissible. To avoid the appearance of an admission of guilty negligence, the dentist may write on the refund check "Refund settlement" or draft a release (Form 6.10), which the patient should sign at the time of refund. A recent California case held that unless with a refund the dentist also advises the patient of the applicable statute of limitations, the statute of limitations may be tolled.[69]

Examples of esthetic malpractice cases

Case 1: overcontoured crowns

A 45-year-old woman wanted to improve her smile. Neither bonding nor orthodontics was offered as alternatives to crowning. Overcontoured crowns contributed to periodontal disease. Her appearance after the necessary periodontal surgery was unesthetic due to the continued existence of the original crowns and the newly exposed crown margins and roots (Figure 6.3A and B). See also Figure 6.3C and D.

RELEASE OF ALL CLAIMS

______________________________, in consideration of $ ______________________________, hereby acknowledges as received, does release ______________________________, DDS, his agents, and/or employees, and all other persons or corporations of and from any and every claim, right, liability, and/or causes of action of whatever kind or nature the undersigned has, or may hereafter have, whether known or unknown, arising out of, or in any way connected with, the dental care and treatment of ______________________________, including any act or omission of ______________________________, DDS, his agents and/or employeees.

It is likely that future harm or injury may occur. This release is intended to cover and does cover all present and any and all further claims against ______________________________, DDS, his agents, corporations, and/ or employees, who are finally and forever compromised, settled, and discharged.

The undersigned acknowledges that ______________________________, DDS, denies any liability but has agreed to the terms of the release to buy peace and resolve all differences between dentist and the undersigned patient.

Date ________________________________

Patient' signature ____________________

Witness _____________________________

Form 6-10 Release of all Future Claims with refund settlement check.

Figure 6.3 **(A)** Crowns prior to periodontal surgery.

Figure 6.3 **(B)** Postperiodontal surgery. Note grossly open margins.

Case 2: overbuilt laminates

A young model sought to improve her smile. The dentist suggested porcelain laminates to improve the shape and color of her teeth (Figure 6.4A). Unfortunately, the dentist overbuilt the laminates with a resulting bulky look that destroyed her original smile's attractiveness (Figure 6.4B). A new dentist reconstructed porcelain laminates that provided the esthetics that the woman sought. Dentists have an obligation to provide esthetic enhancement to their patients upon request if reasonably attainable. At the very least, patients should not be restored in an esthetically inferior way or appear worse than when first presented.

Case 3: external root resorption with bleaching

Figure 6.5 is a California case in which the dentist was unaware of the risk of external root resorption associated with bleaching endodontically treated teeth and failed to disclose such a risk to the patient despite the literature discussing such risks. The manufacturer of the bleaching agent was also a defendant in the lawsuit for inadequately disclosing root resorption risks in the product information provided with its product. Root resorption is usually avoidable by retaining endodontic root obturation fill to the cement–enamel junction.

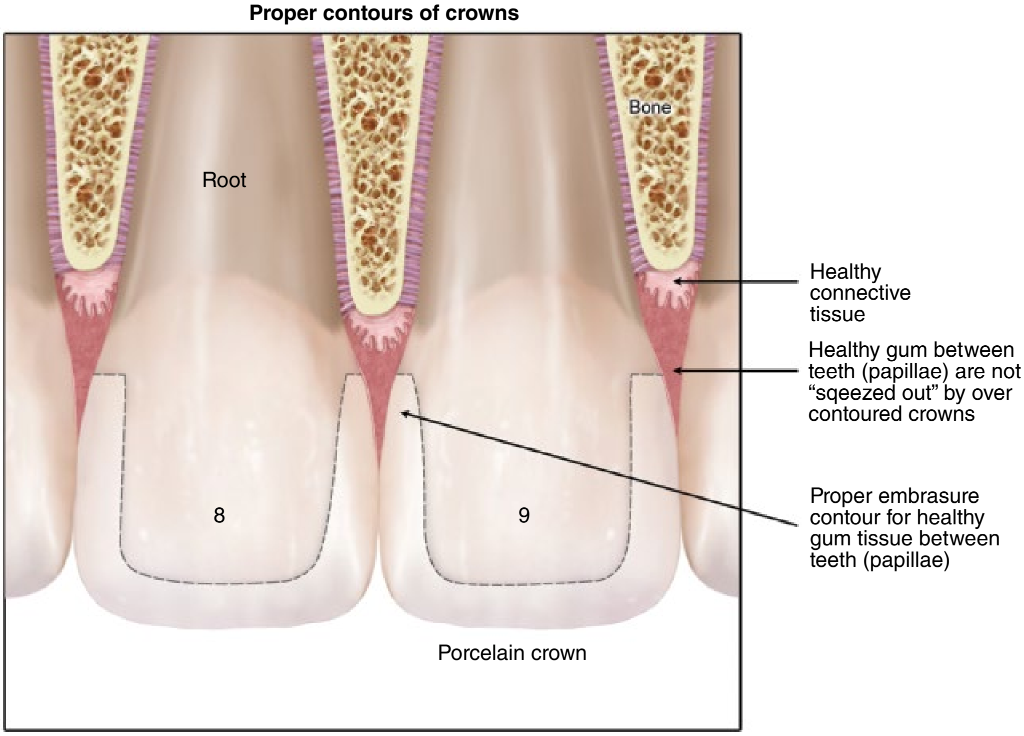

Figure 6.3 **(C)** Proper contours of crowns.

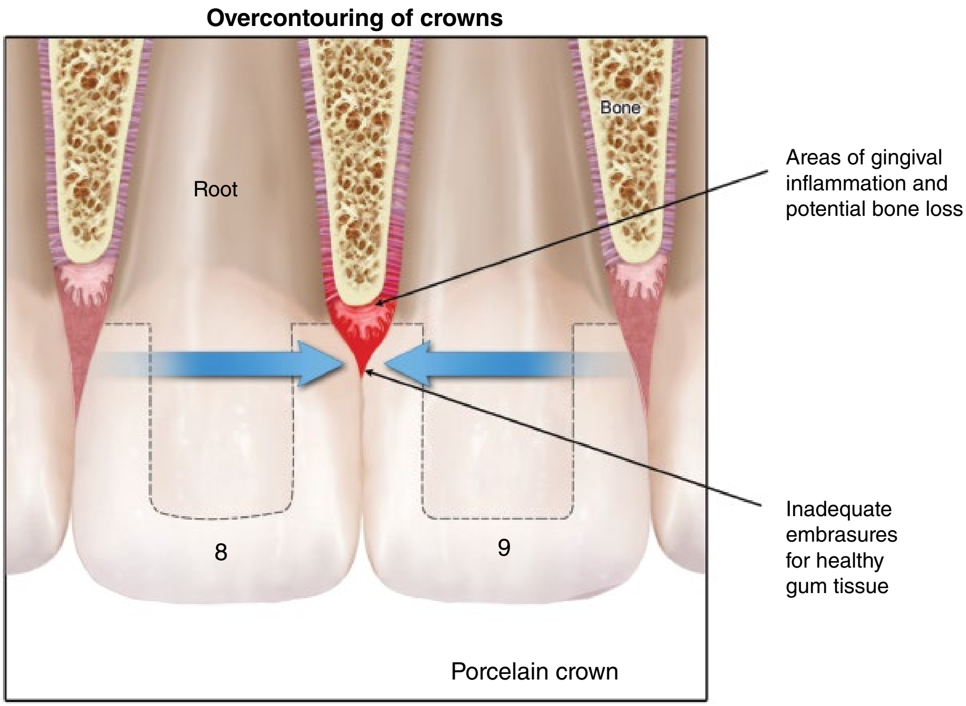

Figure 6.3 **(D)** Overcontouring of crowns.

Case 4: excessive laser sculpting

Biologic width invasion causation commonly is caused from direct invasion with restorative marginal placement into the epithelial or connective tissue attachment.[33,70] On the other hand, if gingival tissues are laser sculpted excessively, subsequent gingival healing re-establishes the former biological width causing biologic width invasion with resultant gingival inflammation. A California general dentist advertised that she strived for perfection in performing her cosmetic dentistry. The patient's chief complaint was her discolored tooth #9 and a gummy smile. Figure 6.6A is preoperative photo.

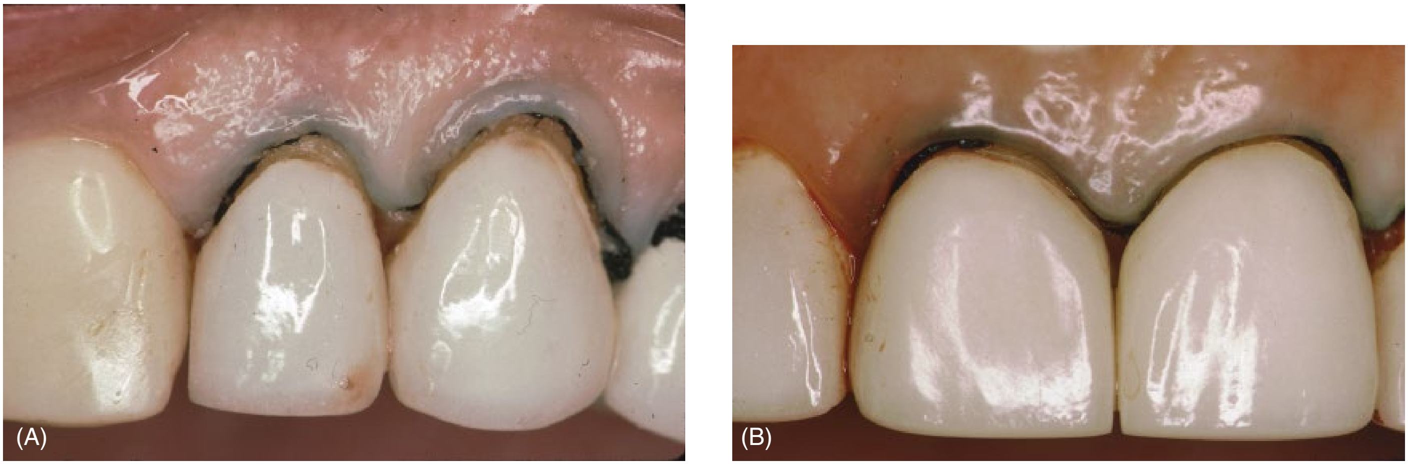

Figure 6.4 **(A and B)** Cotton displacement cord packed into the gingival sulcus to illustrate defective margins.

Figure 6.5 Postbleaching external root resorption.

The defendant dentist claimed she performed laser sculpting with minimal gingival reduction during the preparation of veneers from #5 to #12. Twenty-three restorations were prepared and temporized in 2 h 40 min under intravenous sedation to achieve an improved smile. Figure 6.6B demonstrates biological width adjacent to porcelain, rather than epithelial and connective tissue attached to root surfaces, causing iatrogenic gingivitis. Resultant gingival inflammation and ulceration required crown lengthening surgery to re-establish a healthy gingival complex.

A judgment of $641,441 was satisfied,[50] which included fees for future veneer replacements for lower anteriors since the option of noninvasive bleaching and Invisalign was not offered. Instead, the dentist only recommended and performed invasive mandibular anterior veneers.

Telephone or e-mail consultation

Offering advice without conducting an examination increases the risk of an erroneous diagnostic or treatment decision. Courts have held that telephone communications between a dentist and a patient can be sufficient to establish a dentist–patient relationship necessary for malpractice liability. It may even constitute negligence to e-mail advice to a patient who was never examined rather than be examined in person. E-mails may create a written documented record of negligent advice. On the other hand, e-mails may help prevent adverse events by allowing a patient to express clinically significant concerns that the patient does not believe warrant an office visit so that the dentist may offer suggested home care, specialist referral, or stat reappointment.

E-mails that are answered with boilerplate language from staff members, or otherwise unresponsive to patients' concerns, are likely to provoke patient dissatisfaction. Failing to respond to patient e-mails within a reasonable period of time could constitute a violation of the standard of care. Conversely, dentists who are highly responsive to patient e-mails may strengthen the dentist–patient relationship. Research has linked a propensity to sue with patients' satisfaction with their dentists and the dentist's communication skills. Dentists should establish a protocol for e-mails before initiating an e-mail relationship. Also, dentists should notify patients of these guidelines and obtain informed consent for the use of electronic communications.

Federal requirements and product warnings

Under federal law, the OSHA requires manufacturers to supply material safety data sheets concerning their products. If not given with the product at the time of sale, it must be available from the manufacturer upon request.

The Hazard Communication Standard (HCS) requires chemical manufacturers, distributors, or importers to provide Safety Data Sheets (SDSs) (formerly known as Material Safety Data Sheets or MSDSs) to communicate the hazards of hazardous chemical products.

Product liability suits require that the patient who is injured prove a product defect. Once proven, the product manufacturer is strictly liable even in the absence of any proven negligent design or manufacturing process. Product design defect includes failure of the manufacturer to warn of likely injury risks associated with product use.

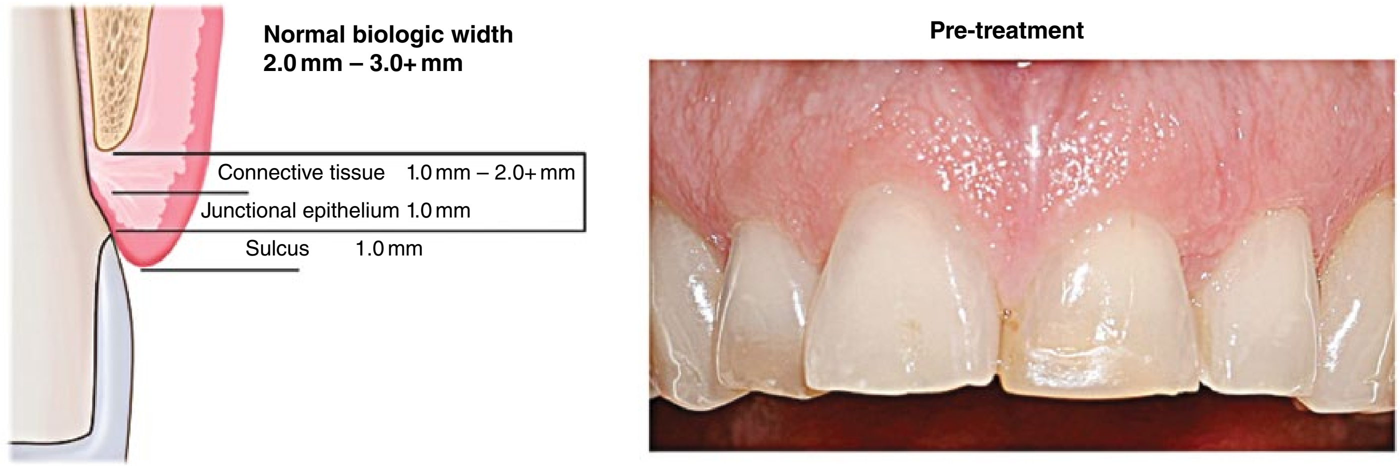

Figure 6.6 **(A)** Normal biological width.

Figure 6.6 **(B)** Gingival inflammation of biologic width invasion resulting from failure to wait for laser sculpting to heal before veneer preparations.

Botox

Approximately 21 states allow dentists to use Botox. Many states require at least 16 hours of training to use Botox. A Massachusetts dentist was disciplined for unauthorized use of Botox and inadequate sterilization procedures.[71] Under the Massachusetts board's rules, only certified oral and maxillofacial surgeons who have been trained in the use of Botox and dermal fillers can use Botox for the treatment of "disease, disfigurement, or dysfunction." Dentists who provide Botox should possess adequate training and comply with their respective state dental board requirements for Botox training and administration.

Jury trials

Esthetics may be in the eye of the beholder. However, in a civil trial, both the dentist and patient are beholden to the jury. A reasonably careful dentist has little to fear and much to appreciate with juries who are generally fair minded in rendering a verdict. The runaway verdict is mostly mythical and rare since judges and appellate courts reduce or reverse such verdicts exercising their sound judicial wisdom. A fair trial requires expert witnesses who are not biased or disregard contrary evidence-based research.[57]

Conclusion

Here is a summary of malpractice prophylaxis meaures.

1. Suggest that your patient read your cosmetic dentistry literature, which provides a list of the limitations as well as advantages of the proposed esthetic treatment. An excellent example of this would be a specific chapter in *Change Your Smile*[47] that the patient acknowledged having read, and had all his or her questions answered. The note might read as follows: "Patient read and discussed Chapter X in *Change Your Smile* with the doctor. All patient questions answered and patient consented to treatment of teeth # ___ and #___ with ________ (restoration)".
2. Educate your patients about their esthetic problems as well as any potential complications that may occur during treatment. Give alternatives or choices of treatment for each problem explaining risks and benefits of each alternative. Communicate verbally the limitations of each proposed treatment. Consider supplementing this verbal consent with a written consent form.
3. Forecast an accurate range of restoration life expectancy, both esthetically and functionally.

4. Following the consultation, write a treatment plan letter to the patient confirming your findings and plans.
5. Do not promise to satisfy the patient's esthetic demands. Rather, state you will work hard to do your best in an attempt to please the patient, although there are no guarantees of success.
6. Provide good-looking and well-fitting temporaries to fulfil your patient's esthetic desires. Make sure the color, form, fit, and tissue compatibility are acceptable.
7. Obtain and record the patient's approval at the try-in appointment before placing any final restoration. Ask questions at the try-in stage, such as "Do you see anything else you wish to be changed before we place the final glaze or polish?"
8. Determine if there is anyone else whose opinion the patient values, and, if so, include that person at the try-in appointment. It is most helpful and a valuable source of psychological reinforcement to have the patient's spouse, family member, or friend present at this appointment to offer suggestions and aid the dentist in obtaining the final approval.
9. Observe gingival healing following your treatment. At the postoperative examination verify removal of all cement, absence of overhangs, and that all surrounding gingival tissues are healthy. If not, continue to see the patient until tissue health is restored. Correct all deficiencies. Re-emphasize oral hygiene measures necessary to maintain the esthetic restorations. Record your recommendations legibly in the patient's chart.
10. If the patient fails to return, telephone to make sure there is no problem. Most patient dissatisfaction can be eliminated or eased with good communication between the dentist and the patient, even in instances of evident dental negligence. Patients are more likely to sue an uncaring dentist than a perceived friend.
11. If the patient expresses dissatisfaction, suggest that he or she return to the office to attempt to solve the problem. If the patient refuses, again be helpful in letting the patient know that you have done your best, would be happy to refer him or her to another dentist for further treatment or consultation, and would be willing to discuss the matter with any other dentist of the patient's choice, or consider paying for another dentist's corrective care upon receipt of a treatment estimate. Your general liability policy, usually included with the professional liability policy, typically pays $5000 or more for any "accident" under the medical benefits portion of the policy. This can be applied to the corrective care fee of another healthcare provider.
12. Plan a potentially difficult patient's treatment plan in stages. For example, the first stage is the temporization phase, and you should quote a fee for just this service. This fee will take into consideration approximately how many hours it may take to satisfy your patient's reasonable esthetic demands for temporaries. If initial esthetic success is unattainable, the patient has the option of being referred elsewhere. The patient's only obligation is the fee charged for performing stage one, already paid in advance.
13. Legal abandonment does not result if the patient is notified of the termination of the dentist–patient relationship, is given ample opportunity to find another dentist, and the termination does not jeopardize the patient's dental health. Thus if both the dentist and patient agree that the final restorations will be completed with another dentist, no legal abandonment occurs. Offer to transfer patient models and records to the new dentist and to care for the patient's emergencies for 30 days until the transfer is complete.

The only guarantee for esthetic dentistry is to do your best rather than guarantee or warrant a specific esthetic result. Keeping current with continuing education courses in esthetic dentistry optimizes the outcome for successful esthetic restorations and surrounding tissues.

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Nikon

Chapter 7 Practical Clinical Photography

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For years, dentists have struggled to find effective ways to communicate with patients about treatment. Many dentists have fumbled with an articulator while discussing treatment needs with a wide-eyed patient. Bracket tray covers have served as canvases for the charcoal drawings of clinicians trying to explain a procedure to a disengaged patient. The most technologically savvy dentists would project a slide on a viewer in a somewhat scary approximation to a family vacation gone wrong. No matter the medium used, dentists have continuously encountered difficulty helping patients better understand their current conditions and dental needs.

Clinical photography helped to close the communication gap; however, film and slides were not without their problems. The time necessary for the developing process often delayed the treatment planning phase, and errors in taking pictures didn't show up until the processed images were viewed at a later date. Often, faulty shots were not able to be retaken because treatment may have already been finished by the time the images were

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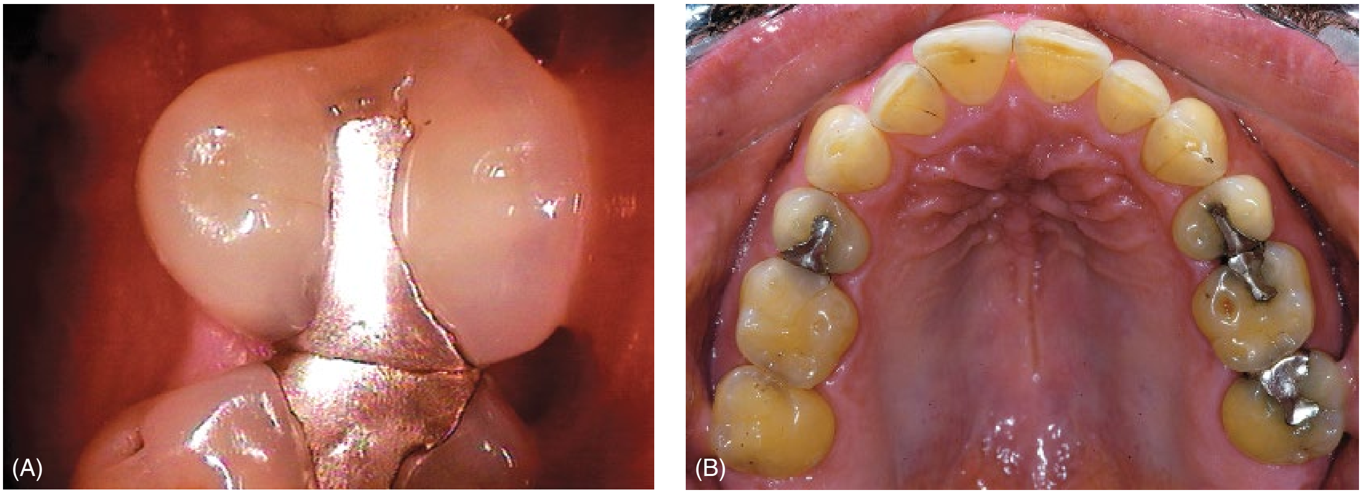

Figure 7.1 **(A and B)** Notice the different fields of view of the same teeth when viewed through a wand-like camera (A) versus a single-lens reflex (SLR) camera. Wand-like cameras, though simple to use, may detract from a patient's ability to understand how one tooth fits into the bigger picture.

returned from the lab. The clinician got one chance to master lighting and composition while photographing clinical procedures. Too dark or too light, out of focus or damaged film, the images of surgical procedures or restorative techniques could not be retaken. Although film cameras had drawbacks, until recently they were the only choices that dentistry had. One could choose the speed of the film and slide versus prints and could even choose a brand that suited their color preferences; however, the applications were limited. Dentists often had to convert slides to prints to communicate with the patients. Printed 8×10 blowups of clinical images, superimposed with tracing paper, were often the best way to demonstrate proposed outcomes. The return on investment for the time spent getting images ready for presentation often wasn't worth it. That is, until the advent of digital photography.

Early digital cameras for clinical use were large and expensive pieces of equipment whose quality rarely rivaled that of film. First-generation digital cameras were fickle, and their images were almost always recognizable as being taken with a digital camera. Color saturation was often far off, and the screens on the back of the camera almost required superhuman vision to discern the subject matter being photographed. However, these digital behemoths did afford one major luxury that even the finest film camera could not match: they allowed instantaneous viewing and processing of an image. Finally, a clinician could capture an image and retake it if any aspect didn't meet expectations. Images could be transferred quickly and easily from the camera to a computer and quickly printed out for patient viewing or to accompany a laboratory prescription. Sure, the images were of lower resolution, and the cost of such technology made it a difficult leap for the average dentist, but even with its limitations early digital photography showed promise of a new world of communication for the dentist with patients, technicians, insurance companies, and colleagues.

Of course, "wand-like" digital cameras had been around, but these limited-field cameras, often with "fish eye" lenses, were limited in their application. Although excellent for tooth-by-tooth demonstrations for patients and insurance documentation, the small fields of view (Figure 7.1A and B) hampered dentist's abilities to discuss comprehensive treatment plans or collaborate for interdisciplinary treatment planning. The new generation of digital "35 mm-like" cameras allowed full arches and portrait images to be captured without distortion and in their entirety, albeit with odd colorations, touchy mechanics, and a "digitized" look and feel. Thankfully, subsequent generations of digital cameras improved upon the early models. They became more rugged and less expensive, offered higher resolution, and began to rival, and ultimately surpass, the quality found in traditional films. Suddenly, dentists found a predictable, cost-effective, instantaneous way to document cases and present treatment options to patients, and a whole new world opened up to them.

Why take clinical images at all?

Whether collaborating between colleagues or presenting treatment options to a patient, a well-composed set of clinical images is the most valuable tool in the dentist's office. Nonetheless, there are numerous reasons why one would want to capture images in other situations as well. Clinical images are the best way to document any condition or treatment. One can observe a hard- or soft-tissue lesion and follow it over time through the proper use of images. In addition, one can take images throughout the course of treatment to teach other dentists how to perform a procedure. Another good reason to capture images is to provide a solid means of legal documentation of every case. Time and again, clinicians have found themselves in cases that could have been easily dismissed had preoperative images been available. Of course, practicing defensively is not a fun way to run a clinical practice; however, if the images are already being used for other purposes, isn't an ancillary use as legal protection a nice benefit?

When to take images

Imagine a patient who requires a considerable amount of dentistry involving several specialists and a treatment plan that could take years to complete. Of course, in a case like this, one would consider taking a comprehensive set of images before treatment planning and presenting the case to the patient. However, at what other times should images be taken, and why?

The aforementioned case is an obvious situation where images could help a dentist and patient agree upon a treatment plan and for collaborating dentists to agree upon a treatment sequence and roles. Unfortunately, even in extensive interdisciplinary cases, many dentists take that first set of images and stop there. They view the images as simply "a means to an end." In other words, the images are seen as a way to increase case acceptance and design a treatment plan, but not more than that. Often, clinicians learn best by looking at cases that have been treated, including steps along the way, to objectively evaluate how to best treat future cases. Any dentist who has looked at their cases after completion can affirm that it is a humbling experience, but one that leads to phenomenal clinical growth. Ultimately, it is up to the dentist's discretion when to take images; however, when in doubt, consider capturing images. One can always ignore images that have been taken, but can never go back in time to document a case that wasn't photographed.

Clinical applications for images

One can obviously use images as a part of the diagnostic workflow or as a part of the treatment planning process; however, there are numerous applications aside from those already mentioned. Included are case documentation, laboratory communication, patient education, and dental education.

Case documentation

Case documentation is an excellent reason to take images. Documenting a patient's initial presentation is a great way to be able to reference back to the beginning of a case at any time. If one has questions about the patient's initial tooth position or lip support related to the overall esthetics of the case, one need to only look back at the original images. Furthermore, documenting initial presentations in cases where there may be unrealistic patient expectations can assist dentists in avoiding difficult misunderstandings later in treatment. There is no substitute for color images of the original condition when it comes to referencing the initial presentation of the patient. Another aspect of case documentation is the photographic documentation of undiagnosed conditions. For instance, soft tissue pathology or "odd" presentations of any kind may be followed for extended periods of time through the judicious use of serial images.

Laboratory communication

Images play a vital role in the successful outcome of any esthetic case, but not for the reasons that most clinicians think. Although shade match is by far the most thought-of reason for taking images, other reasons for taking images include representation of form, shape, surface texture, and other aspects of the hard and soft tissue worth presenting to the laboratory technician (Figure 7.2).

Figure 7.2 Well-composed clinical images allow exceptional communication between all members of the team. Nuances including tooth shape, form, translucency, color, and texture can be well represented in a properly composed image.

In terms of shade matching, there is an extremely broad topic. Although high-quality digital single-lens reflex (SLR) cameras can do an adequate job of capturing basic esthetic information without having to make many adjustments or accommodations, shade is an altogether different situation. Currently, there is no camera capable of capturing "perfect" color without having to create custom settings using a white balance-like card. Although not a difficult concept to understand or implement, it does require a basic working knowledge of the concepts related to color and how the camera views it. It is not the intention of this chapter to delve into all of the aspects related to the workflow of color management; however, there are many resources available today that can assist clinicians in a number of different methods to attain accurate color of their images. Simply recognize that no matter what is claimed by those manufacturing or selling cameras for clinical use, there is no such thing as a camera that will capture perfect color directly "out of the box."

Nonetheless, it is worth recognizing that for most situations perfect color accuracy plays a relatively small role in the overall needs analysis when considering the implementation of a clinical photography protocol. Of greater importance is the need for color *consistency* throughout a series of images and proper lighting. Of course, it would be ideal if every single image ever taken had the same level of color accuracy; however, as mentioned earlier, attaining this goal does require some investment of time and energy. If one is taking a set of images to show a patient their current condition, the need for perfect color is far less important than a case where shade is being communicated to a laboratory for veneer fabrication, and, even then, color plays only one part in a larger equation. Of importance in every image is proper lighting management and composition because without these, perfect color is virtually useless.

Patient education

There is nothing that can motivate a patient toward accepting ideal dental care better than a well-composed set of clinical images demonstrating failing dentistry or dental pathology. Of even more importance is the fact that "seeing is believing" and patients who visualize their dental problems are more likely to accept responsibility for their dental care. Clinicians who utilize a stepwise approach to case presentation which includes digital case presentation will generally find that patients become their partners throughout treatment. Gone are the questions like "What treatment are we doing today?" or "Why are we doing this treatment?" The dentist can feel more comfortable in knowing that patient decisions about treatment are made with a deeper understanding of the current condition and potential treatment options.

Although intraoral cameras are ideal for documenting single-tooth issues such as cracks, decay, and failing restorations, many dental offices do not own one. Digital SLR cameras, used properly, can produce extremely high-resolution pictures of a single tooth in place of intraoral cameras. One need to only set the image up as if it were an occlusal image (discussed later in this chapter) and zoom in on the single tooth (Figure 7.3). An alternative is to crop an existing occlusal image to the desired composition (Figure 7.4). Although not practical for use in all single-tooth applications, it is a fantastic technique when an intraoral camera isn't available.

Dental education

It has been said that "photography is the language of dentistry." Without images, it would be impossible for dental colleagues to discuss a case or come to proper treatment planning decisions. Collaboration between specialties would be based solely on opinions and conjecture, and it would be very difficult to visualize the proposed outcome.

Without photographic documentation of the treatment rendered, it would be extremely difficult for dentists to learn new techniques or applications of materials. Learning would be hindered and the dissemination of information slowed. It is for this reason that most dentists should develop the habit of photographing the steps involved in treatment so that they can, in turn, present their cases to colleagues at study clubs or larger meetings. Without images, there can be no presentation, and the habit of routinely documenting techniques through photographic means is one that must be learned and honed through practice. Of no lessor importance is the value of simply taking images and seeing them enlarged on screens for presentation. There are very few other methods for learning that allow dentists the ability to see their crown preparations or cemented veneers enlarged 30 times. Photographing one's cases causes clinical growth which is further amplified when one starts to present cases to others.

How to select a camera

There are two general categories of cameras available for dental use: single-lens reflex (SLR) and "point-and-shoot" (Figure 7.5A and B). Each type offers advantages and limitations for clinical use. SLRs are characterized by a moving mirror system that permits the photographer to see exactly what will be captured by the film or digital imaging system. Although non-SLR cameras have been touted as being considerably easier to use than SLRs, in

Figure 7.3 This image was captured by itself, filling the entire frame, rather than capturing it as part of a full arch and "zooming in." Notice the detail in terms of sharpness and color as compared to Figure 7.4.

Figure 7.4 This tooth was cropped from an image of the full arch. Aside from loss of detail, capturing a full arch from roughly 60 cm away often makes it difficult to see issues such as saliva, which can block vital components of the image.

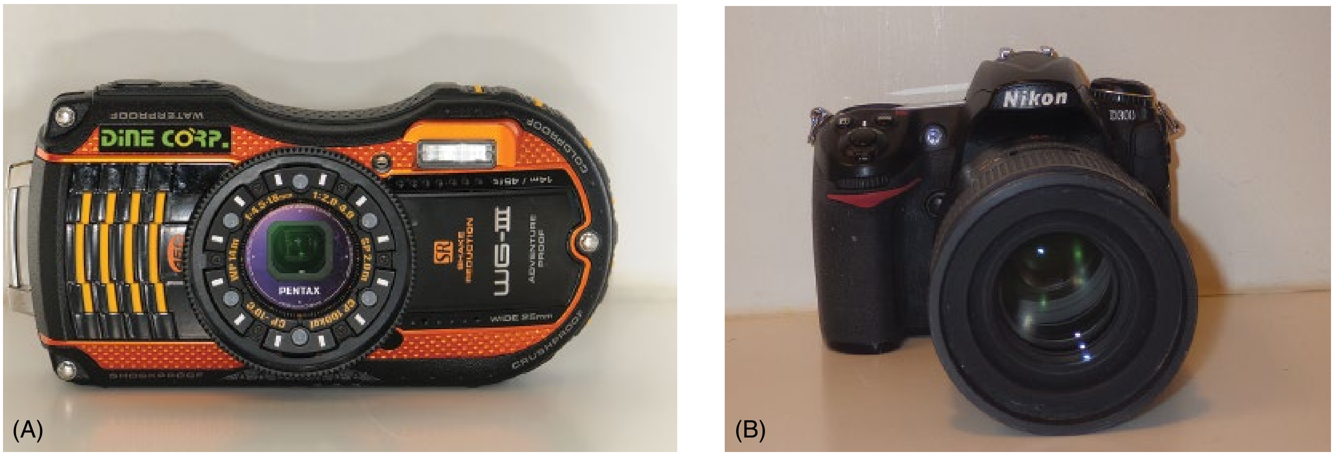

Figure 7.5 Examples of standard "point-and-shoot" **(A)** and single-lens reflex (SLR) **(B)** cameras. It can often be difficult to differentiate between the two; however, almost all point-and-shoot cameras do not allow for lenses to be removed and exchanged for other ones.

fact, for dentistry they are not. To capture appropriate images for clinical photography one must be able to control the depth of field, f-stop, flash settings, and, in some cases, shutter speed, features that are almost always absent in non-SLR cameras. Although point-and-shoot cameras can be picked up and quickly utilized, almost no point-and-shoot camera has "macro capability." What this means is that images captured from shorter distances (such as standard dental images) are unable to be brought into focus by the camera. For a camera to capture clear, visible images from close distances, it must have either macro capability or specialized adapters.

Another downside of point-and-shoot cameras is that one cannot change lenses. The standard lens in restorative dentistry has generally been one between 85 mm and 105 mm with some specialists using 60 mm, with all lenses having macro capability. Choosing a single lens for the clinical setting is all that is necessary; however, getting lenses of these types for a point-and-shoot camera is something that simply cannot be done. In SLR cameras, because the macro capability is a function of the lens, not the camera body, one can connect a lens of the proper magnification with macro capability. In short, although a point-and-shoot camera may seem appealing for clinical photography due to its purported ease of use and lower cost, most dentists find an SLR to be far easier to use once they understand the basic setup and use. Because SLR cameras are considered the standard in clinical photography, all discussions from this point forward will center on SLR cameras only.

Important features in choosing an SLR camera

When buying an SLR camera for clinical use, there are a number of features that one should look for. They include cost, screen size, lenses, resolution, functions, size/weight, and flash systems.

Cost

There are a variety of options available when looking at digital cameras in today's marketplace. The consumer-level cameras simply don't have enough features or compatibility to succeed in the dental clinic. As a result, the SLR market for dentists can be broken down into two particular groups: professional and prosumer camera bodies. The professional line is simply something that most dentists do not need to consider. Professional camera bodies are extremely expensive and have considerably more features than any dentist will use in clinic. For instance, shooting 20 frames per second is not something most dentists are ever going to have to worry about. In addition, video capability is something that most dentists won't use and, as a result, is something that doesn't need to be a part of an appropriate clinical camera system. The prosumer line of cameras by any manufacturer is the "sweet spot" for any dentist looking to get started with clinical photography. Camera bodies generally range from US$750 to $1500 with lenses costing an additional $500 to $950 and flash systems anywhere from $250 to $500. If one truly understands what is needed for capturing images, the cost/benefit can be fairly evaluated. Generally, the least expensive SLRs aren't appropriate for dental photography, and the most expensive generally are overkill. By evaluating the features of each particular model, one can determine which camera is truly best for them, rather than taking the advice of a salesman and ending up with a camera that sits on the shelf, unused.

Screen size

The size of the screen on the back of the camera is one of the less important features for clinical photography although many advertising dollars are spent by camera companies to convince you that screen size is of the utmost importance. The only factors one needs to really take into consideration when looking at screen size is "can it be easily viewed while I am capturing images?" The smaller the screen, the harder it is to view an image after capture. Older digital SLRs had screens as small as 4 cm. However, the images they captured were excellent, and if one was able to discern the quality of the image on the screen after capture, a bigger screen would make no difference. The majority of today's digital SLR cameras have screens that are big enough for most clinicians to view images (6–8 cm), so screen size simply isn't as important as it was in earlier generations of digital cameras. However, if one has a difficult time viewing details on the screen, a camera with a larger screen should be considered. To avoid any problems, one should always consider capturing images and viewing them on a screen before buying a camera.

Lenses

It is the opinion of most professional photographers that lenses should be of the same manufacturer as the camera body. There are a number of reasons for this. It is commonly believed that camera manufacturers create lenses to specifically match the camera bodies that they have produced. Although other companies can make duplicate lenses (Figure 7.6A and B), the original research and development has come from the camera company, and, as such, most professional photographers believe in matching their "glass" to the camera manufacturer. A second reason why this is not a bad idea is in the event that something should malfunction, it is always easier to take a camera system that is all of one manufacturer to a certified dealer of that manufacturer and allow them to fix it. Any person who has ever suffered a computer crash and heard the hardware manufacturer say that it is the software and the software manufacturer saying that it is the hardware can understand the value of one company being responsible for both the lens and the camera body. In the long run, this will probably save you a lot of trouble.

Lenses come in a variety of shapes and sizes. The lens for dental use is generally between 60 and 105 mm (Figure 7.7A–C). This is the standard in the industry for the last 30–40 years because it allows the image to have a composition that fits perfectly for dental images that are of the proper composition. Lenses that are bigger (i.e., 200 or 300 mm) do not allow a wide enough field to capture full-face images in a standard dental setting and lenses that are smaller (i.e., 35 or 55 mm) are often too wide to allow us good close-up images of patients' teeth. As previously mentioned, all lenses for dental use must have macro capability. This allows the clinician to capture an appropriate image from very close. Any dentist who has ever attempted to capture an image without macro capability understands the difficulty in trying to focus an image that is too close for the lens to handle.

Resolution

Resolution, or the amount of information in an image, is a generally misunderstood concept. Years ago, some of the first digital cameras had images that contained 1–2 megapixels whereas cameras of today have more than 20 times that amount. To understand what this means, one must first understand how a picture is composed, from a digital perspective. The basic building block of any digital image is the pixel. A pixel is a square of color that makes up a part of a greater image. A 1 mega (million) pixel image has 1 million squares of color that make up the image. It's easier to understand if one thinks of a digital image as if it were a painting from the famed era of pointilism, where the numerous dots that of paint that make up an image look very different depending on the distance from which the painting is viewed. When viewed up close, all one sees is simply dots of color; however, when viewed from far away the image becomes a masterpiece. This is exactly what occurs in photography with

(A)

(B)

Figure 7.6 **(A and B)** Examples of two similar lenses made by different manufacturers. In this case, they are both 105 mm macro lenses.

Figure 7.7 One can differentiate lenses by looking on the body of the lens for a proper marking. In this case, three different lenses (A, 60 mm, B, 85 mm, and C, 105 mm) are shown in a close-up view with their markings highlighted in yellow. Note that lenses with a range (i.e., 18–200 mm) are not appropriate for dental use.

pixels. A 1 million pixel image means that there are 1 million squares of color making up the entire image. If one were to enlarge the image to see each individual pixel, one would simply see a blurry square of color, but when seen in normal viewing on a screen, the million pixels appear to be a standard image (Figure 7.8A–E).

It is important to note that the more pixels in an image, the greater the resolution of the image. If an image needs to be enlarged to a much bigger size, there must be much more information present to be able to fill in the new, larger "canvas," and an image that does not have enough pixels to fill the screen will look blurry and "pixelized" (Figure 7.9). Due to the higher resolution of modern digital SLR cameras, this really isn't a concern for anyone looking to capture exceptional clinical images, and one should not necessarily believe that the more pixels, the better the image. If one were going to take an image and enlarge it to fit the size of a billboard, of course, the more pixels the better. However, for dental applications, it is rare that one will ever need that much information in an image. To put this into perspective, let us look at today's traditional monitors, the common output source for most of our images in dentistry.

If one has ever tried to set the properties on a clinical monitor, one would see several different settings appear. The computer might ask you if you wanted 764 × 620, or 1024 × 768, or 1600 × 1200, and so forth (Figure 7.10). The computer is asking how many pixels wide by how many pixels tall the user wants to display for the settings on the monitor. As previously mentioned, the more pixels, the more information, and the crisper the image. So a monitor that is set at 1600 × 1200 will allow much greater resolution than a monitor set at 600 × 400 (Figure 7.11A and B). The monitor that is set by 600 × 400 is only displaying 240,000 pixels. The monitor that is set at 1600 × 1200 is demonstrating 1.92 million (mega) pixels. If one sets their monitor to the highest resolution of 1600 × 1200 (a nice mid-level resolution for many monitors), one needs less than 2 million pixels to show a crystal-clear image that can look no better on that monitor. Does it matter if the camera that captured the image can display 6 or 14 million pixels? Not for this particular application because the most that this monitor can show is 1.92 million pixels. As a result, one might believe that more pixels means better screen resolution, but this is untrue, because most modern SLR cameras capture more than 10 megapixels per image.

However, if one is thinking of going to print media such as a publication or large posters, or if one needs to crop the image a great deal, the more resolution the better. That doesn't mean that one should buy a 16 megapixel camera over a 12 megapixel camera simply for printing purposes. Even for cameras that shoot only 3, 4, or 5 megapixels there are software programs available today that will allow lesser pixel images to be enlarged for "bigger" applications. In short, one should not get hung up on the resolution of a camera. This should not be a concern in today's SLR market. Most cameras available will provide more than adequate resolution for any dental use.

Functions

Today's SLR cameras offer a wide array of functions for the user to enjoy. However, many of the functions that separate one model from another are generally unused in dental photography. For instance, some cameras will allow the user to capture 20 images per second, something that no dental photographer will ever use. Other models will allow high-definition video capture, something that most novice clinical photographers can easily do without practice. Understanding the "essential" functions that a camera must possess is important for anyone thinking of buying a camera for clinical photography. Many camera manufacturers differ in the way they approach the features of the cameras, so it is important that users try out each system to see which one fits them best.

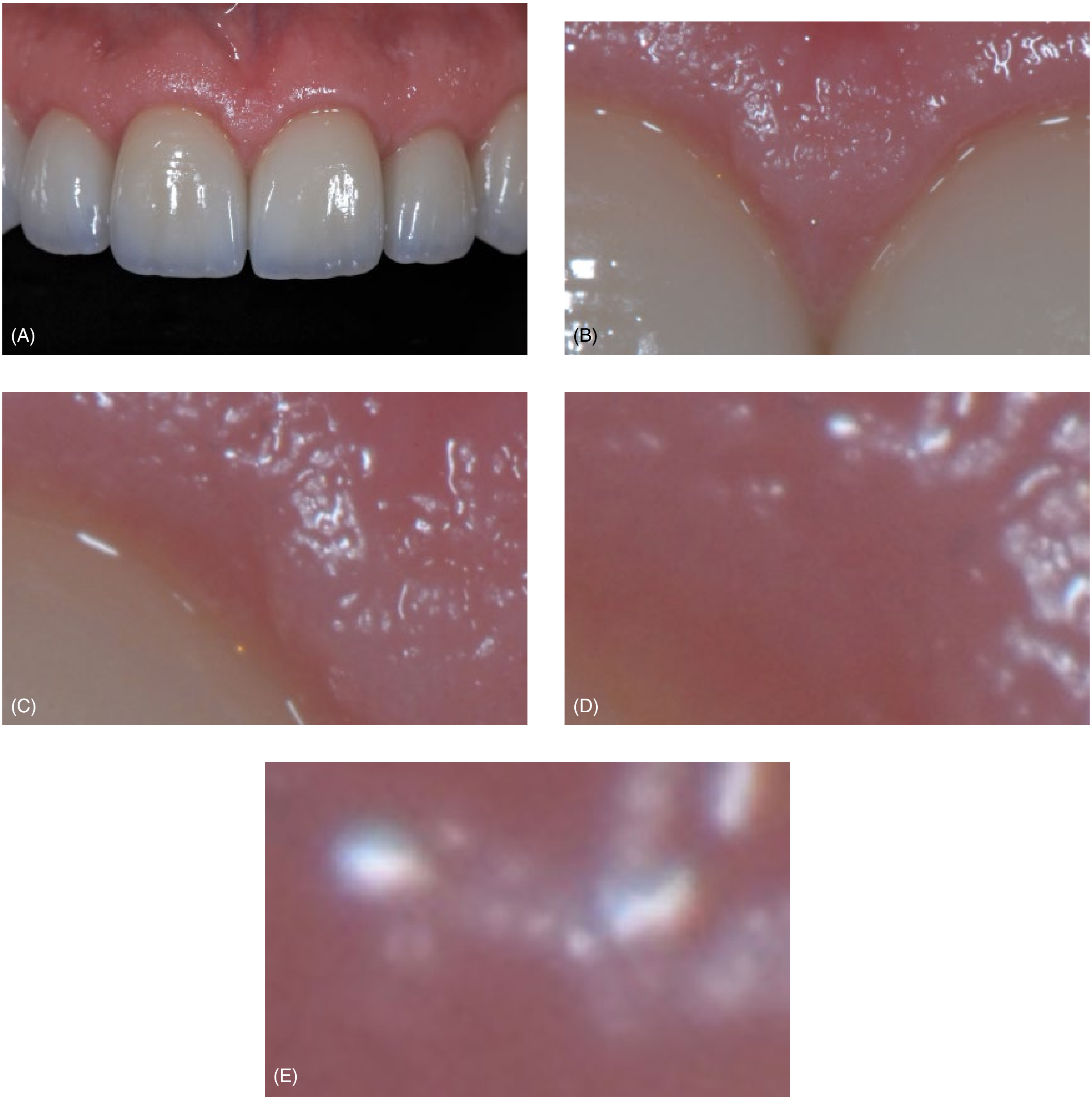

Figure 7.8 **(A–E)** Starting with a well-composed image, consecutive images demonstrate how pixels can become more apparent as one repeatedly zooms in. In the final image, particularly in the light areas, one can see the individual pixels very clearly.

One of the major features that virtually every SLR has is the ability to view the histogram. Discussion of the histogram will come later in this chapter; however, one can consider it a vital tool in evaluating the lighting of a captured image. Some cameras display the histogram as a small tool in the corner of the screen, whereas others allow a full screen overlay. Just like the image itself, the larger the histogram displayed, the easier it is to see and evaluate. This should be a consideration when looking at different camera models. Another component of every camera system is the ability to access and change camera settings. Some cameras make it extremely easy and others are more difficult. One should certainly evaluate a number of systems to determine which one makes them feel comfortable with its daily use.

Size/weight

Cameras come in many different sizes and weights. There isn't much to say on the subject other than one should find a camera that fits their hands comfortably. Although some camera bodies

Figure 7.9 When one crops an image too much and then expands it to fit a larger area, the amount of pixels in the image may be less than the display requires. In cases such as this, the image is said to be "pixelized."

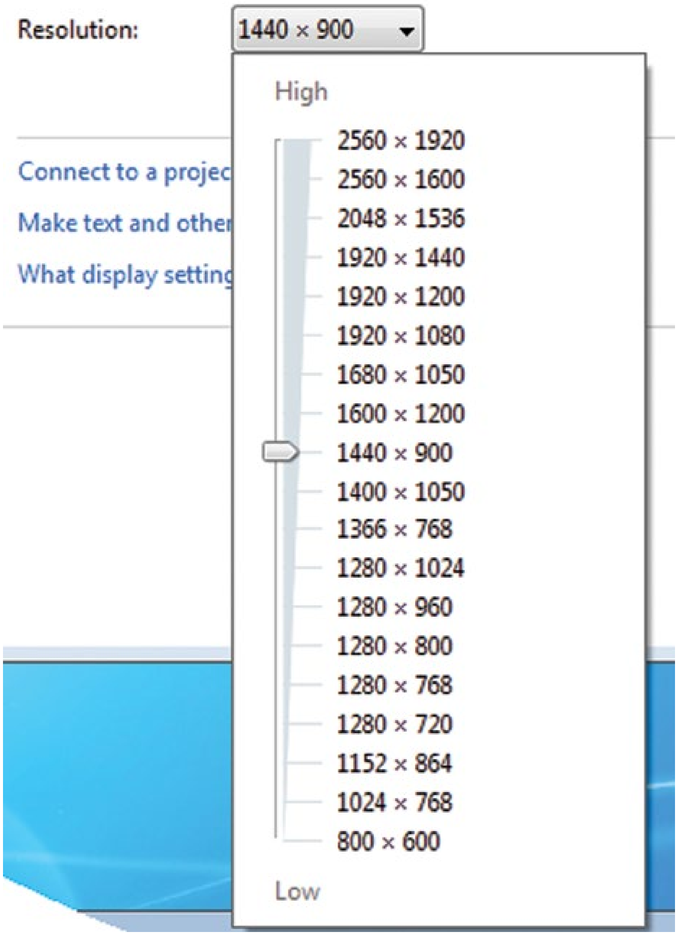

Figure 7.10 An example of different monitor resolution options offered in Microsoft Windows.

are heavier than others, before selecting based solely on the body's weight one should definitely attach the matching lens and flash first. Some camera companies produce a lighter camera, but heavier flash systems or lenses, making the overall weight greater.

If one is buying a camera to be used primarily by the staff, one should keep in mind that a camera system that feels good in the doctor's hands may not feel the same to the staff. One should certainly let the staff members pick up and handle the cameras before purchase if they will be the ones shooting most of the images.

Flashes

Flashes come in a variety of shapes and sizes. The two primary types of flashes for use in dentistry and macro photography are "point flashes" and "ring flashes" (Figure 7.12A–C). A point flash, as its name would imply, is a flash that has a single point of light to be focused in an area. Traditional older camera systems used single-point flashes that could be rotated around the lens for different directional lighting capability. With only one point of light, many shadows were produced, often obscuring vital parts of the subject. Most modern systems have solved this problem by containing at least two point flashes allowing for better lighting and more effective control of the shadows.

Ring flashes have a continuous circle of light around the lens which allows even lighting on the subject. The advantage of a ring light is its even light; however, this can also be a disadvantage. Dentists and technicians need to see appropriate shadows to truly understand the contours and shapes of teeth. Ring flashes, particularly when used from short distances, tend to "wash out" most shadows thereby creating a very "flat" surface texture. Double-point flashes do not have this problem. They provide an even light but at the same time allow a dentist to view surface texture and shapes in a way that ring flashes simply do not. There are attachments that allow users to mount flashes on a very wide or narrow mount to allow different lighting setups and angles. If one is looking to experiment with different lighting scenarios, these attachments are generally inexpensive and are worth trying; however, one should first try to use their flash system as described by the manufacturer (Figure 7.13). Another consideration in today's technological world is whether the flash is wired or electronically controlled. There are flash systems available today that send an infrared pulse to an external flash to allow it to fire without the use of any wires. Although not a major consideration, it is worth thinking about if you are concerned about wires getting in the way.

Every flash system, regardless of manufacturer, point or ring, and wired or unwired, should allow adjustment of the intensity of the flash power. This will be discussed later in this chapter and is one of the major reasons for choosing SLR cameras over other camera types. The flash should allow adjustable power settings of at least full power and a quarter of full power. Of course, the more settings, the better, but it isn't necessary.

Setting up the SLR camera

Setting up an SLR camera can seem like a daunting task; however, if one realizes that there aren't really a tremendous number of settings that we need to be worried about, it becomes much easier. The settings that one needs to consider include ISO, flash settings, image type, image quality, image size, and display mode, some of which will be discussed further here.

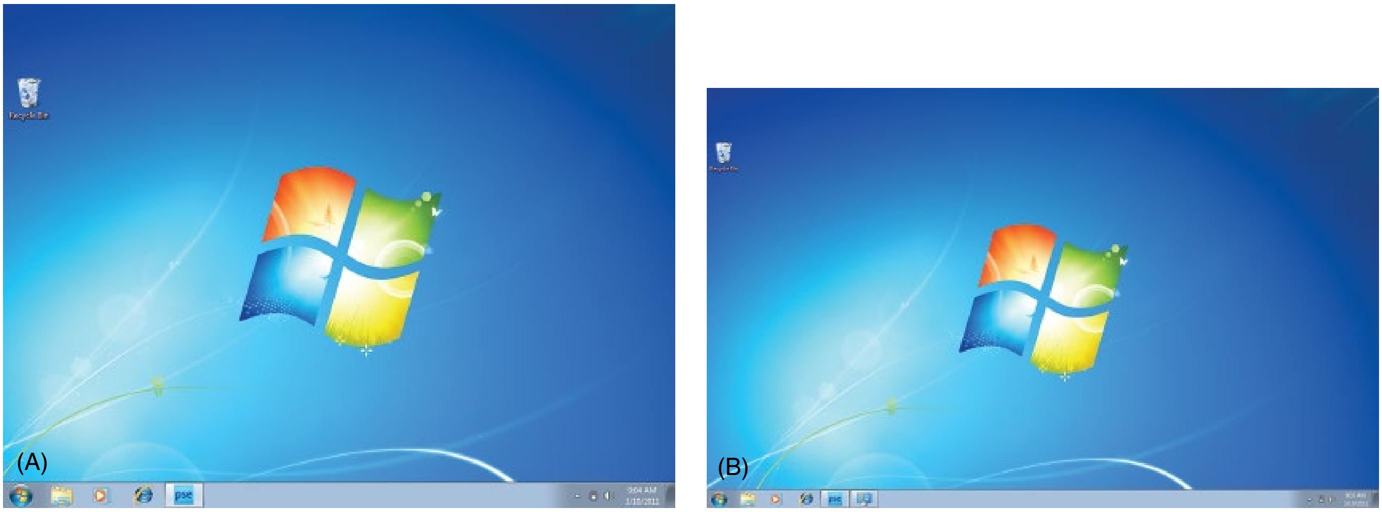

Figure 7.11 Example of the same monitor set to two different resolutions. **(A)** It is set to 1024 × 768 and **(B)** it is set to 1440 × 990. Notice how some icons become smaller (B) because their set number of pixels making up the icons take up less space on the screen with more pixels.

Figure 7.12 **(A)** Example of a single-point flash with a ring flash.

Figure 7.12 **(B)** Example of a double-point flash.

ISO

ISO refers to the camera sensor's sensitivity to light. The higher the number, the greater the sensitivity. For instance, an ISO of 100 is far less sensitive to light than an ISO of 3200. Although

Figure 7.12 **(C)** Example of a ring flash alone. Many dentists confuse their double-point flashes with ring flashes. To be a true "ring" flash, it must be an uninterrupted circle of flash.

one might shoot ISO 3200 in a dark room such as a sporting event or a concert, ISO 100 would be perfect for shooting a bright sunny day in the park or indoors with an extremely strong flash. For dentistry, the ideal ISO is 200. This allows a proper balance between flash and lighting for a well-lit image.

Image types

There are generally three choices of image type on most SLR cameras. They are RAW, TIFF, and JPEG. A good way to compare the differences in these three image files is to think of three options of preparing a pizza. The first option is homemade from

Figure 7.13 An example of a camera attachment which allows multiple positions for the macro flash. Moving the flash away from the lens makes it more difficult to control lighting, but it rewards the photographer with better shadows and highlights for diagnostic purposes.

scratch which produces the best quality but is the most time-consuming and difficult. This is like the RAW image which gives the photographer full control over every aspect of the image but requires a tremendous amount of time and expertise, which is not what most dentists need for everyday clinical practice. The second pizza option is one with premade commercial crust and sauce and with options to choose cheese and toppings. This is comparable to the TIFF image which requires less time and management than a RAW image, but still offers a good-quality image. Unfortunately many cameras manufactured today do not include TIFF as an option. The third option is the quickest and easiest: order a pizza to be delivered. This is equivalent to the JPEG image which is suitable for dentists in everyday use and requires less space on the hard drive. The JPEG with a large/fine setting gives the dentist enough information to display any image on a monitor or screen. If one wants to use the images for commerial publication or enlarge to poster size, JPEG files present a bit of a challenge. However, there are software programs that can convert JPEGs for publication or enlargement. For most dentists, a JPEG image is fine.

Through the lens versus aperture priority

Through the lens (TTL) is a setting available on almost any SLR digital camera. It was designed to allow the camera's metering system to make most of the decisions related to settings rather than leaving it to the photographer. TTL does work beautifully in many settings; however, the extreme images of dentistry which include only two to three colors (white, black, and pink) from 15 cm away is something that confounds most TTL systems. Camera manufacturers have consistently produced better and better systems for helping photographers; however, none of them are yet to match the photographer's ability with manual settings for the dental arena. As a result, the best setting on any SLR camera for dental photography is "aperture priority." To better understand what aperture priority is, one must first understand the end goal when capturing images.

One of the main advantages of an SLR camera over a point-and-shoot camera is the ability to instantly view the histogram. A histogram is a diagrammatic representation of how light entering a camera is processed by tone. The easiest way to think

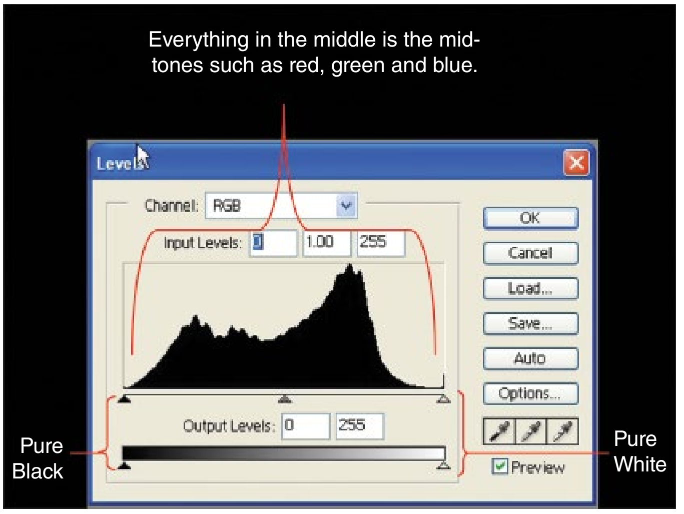

Figure 7.14 An example of a histogram showing what the information means.

of the histogram is as follows: imagine one were to visit an orchard that produced both yellow and red apples. There are millions of apples in the orchard; however, this individual is charged with the task of diagramming the exact makeup of the orchard based on the apples that are produced. Imagine further that there were 255 empty barrels lined up in a row and on the left-most barrel one placed the reddest apple from this orchard, and on the right-most barrel was placed the most yellow apple in the orchard. Every other apple in the orchard can then be graded using that left-most and right-most apples as your guide. If an apple had an equal amount of red and yellow in it, it would go in the middle barrel. Anything with slightly more red would go to the left, anything with slightly more yellow would go to the right, and so on. At the end of the day, one could count the number of apples in each barrel and chart them on a graph with the *x*-axis being the color of the apples in each barrel and the *y*-axis being the number of apples in each barrel. This would allow one the opportunity to look at a graph and immediately understand the makeup of the orchard in terms of red versus yellow apples.

A histogram is exactly the same thing as the orchard; however, instead of using red and yellow apples as the guide, the camera is using absolute black and absolute white as references, with black on the left and white on the right and all the other color combinations in between, based on lightness versus darkness (Figure 7.14).

If an image is slightly darker, meaning it has more dark pixels, the biggest broadest peak will be slightly left of center. If an image is lighter, containing more light pixels, the biggest peak will be slightly to the right of the middle. The darker an image gets, the more the biggest and broadest peak will swing to the left. The lighter an image, the more it will swing to the right. A histogram will allow a photographer the opportunity to instantly view the tonal makeup of an image by simply using that tool (Figure 7.15A–C). What does a histogram have to do with the quality of one's images? If one can master the tonal control of an image, the lighting will be perfect every time, so understanding the histogram is a key to capturing proper lighting. Although it may seem like a daunting task, over time, understanding a histogram will be simple. If one looks at a histogram, one can tell what is in the image. For instance, notice the picture of the molar in Figure 7.16A. If one was to look at all the pixels making up this image, one could see that the general makeup of this image would be composed of cream or lighter pixels. Of course there is some blue and some brown and some gray, but the general makeup of this image is on the lighter side. It is not bright white (like the reflections on the tooth which are, in fact, bright white), but it is lighter. By looking at the histogram (Figure 7.16B), one can notice that the biggest and broadest peak is to the right side, not to the left. This is exactly what one would expect. In looking at another non-dental image, one can see a perfect balance between light and dark. In this particular image, one can notice all of the darker trees which represent the darker pixels on the left side as well as the whiter pixels that make up the snow represented on the histogram on the right side. If one understands the makeup of a histogram, one understands exactly the lighting makeup of that image.

One should attempt to shoot all clinical images with the biggest, broadest peak centered in the middle of the histogram. This means that the image has even lighting that is spread out through the entire spectrum and will meet the needs of any application for that image. If one has to err, one should err to the left, or darker side (Figure 7.17A and B). If one needs to edit the image, much more can be done with an image that is slightly darker than one that is slightly lighter. The next question then is how does one control the lighting in an image? This is done through the f-stop or aperture.

Understanding lighting

f-stop and flash settings

All SLR lenses have apertures that allow more or less light into the camera. By changing f-stop settings, one can make these apertures bigger or smaller. The bigger the aperture, the more light is allowed into the camera, and the image will appear brighter. The smaller the aperture, the less light is let into the camera and the image will appear darker. One of the more counterintuitive components of the entire camera flash system is the relationship of f-stops to aperture size. A higher f-stop (i.e., 32) actually causes the aperture to be smaller, thereby letting in less light and making the image darker. An f-stop that is lower (i.e., 3.5) will make the aperture larger thereby allowing more light. It is counterintuitive for most people because we think higher numbers allow more light and lower numbers allow less light. However, that is the exact opposite from the truth. The reason is because the f-stop represents an inverse number. An easy way to think about f-stops and the amount of light they allow is to consider it as if it were sunscreen.

If one were to go out into bright sunlight and was afraid of burning, one would put on a high SPF sunscreen (i.e., 50). If one were to go into a slightly darker, cloudy day, one might use a lower SPF (i.e., 8). Remember that one should treat their f-stop in the same way. When more light is present, the higher of an

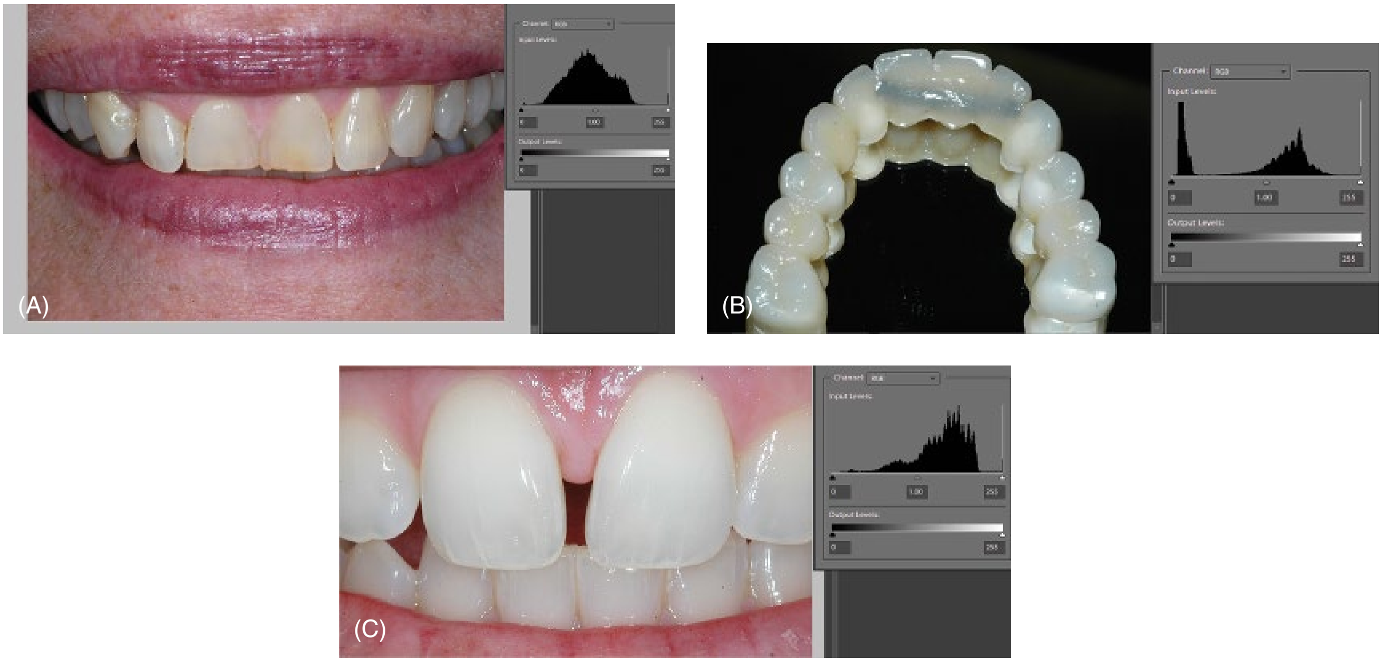

Figure 7.15 **(A–C)** Examples of different images and their corresponding histograms. Examine the images and note what colors within the images create each of the peaks. Every single pixel is properly represented by its histogram.

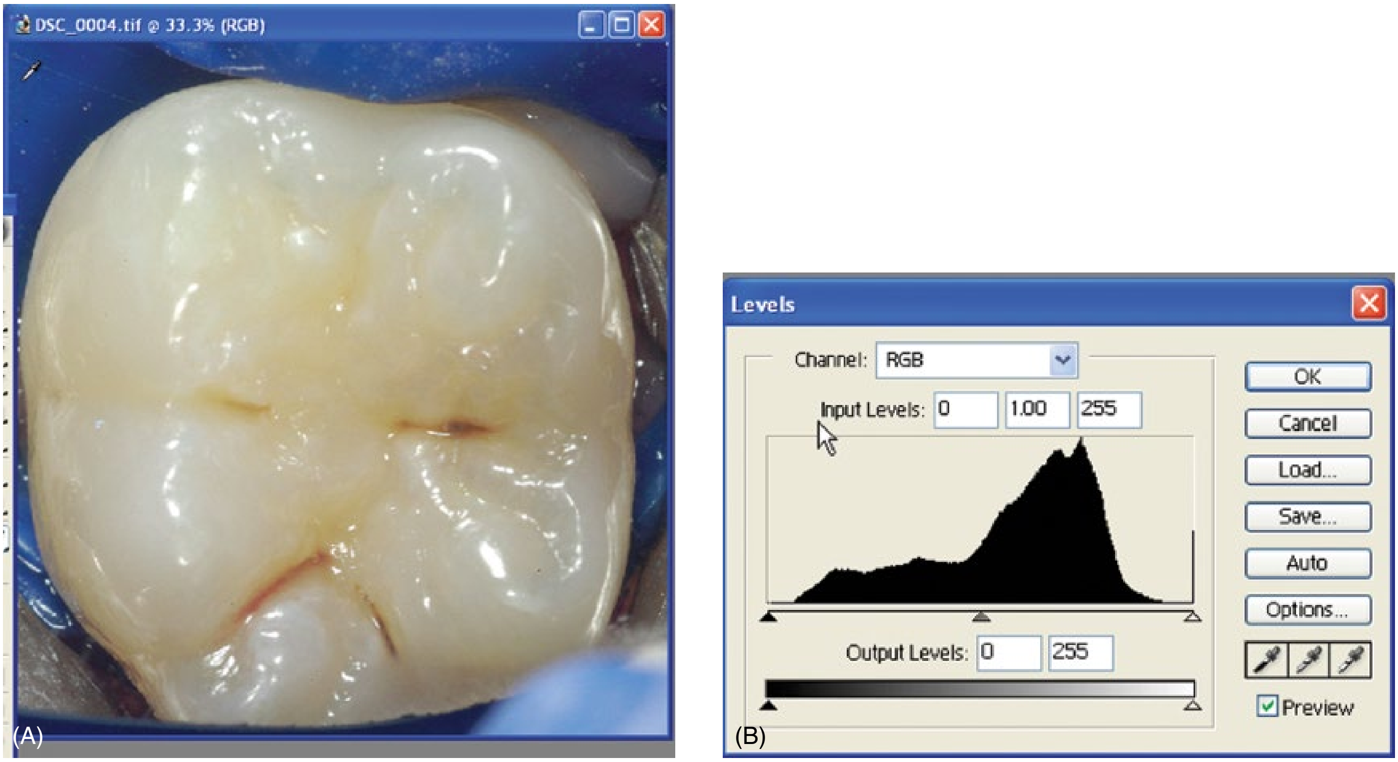

Figure 7.16 **(A and B)** This image of the tooth takes up most of the field of view. The tooth is not pure white, but rather an "off white." Notice how the largest and broadest peak in the histogram is found in an area that is representative of this tonal makeup. The skinny peak on the right side of the histogram represents the light reflecting off of the tooth.

f-stop one should use. The lower the amount of light available, the lower the f-stop should be. It takes a little bit of time to understand this concept, but once mastered will allow ideal control over lighting every time.

Another component to mastering ideal lighting is understanding flash settings. Once again, this is an area that almost no point-and-shoot cameras allow, but it is critical for perfect images every time. An effective flash system for dental photography

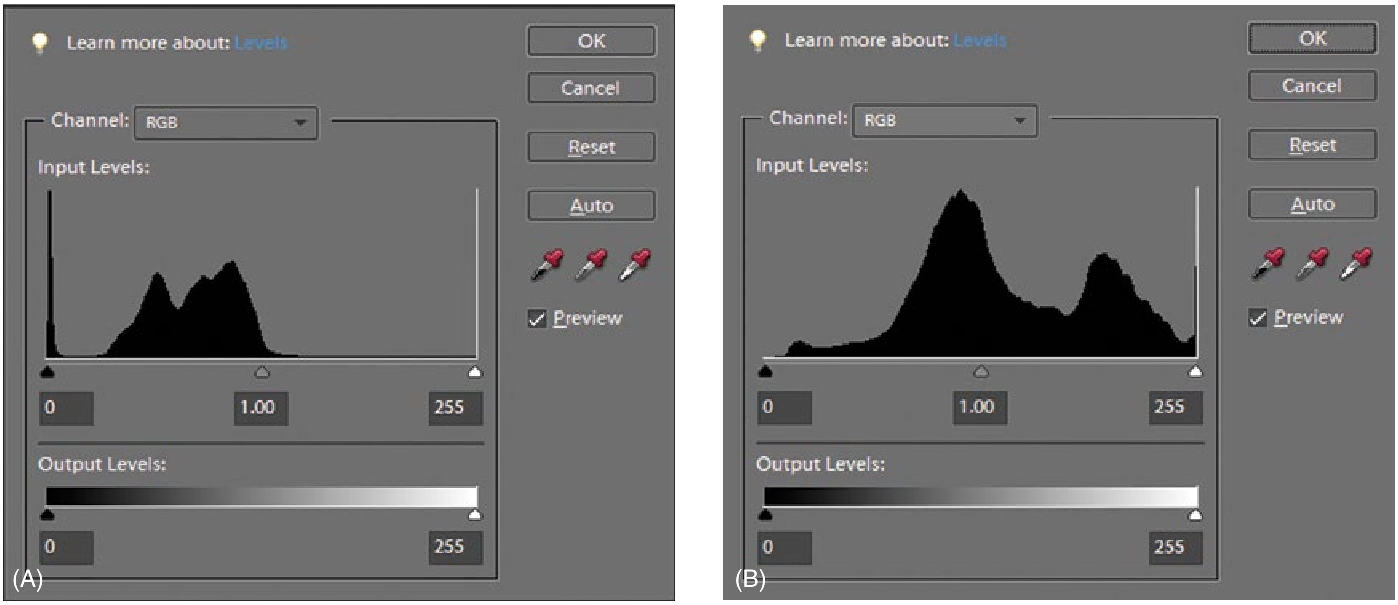

Figure 7.17 Examples of histograms with the largest and broadest peak centered **(A)** and to the left (darker side) of midline **(B)**.

should allow at least three settings: M(1/1), 1/4, and 1/32. This allows the clinician to manipulate the lighting through the flash. Obviously the higher the setting, the more light the flash will supply. The reason why the amount of lighting matters is, because it will work with the f-stop to allow ideal depth of field. A greater depth of field means that more of the image will be in focus. A smaller depth of field means that only a short distance of the image is in focus.

The key to f-stops is the following: the higher the f-stop, the greater the depth of field. The lower the f-stop, the smaller the depth of field. Because of this, a clinician wants to shoot as high an f-stop as possible in almost all dental settings so that as much of the image is in focus as possible. It reduces the chance of an out-of-focus image and allows viewers to see everything in focus rather than some of it in focus and some of it out of focus. How does one achieve this? By using a higher flash setting, it forces one to use a higher f-stop setting (to let in less light). By using a higher f-stop setting, the depth of field is better, thereby allowing more of the image to be in focus (Figure 7.18A and B).

Consider the following: to achieve a centered histogram, one might be able to shoot an image with 1/1 (the most flash). By throwing out a tremendous amount of light on the subject, it would force the clinician to turn the f-stop up as high as possible to let in less light. In doing so, the depth of field will automatically adjust, allowing the dentist to capture a central incisor all the way back to a second molar in focus at the same time with a beautiful histogram. However, one could also capture a broad, centered histogram with a lesser amount of light (i.e., 1/32) and a very low f-stop (i.e., 3.5) allowing a beautiful histogram with very little depth of field. The histogram is an excellent tool for allowing one to understand the lighting, but understanding f-stops and flash settings allows a clinician the opportunity to fine tune the depth of field, which is one of the most important features. The whole concept of histograms, f-stops, and depth of field can be daunting to someone who is not used to it. However, realize that there is a way to capture the ideal lighting every time while taking into account all of these important factors.

Create a quick-reference settings checklist

It is very helpful and efficient to create a quick-reference sheet of settings for the clinic (Figure 7.19). This is easy and should only take about 30 minutes. Start by placing fresh batteries into a camera, seating a patient in a chair, and shooting an image of their face with a full flash and a medium-range f-stop such as 14. Look at the histogram and evaluate where the broadest peak falls relative to the center of the screen. If the histogram is to the right of center, one has an image that is too bright. As a result, one must turn up the f-stop to the next number and reshoot the image. If the image is still too bright, turn the f-stop up again continuing this process until the histogram is centered.

If the histogram is too dark, or to the left, one could turn the f-stop down continuously until the histogram was finally in center. If there are fresh batteries in the camera, one can write down the flash setting and f-stop for the full-face image and use that setting for every other full-face image taken in the practice. Generally speaking, the overwhelming majority of patients will fit into this flash setting. However, should there be an anomaly and one needs to make an adjustment, it is as simple as turning the f-stop up or down one stop to accommodate the histogram that did not fit the proper criteria. If a clinician goes one step further and shoots every one of their possible images with an ideal histogram, recording the f-stop and flash setting, this valuable quick-reference sheet can be used for every image in the dental setting. One need not "reinvent the wheel" every time an image needs to be taken. It is a good idea to create a reference list

Figure 7.18 Examples of how f-stop relates to depth of field. Notice the difference of focus as one moves away from the camera. Images were captured with a very low f-stop **(A)** and with a very high f-stop **(B)**, allowing a much greater depth of field in the latter where many more keys are in focus..

of appropriate camera settings for each image, print it on bright-colored paper, and laminate it. Then the dentist need only glance at this sheet for each image, set the camera, and take the image. This particular setup will work almost every time for every image regardless of the patient variability. If the images are not producing well using these settings, it is probably because the batteries in the flash are beginning to weaken and they should be changed. Although understanding histograms, depth of field, and f-stops can be somewhat challenging to most clinicians, once mastered, the dentist will never have to worry about lighting again, and the advantages of aperture priority over TTL will become apparent.

Other necessary equipment

There are two basic pieces of equipment, aside from the camera, that clinicians need to capture an ideal set of images: mirrors and retractors.

Mirrors

To capture a full arch or lateral image, one cannot fit the camera in a patient's mouth. Nor can one retract the lips to the point where an ideal image can be captured without the use of mirrors or retractors. Mirrors come in a variety of shapes and sizes as well as different coatings. The three most common coatings available today are chromium, titanium, and rhodium. All three offer advantages and disadvantages with rhodium being the most commonly and longest used mirrors of the three.

Mirrors come in a variety of shapes and sizes. Some are designed for lateral arch images, others for maxillary or mandibular arches, and others for lingual or palatal shots. Regardless of the application, one of the most common mistakes for novice photographers is to use a mirror that is too small (Figure 7.20A and B). Because newer clinical photographers are afraid of causing discomfort to the patient, smaller mirrors are generally chosen which do not allow the entire subject matter to be

Approximate Starting Points for Flash and f-stops

Type of Image	Flash setting	f-stop	Magnification
Full Face (smile,repose or profile)	M	14	~1:10
Smile or Repose (close up)	¼	25	1:3
Retracted (Closed or Open)	¼	32	1:2.5
Max or Mand Occlusal	¼	25	1:3
Maxillary Front 6	¼	45	1:1.8
Mandibular Front 6	¼	40	1:1.6
Lateral arch	¼	36	1:2.25
Max 6 Occl	¼	36	1:2
Mand 6 Occl	¼	36	1:1.8
2 Centrals(Characterization)	1/32	32	1:1
2 Centrals(Normal)	1/32	29	1:1
Single tooth (mirror)	¼	57	1:1

Figure 7.19 Keep a quick-reference checklist of correct camera settings to control lighting. It is important to note that different camera and flash combinations can cause many of the settings to differ from the ones in this example; however, once determined, the settings themselves will differ very little from patient to patient.

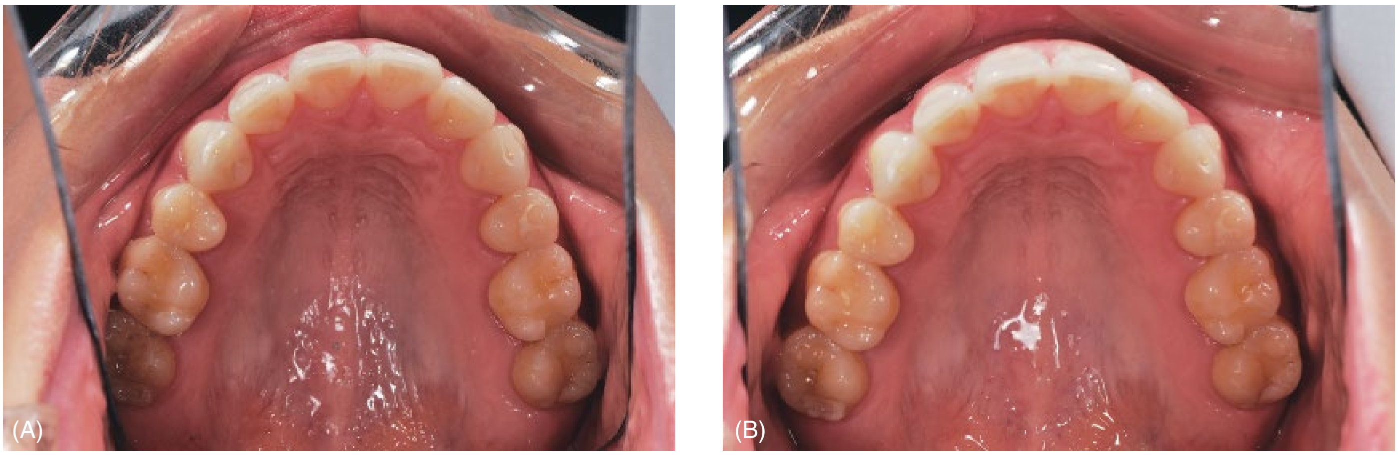

Figure 7.20 A common mistake for the clinician is to choose too small a mirror, thinking that it will be more comfortable for the patient. Notice the difference between **(A)** and **(B)**, based solely on the use of a larger mirror in the second image.

reflected appropriately. A general rule that will guide most clinicians properly is to always start with the bigger mirror and attempt to use it until proven that it is too large, and then only moving to a smaller mirror.

When working with mirrors, one should have a method to avoid fogging. There are many techniques to keep the mirror from fogging and they include heating pads and solutions that are applied to the glass. However, the easiest, quickest, and most sanitary way to keep mirrors from fogging is simply to run them under hot tap water for five seconds before drying and using them (Figure 7.21). Contrary to public perception, rhodium mirrors can be wiped down with paper towels for drying without causing damage. Lens cleaning paper and microfiber wipes are not necessary.

Figure 7.21 Warm running water is a great way not only to clean a mirror but also to keep it from fogging during use.

Retractors

To effectively use mirrors, retractors have been designed to keep the lips out of the way both in direct and nondirect mirrored images. Retractors can be made of either plastic or metal although it is the author's opinion that plastic offers a number of advantages. Because of the curved shape of plastic retractors, they do allow better retraction particularly in the anterior labial region. In addition, they can be shaped and cut down to match almost any clinical need which is something that metal simply cannot do. There are a variety of shapes and sizes that have been developed for retractors with each one providing advantages for certain clinical settings (Figure 7.22). Keep in mind that most retractors will become cloudy rather than clear over time with repeated autoclaving. As a result, many clinicians choose alternate disinfectant solutions like the ones used for X-ray holders. It is also important to remember that all retractors should be moistened before being placed inside the patient's mouth. It makes it easier to place a retractor and makes it a much more comfortable experience for the patient. Learning how to properly use mirrors and retractors in unison is of key importance for ideal outcomes. Although there is a learning curve associated with the clinical use of mirrors and retractors, the benefits of proper placement and angulation are immense.

Composition of images

There are dozens of standard images than one can capture depending on the proposed use of the pictures. Furthermore, many organizations mandate certain images as part of their documentation protocols. Regardless of the image needed, the following "basic set" of images, made up of 11 individual shots, will allow any clinician to develop the skills necessary to meet any future needs. This protocol includes the following images: full-face smile, full-face repose, full-face profile, close-up smile, close-up repose, retracted closed, retracted open, left lateral, right lateral, maxillary arch, and mandibular arch (Figure 7.23A–K).

Full-face smile

The purpose of this particular image is to view the entire face and to evaluate the soft and hard tissue and their harmony. The image should include everything from slightly below the chin to above the top of the head. The ears are an excellent guide for how far away one should stand (Figure 7.24). One should attempt to capture the width of the head by leaving a little bit of background space to the left and right of the ears. That will put one in a perfect position to better capture the face in the proper magnification. The patient should be standing for this image rather than seated as it makes it much easier for the dentist to capture what is necessary. If the patient is taller or shorter than the dentist, one should not use any step stool or ladder for either the patient or the dentist. Numerous accidents have been reported by patients standing on foot stools or doctors who have slipped off of them.

Figure 7.22 The basic types of retractors used for most images.

Figure 7.23 **(A–K)** The 11 basic images in composite.

It is far easier for both the patient and the doctor to be standing and one of them to adjust ever so slightly for a few seconds to capture the image. It is safe, effective, and consistent. The camera should be held vertically rather than horizontally because it will mimic the shape of most heads, which are elongated and not wide. Hair should be tucked behind the ears to view them as part of our landmarks. Glasses should be off, and distracting earrings should be removed. The patient should hold their head as

Figure 7.24 Notice how the face is not centered in the frame. The ears are an excellent way of judging how the patient should be positioned. This patient is also turned slightly to her left and this is also demonstrated very nicely by looking at the ear display. It is important to look at the patient, not through the camera, after capturing the image to determine whether the image accurately represents the patient or if there is some sort of misrepresentation caused by poor positioning.

straight as possible and should not smile until told to directly before capturing the image. Otherwise the smile may not come across as natural.

Full-face repose

The full-face repose image should be captured with exactly the same magnification as the full-face smiling image. Nothing should be changed in terms of settings, and both the dentist and patient should be standing exactly where they were for the full-face smile. The only difference between the full-face smile and full-face repose is that we need to see incisal edge at repose. To do so, have the patient say the name "Emma" and then relax. This will allow a very comfortable incisal edge repose. One can also simply have the patient lick the teeth to allow the teeth to fall into repose. Nonetheless, no matter what method is chosen, all settings and distances should be exactly the same as the full-face smile. It is for this reason that autofocus is never recommended. When one presses the shutter release button on a camera, the camera will automatically try to autofocus for a moment. If one has changed the distance slightly between the subject and photographer, the image will now reflect that, and the full-face images will not be taken from the same distances. For this reason autofocus should always be turned off.

Full-face profile

The goal of this image is to capture the profile on either smile or repose. It is completely at the discretion of the clinician depending on personal preference. The full-face profile image should be set up exactly like the first two images; however, the patient merely turns to his or her left or right side. This can be taken as a smile or as a repose depending upon the needs of the clinician. But once again, the distances in camera settings are identical as the first two full-face images.

Close-up smile

The next image is the close-up smile. The goal of this image is to view the teeth and lips and their relation to one another. There is no reason to include the nose or chin because they are already present in the full-face images. The patient should now be seated in a dental chair with the head against the headrest to minimize movement. Sunglasses should be placed on the patient to avoid over exposure to the eyes. Unlike the full-face images, the camera is now held horizontally. The shooting goal of this image is to capture a full smile from one corner of lip to the other corner of lip with a little bit of space on each side. The way to do this is to have the patient smile as big as they can while looking through the view finder. The dentist should move forward or back until the entire smile (but not much more) is seen to fit on the screen. The clinician should then adjust the lens to bring everything into focus. With the patient now relaxed, the dentist can tell the patient to smile again, being ready to capture the image shortly after the smile occurs. It is vital that if one is going to capture a smile image, let it truly be of a "natural" smile and not the one that has been held for 10 or 15 seconds (Figure 7.25A–C).

The incisal plane and lips should be captured as they are naturally. If the patient has a cant, do not correct it by adjusting the camera (Figure 7.26A and B). Remember that the goal of these images is to capture clinical information the way it is. To alter it by changing camera angles will misrepresent the patient's information and may lead the clinician down the path of incorrect diagnostic choices.

A common mistake is to have the patient's head tilted back or to have the chair reclined too far. As a result, the image will look as if it is being "shot up" at the patient and the diagnostic information will not be appropriate (Figure 7.27). Try to remain perpendicular to the patient's face thereby giving a natural view of their smile. If there is something in the image that doesn't look natural (i.e., asymmetry in the smile or buccal corridor), do not simply dismiss it as a poor shot. Evaluate the patient relative to the image to determine whether, in fact, it does accurately represent the subject.

Figure 7.25 **(A)** Image of a laugh.

Figure 7.25 **(B)** Image of a smile.

Figure 7.25 **(C)** Smile held for too long with same patient.

Figure 7.26 Images of a cant as found naturally **(A)** and an artificially corrected through camera rotation or software manipulation **(B)**.

Close-up repose

Just like the full-face repose image, the goal of the close-up repose image is to capture the incisal edge at rest. All settings of the previous close-up smile image are maintained for this shot. It is identical to the close-up smile with only the amount of tooth demonstrated altered. Simply have the patient go into repose exactly like the full-face repose and then capture the image. It is important to keep in mind that one must capture the close-up smile before the close-up repose for the following reason: if the close-up repose is captured first and fills the frame, when the

Figure 7.27 Image of a patient too far reclined in the chair and the resultant image. Notice how it looks as if one is looking up at the patient rather than straight on.

Figure 7.28 **(A)** Examples of a visible incisal edge at repose.

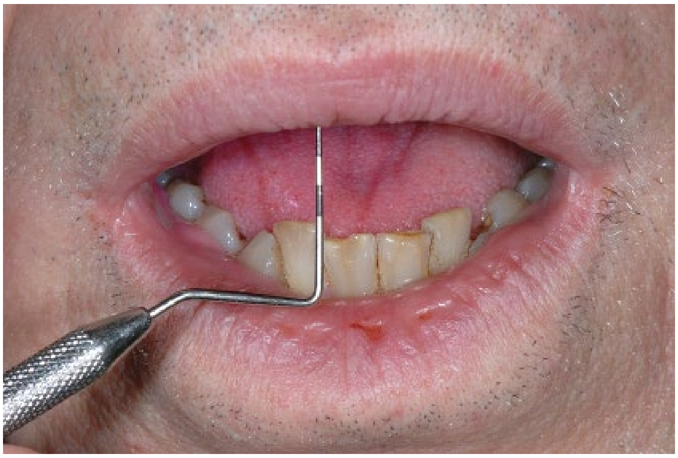

Figure 7.28 **(B)** The need to use a periodontal probe to demonstrate an incisal edge that is superior to the lip, and therefore not visible. Without a probe, one cannot determine whether the incisal edge is 1, 3, or even 8 mm above the lip at repose.

patient smiles the corners of the lips will be off of the field. Therefore, frame the full-face smile and then have the patient do the repose. There may be skin visible on the left and right of the lips in repose, but that is okay. It merely represents the difference in the facial features between smiling in repose for this particular patient.

A common issue with this image is the patient who demonstrates no visible incisal edge at repose; however, even that is relevant clinical information. One must capture this information for future evaluation. Simply have the patient in repose and place a periodontal probe on the nonvisible incisal edge. Capture the image as if it were any other close-up repose and one will be able to effectively evaluate how far above the lip the incisal edge truly rests (Figure 7.28A and B).

Retracted closed

The goal of the retracted closed image is to capture as much of the teeth, attached gingiva, and oral mucosa as possible, in focus without lips or retractors in the way. Think of capturing from second molar to second molar with all attached gingiva and oral mucosa. The image should be taken straight on to the patient just like the close-up repose and smile images. Retractors should be placed in the patient's mouth and held outward and forward to move the lips out of the way. Retractor placement plays a huge role in capturing this image without the presence of lips or secondary structures.

With the patient turned slightly toward the operator and the occlusal planes seen as they present naturally, the image should be taken. The ideal image would allow second molar to second molar with everything in focus. This is where the understanding depth of field plays a vital role and why a higher f-stop really does make a difference. Traditional TTL images of this particular shot will have many teeth out of focus (Figure 7.29). Gone are the days of having to simply focus on the lateral incisors and hope that the bicuspids and molars are in focus. If the f-stop has been appropriately adjusted and lighting is correct, one can truly capture second molar to second molar in focus.

Figure 7.29 An image taken using TTL. Notice how the camera has arbitrarily chosen an f-stop that doesn't allow all of the teeth to remain in focus.

Retracted open

The retracted open is exactly the same as the retracted closed but with a goal of seeing the lower and upper incisal edges without overlap. Simply have the patient open, so that the anterior teeth clear one another by 4–6 mm and shoot the image. Looking at the lower incisal wear patterns is often the key to understanding a case (Figure 7.30A and B). The retracted open and retracted closed images should look almost identical with the exception of an open, rather than a closed mouth. One should be careful of accidentally shifting the camera either up or down to follow the opening of the jaw. It is a common mistake that can cause other vital information to be left out of the image. The easiest way to avoid this problem is to maintain the incisal edge of the maxillary teeth in the same position as in the retracted closed image (Figure 7.31A–C).

Left and right lateral

With the left lateral image, the introduction of mirrors now occurs. This is where altered retractors make a big difference. If one simply uses traditional retractors to capture an image, the tension on the lips is such that retracting the mirror for a full lateral arch view becomes very difficult. One should use a standard retractor with the tips cut off. This is placed in the contralateral side from the desired arch. A full-size retractor is placed on the side of the arch that one does want to capture. While holding both retractors, a lateral arch mirror can be placed on the side of the arch to be captured. While holding the mirror in place, the retractor on the same side is removed. The patient finds themselves holding the mirror on the side that will be captured and the smaller retractor on the side that will not be captured. This is where most doctors run into trouble. By keeping a full set of full-size retractors in the mouth, the tension is such that it is nearly impossible to capture a proper image. By removing one retractor and leaving a smaller retractor in the mouth, one will find that there is more elasticity to stretch the mirror. Furthermore, if one slides the cut-down retractor toward the midline, it will allow even more room for the mirror to be extended (Figure 7.32).

Another common mistake for novice photographers is to not stretch the patient enough (Figure 7.33). It is a valid concern that the patient is going to experience discomfort. However, most beginning photographers are amazed to find how far they can

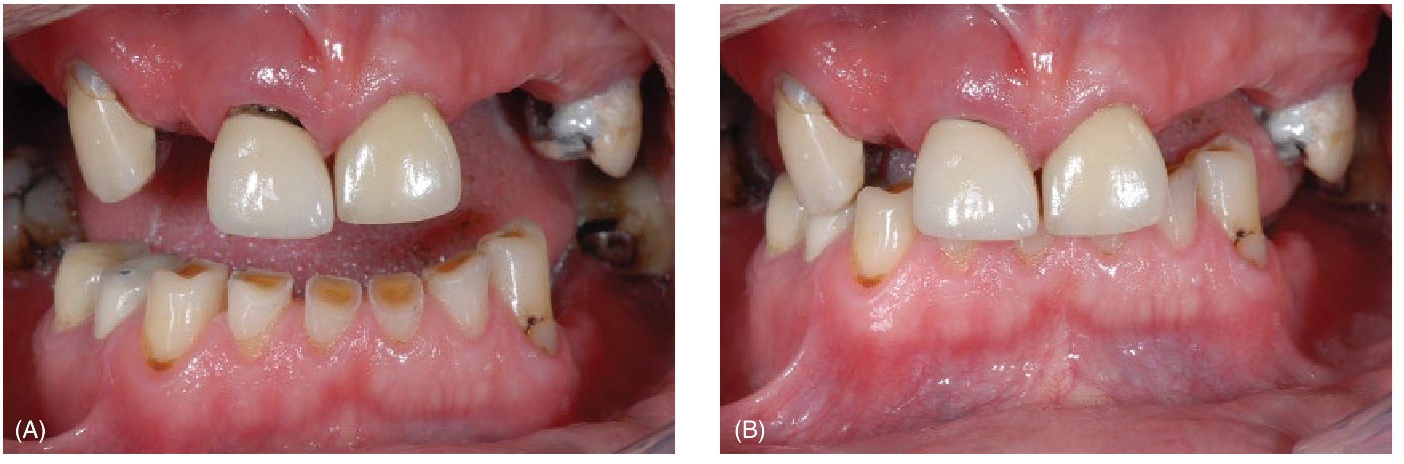

Figure 7.30 **(A and B)** It is vital to capture a retracted "open" image after the "closed" image. Often, vital information is not visible if only a closed image is captured.

Figure 7.31 **(A)** Closed bite image.

Figure 7.31 **(B)** Image with patient opening too wide and distorting image.

Figure 7.31 **(C)** Image captures important information below the lower central incisors missed in previous image.

Figure 7.32 To properly capture a lateral arch image, one must not pull the contralateral retractor very far back. Ideally, one wants to move it as close to the midline as possible to reduce "pull" on the working side lips through tension. In this case, the height of concavity for the mirror is between the lateral and cuspid.

Figure 7.33 In contrast to Figure 7.32, notice how much more the contralateral retractor is being pulled, not allowing the mirror to be rotated and how misrepresented the angles classification has become.

stretch the lips with the mirror before any discomfort actually does occur. If one does not feel that they are capturing the entire image and also feels they have the proper size mirror in place, continue to stretch a little bit further and generally one will find that the patient does not feel any discomfort. As long as the distal end of the mirror is not resting on the attached gingiva, it is almost impossible to cause discomfort to the patient. Explain to the patient that they will feel tension, but not pain, and most patients will come through the process without trouble.

Of primary importance for the right and left lateral images is a proper representation of the angles/classification of the first molar and cuspids. Many dentists attempt to capture second molars with poor angulation and the images are simply useless (Figure 7.34). It is better to capture the arch from the first molar forward in the proper angles classification than it is to capture a second molar with an improper representation (Figure 7.35). Also worth noting is that after the mirror has been placed properly, one should use high-speed suction to dry the arch. Blowing air tends to create a lot of saliva over the mirror, whereas

Figure 7.34 Although this image looks "clean," the clinician has captured the second molars at the expense of a misrepresented angles classification.

Figure 7.35 In contrast to Figure 7.34, this clinician has chosen to omit the second molar to properly position the mirror for an accurate representation of the angles relationship.

suctioning tends to dry things off. As mentioned earlier, to prevent fogging the best method is to run the mirror under hot water for a few seconds and then dry it. By doing so, the mirror will stay warm and will not fog for a period of 3–5 min, allowing the clinician to capture an ideal image without any fog.

Maxillary arch

For this image, the patient is seated flat in a chair with the dentist standing behind the patient (Figure 7.36A and B). Once again retractor and mirror use is the key for proper representation of maxillary arch. One should try to capture an image that shows all of the maxillary teeth straight on with the buccal surfaces of each tooth ever so slightly visible. The lip, nose, and retractor should be out of the way and one should only be looking at teeth and the palate. To achieve this consistently, a couple of steps should be followed: customized retractors should be used to hold only the upper lip out of the way. By using standard retractors and holding the lower lip at the same time, tension is put in places that do not allow mirrors to properly fit. By using specialized retractors, tension is released and the patient can actually open farther (Figure 7.37A and B). The patient should tip their head back after the mirror has been placed and the dentist's nose should be directly over the nose of the patient. All too often, clinicians attempt to capture this image from too far behind the patient. If this happens, the patient will appear as if they cannot open wide enough to capture an ideal image. Moving closer to the patient will assist in easier capture every time. Patients should not open fully until the operator is ready to capture the image. Having patients open for too long also makes capturing more difficult. By holding the mirror and angling it appropriately, a full arch image can be captured quickly and easily.

Mandibular arch

The final image in a standard set is the mandibular arch image. The goal is to capture all of the mandibular teeth without saliva or the tongue, or lips in the way. Unlike the maxillary arch, the clinician should be in front of the patient, not in back. By placing the split retractors on the lower lip only, tension is released from

Figure 7.36 Notice the different positions of the clinician attempting to capture a proper maxillary occlusal image. **(A)** Demonstrates proper positioning where the patient's head is tilted back and the doctor's nose is directly over the patient's nose. **(B)** Very common example of improper patient positioning where the clinician's nose is behind the patient's head. It is nearly impossible to capture a proper occlusal image from this position. Most clinicians who are in this position generally feel that they cannot get the patient to open wide enough.

Figure 7.37 **(A)** The differences in using split retractors and full retractors for occlusal images are considerable.

Figure 7.37 **(B)** Note the way the full-arch retractors get in the way of the mirror and stretch the lips in places not necessary to capture the image, thereby reducing opening.

the upper lip and the patient can open wider. The mirror should be placed in the mouth and the patient should be asked to place their tongue behind the mirror. The operator can then slowly and gently slide the mirror back in the mouth, keeping the tongue retracted behind it. With the head tilted back slightly and in a reclining flat position, the patient is asked to open as wide as they can and the image is captured. This will allow ideal capture every time of a mandibular arch. If one is "tongue tied," it is okay for the tongue to be in the image. However, wherever possible, having the tongue behind the mirror is preferable because it allows better visibility of the entire arch. Although there is as tongue to contend with, because the lower arch is generally smaller than the upper arch, the mandibular image is usually easier to capture than the maxillary image.

Image storage and presentation

Once images have been captured, there are many option regarding the importing, saving, and presentation of the images. This topic is a broad one which would require far more space than allotted here; however, there are a few key ideas to keep in mind when designing a digital image workflow.

Importing images

There are three basic ways in which an image can be imported to a computer. The camera can be connected to the computer via a cable and images are downloaded directly from the camera, the storage card is removed from the camera and the images are uploaded via a card reader (Figure 7.38A and B) or a wireless transmission of images can be accomplished using a variety of methods. The last method is brought with many potential technical glitches and in the author's opinion is not the most desireable way to bring images to an image server. Although it might seem easier to simply attach a wire to the camera, the correct choice is to use a card reader. Using a card reader reduces the wear on the camera, is faster, and allows the camera to be in use with another patient with an alternate card while the images are being uploaded from the first card.

Saving images

Regardless of the method used, one must give consideration to the software that will be used for editing and saving the images.

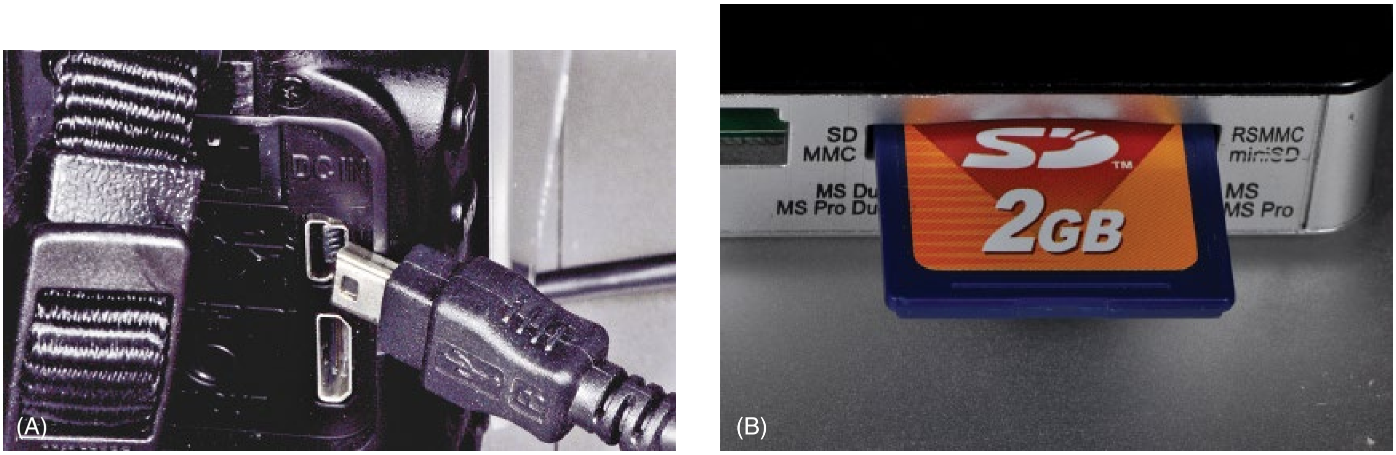

Figure 7.38 One can upload information either directly from the camera using a cable **(A)** or from the memory card using a reader **(B)**.

Figure 7.39 Notice the differences in the original **(A)** and edited **(B)** images. It's important to note that only "global" changes have been made (histogram adjustment, sharpening the entire image, rotating and flipping the arch) and not "regional" changes such as whitening a specific tooth or "morphing" proposed changes.

Just like an articulator needs to be cleaned before showing it to a patient, images should also be "cleaned up" before presentation (Figure 7.39A and B). There are a number of products available for this process, and clinicians need to determine which one is right for them. With programs ranging from free software that comes with a computer to programs that cost over $900 to dental software designed to work in conjunction with practice management programs, each has advantages and disadvantages. Dentists should evaluate each and every program and determine which one fits them best.

One must consider where to store images after editing. Many practice management programs allow images to become a part of the patient's chart; however, they might not allow the images to be transferred easily to another program should the office decide to change management software. Once should check with their software company to find out the limitations before making a decision.

Microsoft Windows Explorer comes free with every PC and is a built-in database management system. It allows one to easily and inexpensively (i.e., for free) store images in a format for quick access (Figure 7.40). The downside is that is doesn't integrate the images into the patient's chart, but every office needs to evaluate whether that is important.

Presenting images

There aren't many choices when it comes to presenting images. There are two main choices, and they simply depend on the operating system being used. If one is using a PC, then Microsoft PowerPoint is the proper presentation software. It is easy to learn, creates "shows" very quickly, and is very cost effective. If one is using a Mac, Keynote is the proper program. Although slightly more difficult to learn than PowerPoint, it allows more options, although most will never be used in dentistry. In the end, there is really little choice: PowerPoint for PCs, Keynote for Macs.

Video

There are many instances where video can be an excellent tool for the clinician. Unlike the static information presented by images, video allows a dynamic representation of the oral condition. Whether it's demonstration of lip dynamics while

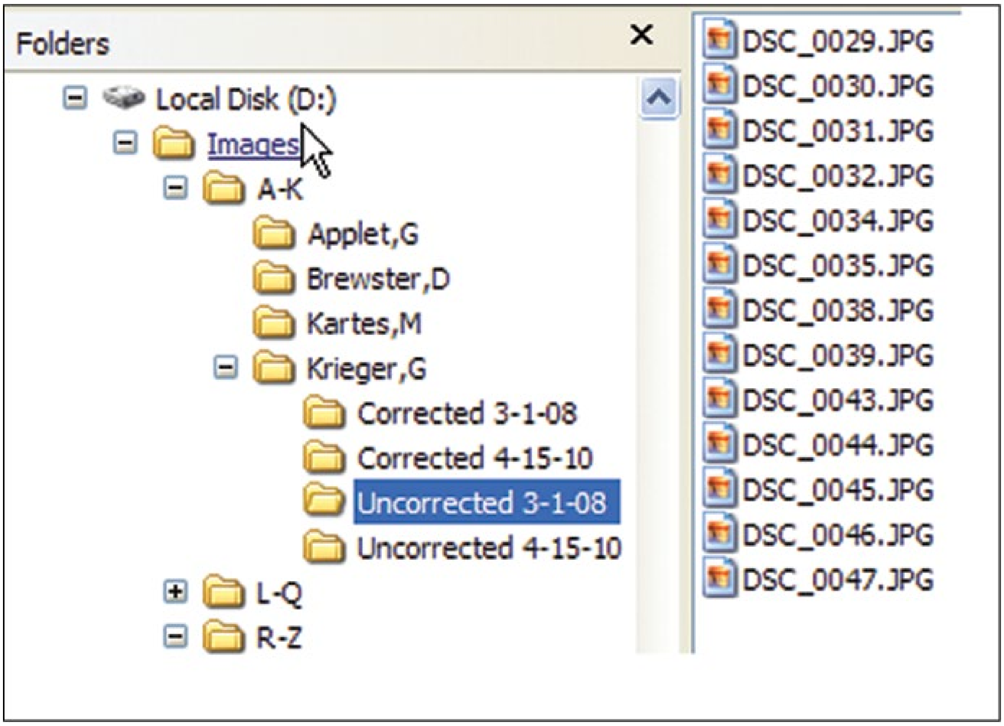

Figure 7.40 One example of database management using Windows Explorer.

speaking or smiling, or examining the facial form during function, video is an excellent way to communicate information to a laboratory or for collaboration among team members. Another excellent application for video is documentation. During the consultation, there is often so much information being exchanged between the dentist and patient that some points may be lost in the process. By capturing a video of the consultation, review of findings, and other pertinent doctor/patient discussions, one has the opportunity to archive and review the patient's exact words and gestures as they discuss goals, desires, or histories. Of course, having a video of patient discussions is always an excellent way of reviewing patient goals both during and after the treatment has been rendered. Once again, the goal is not to practice defensively, but video allows a level of protection that is not offered by any other medium, as the patient's exact words and gestures can be reviewed at any time. One does not need to spend thousands of dollars to start using video. There are many inexpensive options available today, and quality of video is not as important as photography because most video-capture devices that are in use today can offer more than enough resolution to capture what is necessary. Nonetheless, because regulations related to capture of video and audio can differ among regions, one should become familiar with their municipality's rules related to such use.

Video camera recorders (camcorders)

There are a variety of video camera recorders (camcorders) available today. They range from small, ultra-portable to large professional cameras, capable of producing exceptional-quality video. Prices can range from under $100 all the way to tens of thousands of dollars. For almost all clinicians, there is a camcorder that meets their price point. Unless a dentist is producing videos for professional purposes such as for creating DVDs or for educational use, almost any camcorder will serve; however, even for those looking for near-professional quality video, a camera to suit their needs can be purchased for far less than $1000. Advances in technology allow a $500 camcorder today to have more features and better quality than cameras 10 times their price just 5 years ago. The size of camcorders has also been significantly reduced in the past 5 years. Although helpful in terms of portability, their small size and light weight make these cameras somewhat difficult to hold still when being hand-held. It is for this reason, among others, that a tripod is always recommended when using a camcorder for clinical use. Of course, if the camera is going to be used to film a clinical procedure, having it mounted to a rigid, nonmoving system above the patient is generally the best idea. Another consideration is that many high end DSLR cameras have remarkable video capabilities. One need only switch the lens to the appropriate one for the desired effect and professional looking video can be captured. Not to be forgotten is the myriad of phones with HD video capability. Technology in the camera realm changes so frequently that it would be impossible to do justice to a review of systems, but the increase of web driven video for social media and advertising purposes means that one can quickly and easily capture simple video and post it immediately, without ever needing to use anything more than a phone.

Screen resolution and size should be taken into consideration when looking at a clinical camcorder. Like digital still cameras, most digital video cameras today have screens that are more than large enough for most users. However, screens do vary by size and the amount of pixels, and if one needs a larger screen or one with better resolution, solutions are readily available. Most camcorders being manufactured today record on microdrives or flash memory with the cost of storage being exceptionally low. Like a still camera, you need only to remove the storage media and replace it with a new one to keep recording when the card becomes full. As of right now, storage capacities are far greater than any dentist needs for clinical practice, and due to cost of storage clinicians can easily have many cards send to laboratories or collaborating clinicians. Best of all, uploading the video to a patient's digital chart is as simple as uploading a digital image. Simply connect the camera or storage device and upload.

The biggest issues facing most dentists when it comes to video capture are space and cost of good lighting systems. When it comes to lighting video, there are many more choices than simple camera-mounted lights. It is while thinking of lighting that clinicians must decide how far they are willing to go when it comes to their investment in a good lighting system. Unlike intraoral clinical photography, where the light source must be able to be directed into the mouth, limiting the choices to camera-mounted systems, videography is more like studio photography. One can set up multiple light sources around the room, each one serving a specific purpose. For instance, one could have one soft light to light the face, another to create shadows around the head and neck with a third to light up the background. For the clinician looking for this type of arrangement, it will create beautiful light once properly set up, but the cost can easily run to over $1000, and one needs a specific space with enough room to adequately position the lights, camera, and the subject. For dentists looking for simpler solutions with adequate, but reduced, quality, simple "clamp-style" lights can be used to capture all of the relevant details required for documentation and communication. These lights can generally be found for as little as $10 and are a good way to start. Don't fall into the trap of feeling that you must make this more complicated than it is. Some clinicians appreciate the "art" of video while one simply needs to remember that if the details can be visualized in the video, it is generally acceptable.

The last piece to the video puzzle is sound. Like lighting, one can make this as complicated as desired, but generally the choices fall into four basic categories: the camcorder's built-in microphone, a camcorder-mounted (shotgun) microphone, a wired microphone, or a wireless microphone. Because most clinical situations do not involve broad movement, a wireless microphone is generally not necessary and "on-board" camcorder microphones usually produce very good sound. Though generally a step up from the built-in microphone, camcorder-mounted microphones generally cost more and sound inferior to equally priced wired microphones. One can make the choice of wired microphone complicated; however, most electronic stores sell a relatively inexpensive wired microphone that will serve the needs of most clinicians quite nicely. Video is a great adjunct for the clinician who is looking for more complete documentation. However, no matter how good the quality of video, it serves as a supplement and not as a replacement for high-quality digital still photography.

Conclusion

There are many reasons why every dentist should be employing the use of clinical images on a regular basis. Using ever improving technology in today's digital cameras, capturing images has never been easier. Nonetheless, it takes time and energy to develop a system and protocol that allows the dental team to seamlessly move through the process from capture to presentation. If one approaches clinical photography like any other aspect of dental practice, with discipline and patience, it will offer a return on investment that is greater than any other tool in the office. There are many camera choices but, in the end, it is simply about picking up a camera, capturing images, and improving the patient care. Regardless of the system or program used, dentists will find that excellent images combined with good verbal skills will create a situation where patients will become partners in their care, leading to higher case acceptance and better relationships.

Additional resource

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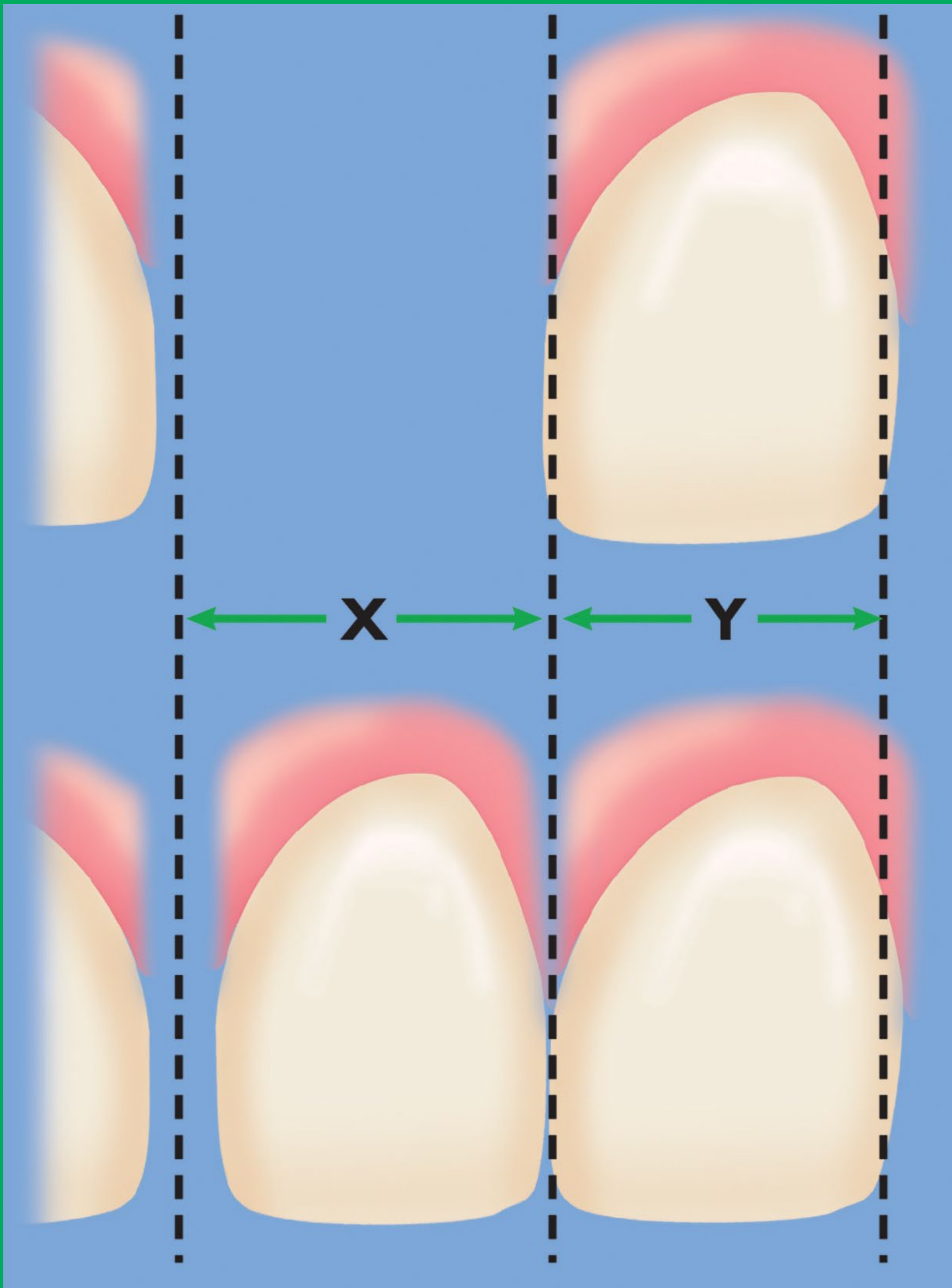
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Chapter 8 Creating Esthetic Restorations Through Special Effects

Ronald E. Goldstein, DDS, Jason J. Kim, CDT,
Pinhas Adar, MDT, CDT, and Adam Mieleszko, CDT

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One cannot overestimate the magnificent contributions that dental laboratories and specifically dental ceramists have made in the advancement of esthetic dentistry. They are true partners in our quest for the best esthetic dentistry has to offer in all forms of dental prosthesis. They help us solve problems with dissimilar spaces, irregularities, and contour and shade problems, plus so many more situations that it would be difficult to practice prosthetic dentistry without them. This chapter will deal with both simple and complex problems that dentists and dental technicians face daily. It is our hope that you will better understand what it may take to better improve your restorations, since our overall goal is always to please our patients.

Special contribution was made to this chapter by Lukus Kahng, CDT, Nasser Shademan, and Guilherme Cabral, DDS, CDT.

Seeing teeth in a different light

When a technician fabricates teeth in a dental lab, he or she does so under the bright fluorescent lights typical of any modern dental laboratory. The individual restorations look great when bathed in direct light from all sides, and when placed on a typodont or stone model. Likewise, when a dentist receives the restoration from the lab and places it in the patient's mouth for the first time, it will be in a controlled situation: the dentist asks the patient for a big smile while shining the operatory light on those new pearly whites. They look just as great as they did in the dental lab, and both the dentist and patient are happy with the results. However, once the restorations are permanently seated in the patient's mouth, and the patient steps outside of the dental office, the teeth are no longer in a staged

Ronald E. Goldstein's Esthetics in Dentistry, Third Edition. Edited by Ronald E. Goldstein, Stephen J. Chu, Ernesto A. Lee, and Christian F.J. Stappert.

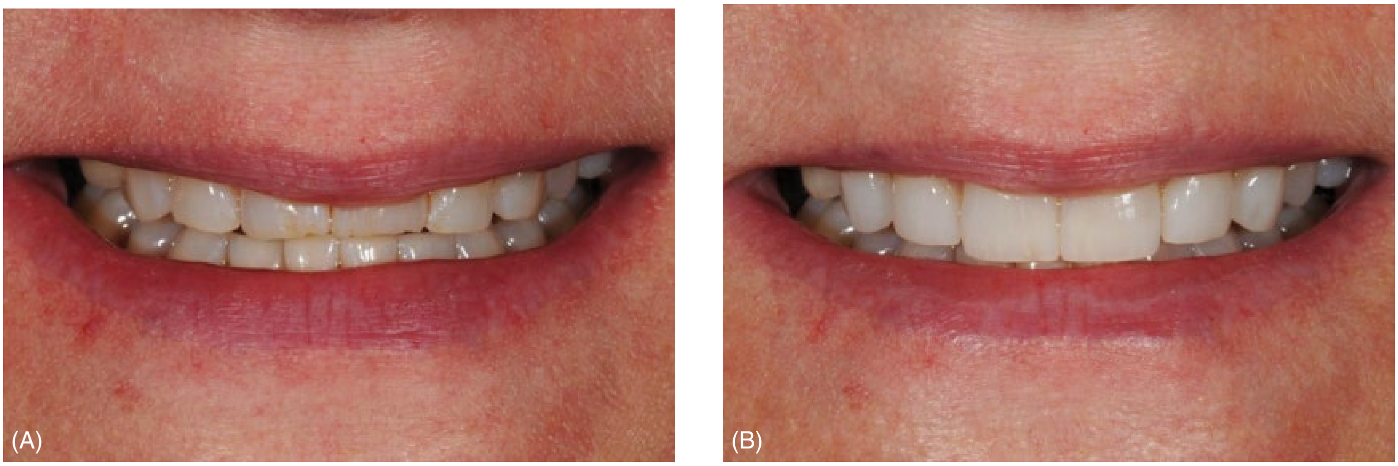


Figure 8.1 **(A and B)** Correction of negative smile line with porcelain veneers.

or controlled environment. The patient's teeth are now framed by the mouth, lips, and face. The mouth is not static but always changing as we smile, frown, laugh, and speak. The appearance of our teeth change as our facial features interact with available light that strikes our teeth. Various types of light affect the appearance of the teeth: daylight, incandescent, fluorescent, the strength and brightness, direct, indirect, light from above and below, and light that is diffused and shadowed by the shape and size of the lips. Our environment is filled with these various types of lighting that can affect the appearance of shape and color of teeth (Figure 8.1A and B).

Positive and negative smile line

Smile line refers to the line formed when going along the incisal edges of the upper front teeth. This line should roughly follow the contours of the lower lip line. Teeth should always be arranged or in alignment with the lips (Figure 8.1A). The more curved the lower lip, the more curved the incisal line of the upper teeth should be (Figure 8.1B). In most cases, the central incisors should be equal to or slightly longer than the cuspids.

Lips and gums: the frame of our teeth

Teeth are framed by lips and gingival tissue. Actually, the lips act more like the frame, and the gingival tissue acts as the backdrop, or the stage on which the teeth stand. Both the lips and gingival tissue affect the way we perceive the color and shape of teeth. The lips act like a curtain and can produce a shadowing effect on teeth. Gingival tissue is naturally light-reflective and light-transmitting; light will pass through it to varying degrees of intensity, depending on the tissue thickness. Because the gingiva transmits light, darker roots, implants, and metal posts will also affect gingival color. For example, if the root is darker, the restoration will look slightly darker near the gum line. It's that sensitive, and it is little nuances such as this that we must always be aware of, as even tiny details can have a big influence the way we perceive the color and shape of the restoration.

The importance of lip thickness on teeth appearance

The structure of the lips has much influence on the appearance of the restored teeth. Thicker lips can create a shadowing effect on teeth, which can make a white crown take on a gray cast once seated in the mouth. When the lips come down over the teeth, the area where the line angle begins to roll off becomes darker, and the tooth looks narrower. With the lips pulled back, such as when using a retractor, everything looks bigger because there is no shadowing effect.

Thin lips = close lip distance from dental arch. No adjustment to translucency: teeth are virtually unobstructed and unaffected by thin lips. When designing restorations for a thin - lipped person, there is no need to deviate from the natural translucent level.

Medium lips = average lip distance from dental arch. Adjustment to translucency: with a medium smile line, the restorations need to be brighter. A modified value ranging between 10 and 20% greater than natural translucency would be sufficient..

Thick lips = far lip distance from dental arch. Increased opacity: a person with thick, full lips will reveal a very small fraction of their teeth, which appear even less prominent due to shadowing. Although it may seem counterintuitive, creating restorations with increased opacity would help make the teeth appear brighter and more natural.

Illusions

Creating illusions is one of the most important objectives of esthetic dentistry. The ability to make a tooth look wider or thinner, smaller or larger, is an invaluable aid when solving difficult esthetic problems. Esthetic effects of dental restorations are controlled by factors such as form, size, alignment, contour, surface texture, and color of the original teeth. The patients' lip line and gingival tissue can also make a difference in the esthetic effect of dental restorations. When using restorative or prosthetic techniques on one or more teeth, duplicating the conditions and esthetics of the remaining natural dentition should be the ultimate goal. When patients request a "natural appearance," it does not necessarily mean that they want an exact copy of the adjacent or opposite tooth as the goal; the dentist frequently must alter tooth form by illusion to accomplish the desired esthetic results. The presence of space limitations—too much or too little—or other problems may make it impossible to duplicate the original tooth. Nevertheless, in many esthetic situations, the desired objective is to duplicate the natural teeth to attain symmetry in the smile. This chapter presents many of the problems encountered in esthetic restoration and offers techniques of illusion that help overcome these barriers to a desired appearance.

Principles of illusion

Several basic principles of illusion, such as those used to describe form, light, shadow, and line, may be applied specifically to dentistry. In the presence of excess light or in the absence of light, form cannot be distinguished since shadows are necessary to help the viewer perceive the contour or curvature of a surface. The edge of any form is described as a line; therefore, an object with many edges can be drawn "linearly" with little difficulty in visual interpretation (Figure 8.2A). If the object has smooth curved surfaces rather than edges, the form may not be easily comprehended (Figure 8.2B), unless one brings light and shadow into play (Figure 8.2C).

Light has the ability to change the appearance of a surface by its relation to that form. This ability relies on an observer's learned, intellectual approach to perception. For example, we learn that sunlight comes from above; therefore, when we view geometric designs drawn with another light source, an illusion is created. The classic example of this is where three cubes are seen when one side of a figure is up, but five appear when the figure is turned around (Figure 8.2D). This manipulation of light and perception is used in esthetic dentistry to create the ideal dentition: by staining to simulate shadow, creating appropriate shadows through the arrangement of teeth, and shaping or changing the contours of a tooth.

The relationship of lines plays an important role in creating illusion. To anyone who is not perceptually sophisticated, the vertical line seen in Figure 8.2E appears longer than the horizontal line because horizontal movements of the eyes are executed more easily than vertical movements. More time is spent "seeing" the vertical line, so the brain interprets the longer time spent as being due to a longer line. Figure 8.2 F illustrates the effect of convergent and divergent lines. One's attention is directed outward on the right and inward on the left, altering perception, even though both lines are the same length.

The application of light, shadow, and linear elements to illusion and their relationship to each other is seen in Figure 8.2G1. The folded piece of paper in this line drawing may be interpreted as being folded forward or backward. When shade is applied to this linear image (Figure 8.2G2 and 3), form is more easily understood (arrows indicate direction of light). This illusion is aided by the fact that white "comes forward" while dark recedes.

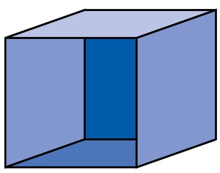
(A)


Figure 8.2 **(A)** Visual interpretation is relatively simple for a linear drawing with many edges.

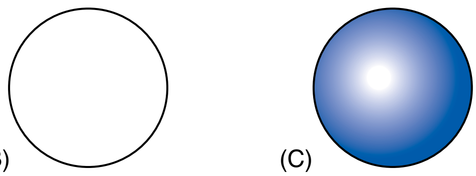

(B) (C)

Figure 8.2 **(B and C)** **(B)** Form is not so easily understood in an object with smooth curved edges. **(C)** Added light and shadow help to clarify form interpretation.

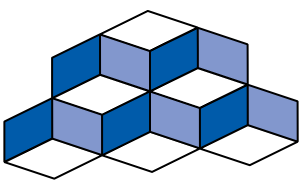
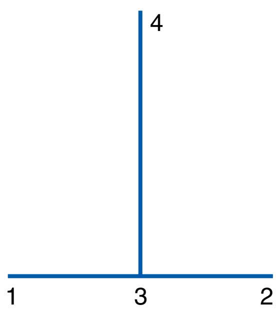

(D)

Figure 8.2 **(D)** Like the illusion created in this drawing, the perception and manipulation of light are used in cosmetic dentistry by staining, shaping, and contouring the dentition.



(E)

Figure 8.2 **(E)** Although the lines are of equal length, the vertical line appears longer because the brain spends more time "seeing" the vertical and interprets longer time as longer length.

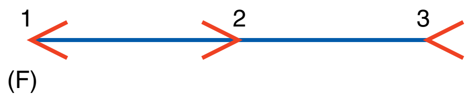


Figure 8.2 **(F)** Illusion is created by the angled direction of the arrows. The outward position of the arrows of line 1–2 gives the illusion that it is shorter in length than is line 2–3.

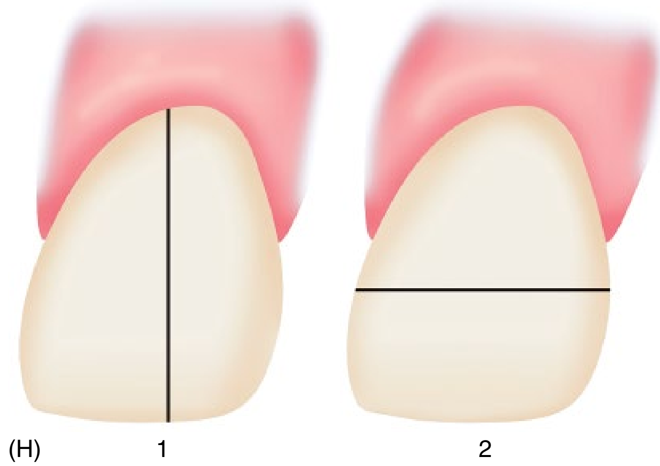


Figure 8.2 **(H)** Although teeth 1 and 2 are equal in size, the accent lines make tooth 1 appear longer and tooth 2 appear wider.

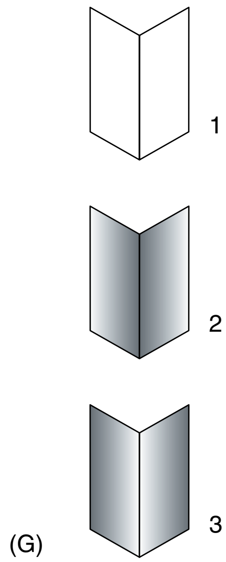


Figure 8.2 **(G)** The interpretation of whether this folded paper is outward or inward can be more accurate when shading is added.

We are accustomed to seeing distant objects as darker and receding objects as darker or shaded from light.

Given two teeth possessing identical shading, the presence of vertical and horizontal accent lines can create the illusion of length or width, respectively (Figure 8.2H). Although one figure may seem wider or longer than the other, both are identical in size, illustrating that combinations of light, shadow, and emphasizing lines are essential in creating effective illusions. Illusions in dentistry are created using three techniques, which are discussed in the following text:

1. shaping and contouring
2. arrangement of teeth
3. staining.

Shaping and contouring

The most frequent illusion is the creation of a different outline by shaping or carving the tooth. The eye is quite sensitive to silhouette form, so the incisal edges of a relatively white tooth will be easily seen silhouetted against the shadows of the oral cavity. The slight alteration of tooth structure done by shaping can alter this silhouette form to create a desired illusion.

Basic principles of illusion regarding shape and outline:

- Vertical lines accentuate height and de-emphasize width.
- Horizontal lines accentuate width and de-emphasize height.
- Shadows add depth.
- Angles influence the perception of intersecting lines.
- Curved lines and surfaces are softer, more pleasing, and perceived as more feminine than sharp angles.
- The relationship of objects helps determine appearances.

The creation of successful illusions is an art that requires advance planning. If the patient has a size, space, or arrangement problem that will need to be solved through illusion or other special effects, the following actions should be considered:

- Look for problems during the clinical examination and when reviewing the study casts.
- Consider whether repositioning through orthodontics, periodontics, preprosthetic surgery, or any other means will lessen or eliminate the problem. If so, the patient should be encouraged to undergo such treatment since the best illusion is none at all.
- If it is necessary to create illusions, begin planning by determining how much tooth reduction is necessary, allowing for any increase or decrease in the size of the intended restoration. Computer imaging will help you see which possibilities will have the best potential solution. Use the images, incorporating the illusion you have created, to show your patient all the possibilities and how his or her new smile can look.

Once this determination has been made, make detailed notes on the shade chart. The teeth are then prepared and the temporary restoration is fabricated. It is essential to make the temporary restoration after tooth preparation and before the final impression is made. The temporary restoration provides a preview of the illusions that are planned for the final restoration and also gives the dentist a working model on which any necessary alterations in the treatment plan may be made. Therefore, the temporary restoration acts as the blueprint for a successful esthetic illusion. Since the final impression will be made at a subsequent appointment, the patient has time to adjust to and voice any criticism of the temporary restoration. The dentist

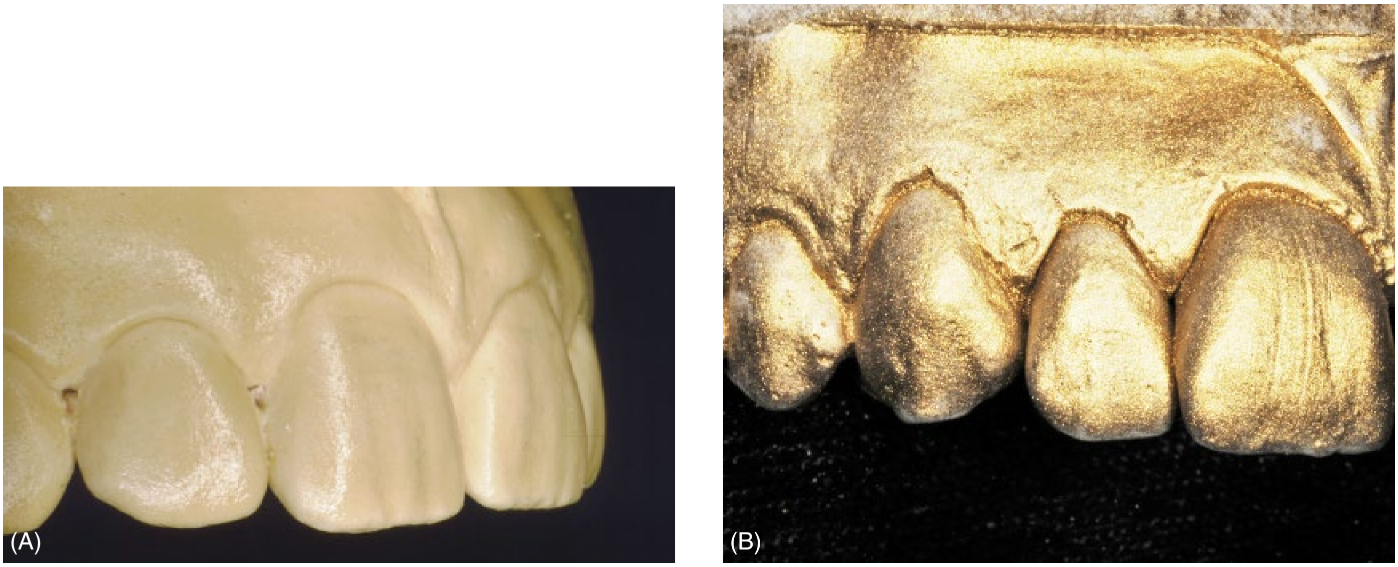


Figure 8.3 **(A and B)** A study cast in yellow or green stone is sprayed with model spray **(A)** or gold powder **(B)** to show texture and highlights.

also has the additional opportunity to alter the tooth preparation, the surrounding tissue, and the shape, size, or arrangement of the temporary restoration. During this appointment make an impression and study cast of the finished temporary restoration. (This can be done while waiting for the anesthetic to take effect for the final impression.) Send this impression, along with the final impression, to the laboratory. This will eliminate any guesswork by the laboratory technician as to the illusion desired.

The next step, shaping and contouring, is done at the try-in appointment. This is the time when any necessary correction through illusion is performed (see Chapter 43). After fitting the restoration to the teeth, examine it for size-of-space deformities. Before correcting with a disc or porcelain stone, outline the intended correction with a black alcohol marker to provide greater perspective. Then proceed with the necessary shaping and contouring. Although the eye is more sensitive to outline than to surface form, it is surface contour, a basic part of good illusion, which controls light reflection. Application of surface characterizations should be done with this in mind.

When planning surface characterizations, these procedures should be followed:

- Study the teeth being restored prior to tooth preparation.
- Study adjacent teeth before and during treatment.
- Make notes on the texture desired. Include convexities and concavities, grooves, fissures, stains, shadows, and highlights. Determine whether the lines are vertical, horizontal, or a mixture of both.
- Take an accurate study model and pour it in yellow or green stone to best show the texture (Figure 8.3). Use model spray (J.F. Jelenko and Co., Kuzler Lab Products) to bring out the highlights (Figure 8.3A). Gold powder can also be used to accomplish a similar effect (Figure 8.3B).
- Then take a digital photograph of the adjacent or opposite teeth. This can be helpful in observing texture and its influence on light reflection.
- Match the degree of smoothness or roughness of adjacent teeth.

When there are no guidelines and the anterior teeth have faulty or unesthetic restorations that must be replaced, it is important to remember that in older patients the enamel is usually worn on the incisal edges and is generally smoother in overall surface texture; younger patients have more textured teeth. If you observe the opposite arch, there may be indications of the type of texture required. Characterized or textured surfaces produce shadows, and shadow position can determine how the mind will interpret contour. A tooth with a shadow or shading on the incisal portion will cause the gingiva to appear more prominent. Shadows or shading can also cause a 2D object to appear 3D and can change the apparent length, width, or height.

Arrangement of teeth creates illusion

The second most frequently used technique for creating illusions involves the arrangement of the teeth being restored. The arrangement of teeth can be modified or changed to create a special esthetic effect. The position or arrangement of teeth can create the illusion of decreased or increased width. If a tooth is rotated distally, it will take on a thinner appearance (Figure 8.4A and B). Conversely, if it is rotated mesially, it will look wider (Figure 8.4C and D).

Alterations of the axial inclination of labial/lingual and mesial/distal surfaces can dramatically change appearance. This is accomplished by placing or building one tooth in front of, behind, overlapping, or rotated with respect to another. Planning must be done at the outset.

Lombardi[1] offers good, simple advice for those taking the first steps in altering tooth arrangement. His one, two, three guide

Figure 8.4 **(A and B)** Narrow, thinner look created with distal rotation of teeth.

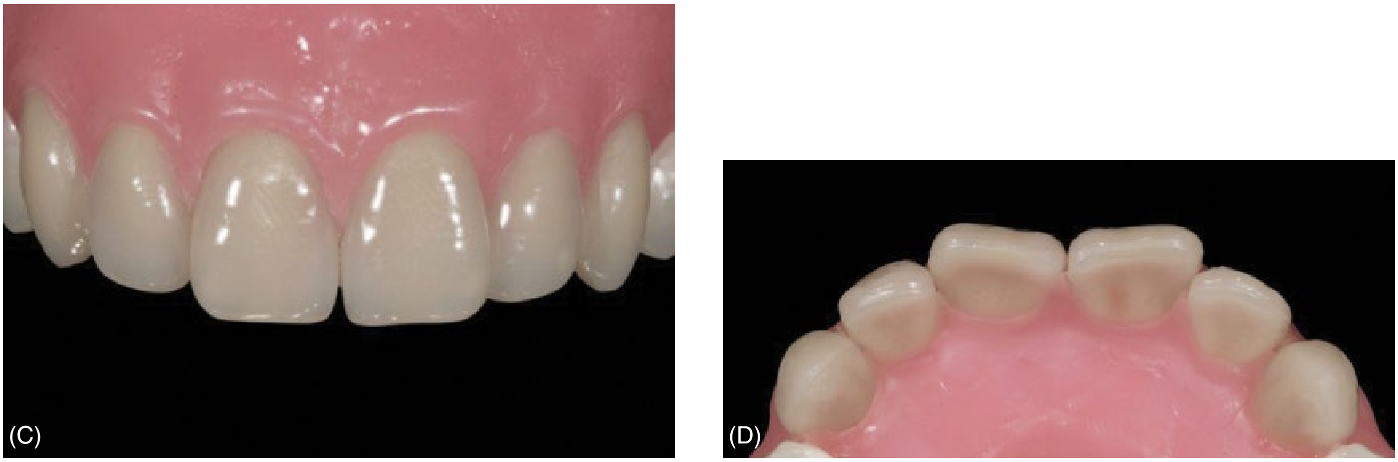


Figure 8.4 **(C and D)** Broad, wider look created with mesial rotation of teeth.

includes incisal modifications (Figure 8.5). One refers to the central incisor, which expresses age; two to the lateral incisor, which expresses sex characteristics; three to the cuspid, which denotes vigor. This guide shows how to use the "negative" or dark space behind the teeth. Alteration of incisal edges, which are then silhouetted against the dark intraoral background, helps to create a nearly limitless variety of illusions.[1]

To predict what type of arrangement will be necessary, construct the temporary restoration before taking the final impression. The effect can then be seen in the temporary restoration or fixed partial denture, and, if necessary, the preparation can be refined before taking the final impression. The patient is allowed time to live with the newly constructed restoration, evaluate acceptability, and express any desires for change. This is especially important in cases where a nonideal arrangement such as overlapping or crowding is to be included. Unless patients have a chance to visualize the arrangement conceived by the dentist, they may react unfavorably when the final restoration is inserted. This can be avoided by allowing the patient to try the restoration and to understand the

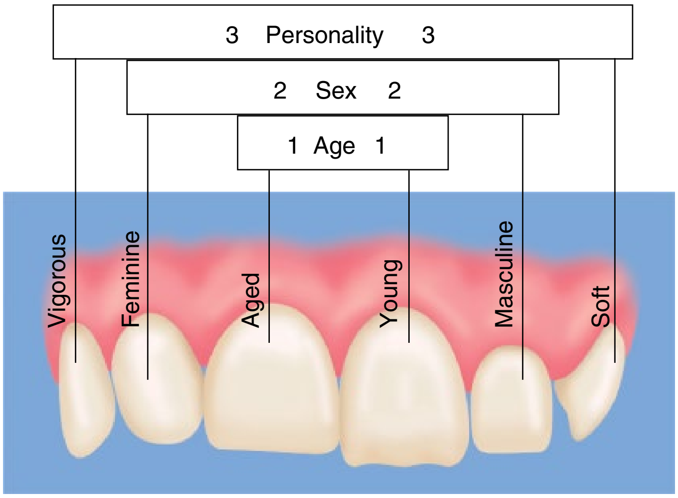


Figure 8.5 Lombardi's guide for altering tooth arrangement illustrates incisal edge modifications that affect personality, sex, and age characteristics.

Figure 8.6 **(A)** A smoother surface results in greater light transmission through the tooth, which results in increased translucency and lower value.

Figure 8.6 **(B)** Incorporating greater texture into the restoration will reflect more light, so the tooth can be designed with a slightly higher value while maintaining a natural appearance.

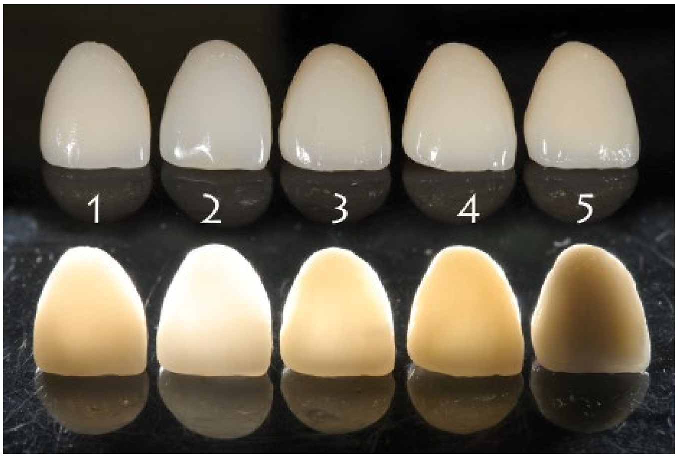


Figure 8.6 **(C)** Note the difference in light interaction of restorations depending on substructure. Top row: reflected light; bottom row: transmitted light. Figure courtesy of Adam J. Mieleszko.

Figure 8.6 **(D)** Split view of the same restoration with different stump preparation color. Notice the value decrease with darker preparation. Figure courtesy of Adam J. Mieleszko.

reasons and space limitations that caused you to elect this type of illusion. For example, a patient who had overlapping centrals may not realize that overlapping laterals can be much more attractive when combined with straight centrals. By creating the new appearance in the temporary, the patient can gain the necessary confidence that will make the final restoration acceptable. It is difficult for most dentists to look at a particular patient and tell what type of tooth arrangement will be best suited for that type of face.

Although there is no convincing research to show that certain types of faces should have certain types of teeth, there are principles that can aid you in selecting the appropriate appearance. These include understanding the patient's personality, age, and esthetic wishes. It is only through trial and error that the delicate balance that creates harmony can be achieved. This takes time and the willingness on your part to experiment and re-experiment in the temporary stage. It is a mistake to wait until the try-in appointment to create or recreate arrangement possibilities. The try-in appointment already takes a great amount of your time and skill to make a properly chosen restoration appear as natural and esthetic as possible.

Special effects by manipulating teeth shape and arrangement

Modifying the surface texture of a tooth will affect its luster and brightness. A smoother restoration surface results in greater transmission of light through the tooth, which in turn results in increased translucency and lower value (Figure 8.6A). If we incorporate a lot of texture into the restoration, the tooth will reflect more light, so the tooth can be designed with a slightly higher value and still look natural (Figure 8.6B). In order for the translucency level, opalescence, coloring, and fluorescence of a tooth to "behave" correctly in the mouth, these characteristics need to be intrinsic—they need to be built in to the actual ceramic structure, rather than applied externally to the surface using stains and glazes.

Substructure material choices and their influence on tooth appearance

Choosing the correct substructure for a restoration is often overlooked, as we tend to pay more attention to the build-up or layering ceramics; however, substrate materials affect light in different ways, and it is important to know what those effects will be ahead of time. Additionally, the color (lightness or darkness) of the patient's tooth stump preparation may affect the final appearance of the restoration (Table 8.1, Figure 8.6C–E).

Staining

Previously, no dental material had the same ability as enamel to absorb or reflect light under all conditions. However, the development of a new generation of ceramic materials for both ceramic and ceramometal restorations makes it much easier to mimic the natural dentition. Staining is the final opportunity to enhance the original shade and to correct or improve restorations. Even though illusions through contouring may have been attempted, a combination of contouring and staining may be necessary to accomplish the desired results. Figure 8.7A illustrates a successful mandibular reconstruction made necessary by periodontal disease. The patient wished to maintain a natural appearance through crowning; effective shading, shaping, arrangement, and staining accomplished this goal (Figure 8.7B).

Staining may be used not only to duplicate the natural variations in tooth color (see Chapter 10 for a full discussion) but also to create and enhance illusions through manipulation of shape and surface characterization. There are two basic aspects of color that you can use to create and enhance illusion. First, by increasing the value of the color (increasing whiteness), you will make the area to which it is applied appear closer. Second, by decreasing the value of the color (increasing grayness), you will make the area to which it is applied appear less prominent and farther away.

Although most dentists leave staining to the laboratory technician, it is desirable to have a small porcelain oven in the office where this type of correction can be done. Staining in the office saves time, and it allows experimentation with different stains until the desired effect is achieved. To rely entirely on the laboratory technician to create the desired stain may require several visits by the patient before the effect is successfully achieved. Unfortunately, after a few visits, the patient or dentist may become impatient and insert a restoration that could have been further improved with additional staining. If the dentist does not employ a laboratory technician, an interested dental assistant who likes to paint is a good candidate to learn the art of staining porcelain or acrylic and may become quite proficient. An important consideration is to refer to a natural tooth while staining. A model constructed from extracted teeth is also an excellent aid when attempting to achieve a more natural result. Whenever possible, staining should be incorporated into the body of the restoration. The closer to the final shade the opaque and body layers are, the more lifelike will be the result. Opaquing material of various colors can influence the appearance of porcelain and add depth to the color. Basic modifying colors can be used for certain effects. Ideally, surface stains should be used only to add the final touch of realism and exactness to the restoration. Figure 8.8A shows

Table 8.1 Substructure Material Choices and Tooth Appearance

Type of Material	Light Reflected	Light Transmitted	Tooth Stump Effect
Feldspatic ceramic	Low	High	High
Lucite reinforced	Low	High	High
Lithium disilicate	High	High	Medium low
Zirconia	High	Low	Low
Metal	High	Low	No effect

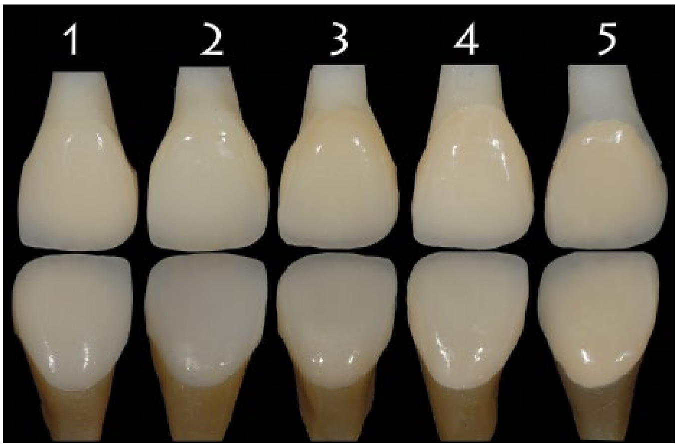


Figure 8.6 **(E)** Influence of stump preparation on final color is evident with all restorations except those with a metal substructure. Top row, light stump; bottom row: dark stump. Figure courtesy of Adam J. Mieleszko.

Figure 8.7 **(A)** This patient required anterior splinting to correct the effects of mandibular periodontal disease and therapy which left her with large interdental spaces.

Figure 8.7 **(B)** A combination of staining, contouring, and effective arrangement of the mandibular anterior crowns gave this patient a natural-appearing result.

Figure 8.8 **(A)** A crown with a zirconia core and a layered ceramic buildup.

crown with a zirconia core and a layered ceramic buildup. Finally, Figure 8.8B shows the crown after glazing. Note the many colors used to create a more realistic and natural looking tooth.

Techniques used with surface stains

- **Glaze the crown first**. This allows surface stains to be applied over the glaze in a separate operation. However, Aker et al.[2] state that unless a second glaze is applied over the surface stain, the resultant wear will be accelerated approximately 50%, wearing through the stain in 10–12 years.
- **Cut into the porcelain**. The porcelain may be slightly cut back and fluorescence stains placed on the surface. An incisal or translucent opalescent porcelain is then added and the crown is reglazed (Figure 8.9A and B).
- **Combine glaze with stains**. Apply the glaze first, using the technique described here:

1. Mix the glaze to the consistency of thick cream.
2. Moisten a dry glaze brush in a small pool of liquid medium and squeeze any excess medium from the brush.
3. Load the brush with glaze mix.
4. Cover the surfaces to be glazed with a thin, even coat.
5. Vibrate the tooth using a serrated instrument to make the glaze flow evenly.
6. Rebrush only where necessary to assure a smooth, even coat with no pooling.
7. Stain as desired.

Figure 8.10A–D illustrates this technique at the try-in appointment. After the restoration has been thoroughly checked for fit, shape, and occlusion, it is removed and cleaned (Figure 8.10A). The preselected stain is mixed as instructed in step 1 (Figure 8.10B). The stain and glaze combination is applied to the

Figure 8.8 **(B)** The completed crown after firing, glazing and polishing. Note how the deep orange-brown modifier provides a more realistic crown.

restoration (Figure 8.10C) and fired at 960 °C (1760 F). The result after firing is seen in Figure 8.10D. When selecting a particular shade of stain, mix enough powder into the liquid medium to achieve a creamy mix. Refer to a color wheel to observe the effects of combining hues.

The decision of which type of stain to use will be based on the degree of shade alteration required and observation of the type of stains in the natural tooth under fluorescence (Figure 8.11A and B). Note that although the stains appear similar in conventional light, they change their behavior under black light (Figure 8.11B). Lack of fluorescence is evident in the conventional stains. The final crowns should look natural both in normal light (Figure 8.11A) and black light situations (Figure 8.11B and C).

When first building the porcelain, it is important to select the proper shade from the guide. If a guide tooth selection cannot be made, it becomes necessary to establish a basic shade with stains. Select a guide tooth that is lighter than the desired one and free from undesirable underlying hues.

Tips on technique

- Keep stain colors pure. Constantly check the porcelain for dirt specks. If you find any, cut back the porcelain and repair. Keep colors far apart to avoid contamination. Wearing magnifying loupes, lenses, or telescopes (Designs for Vision) is helpful.
- If your experience in the art of staining is limited, do not overstain.
- Staining should be done on a smooth surface. The tooth can be textured, but the surface should be free of pits and stone marks. Diamonds may scar the surface and puddles can form. An even, all-over texture is best. Avoid using any stones that could leave a residue that could be incorporated into the porcelain. (Use Dedeco [Dedeco International Inc.], Shofu [Shofu Dental, Lab Division], or Busch [Pfingst and Co.] chipless porcelain stones.)
- Opaque white can be applied better when a small amount of glaze is mixed with it.

Figure 8.9 **(A and B)** This is a good example of internal characterization to mimic the natural effects sometimes seen in the naturally aged dentition.

- While wet, stains have essentially the same color value as when fixed.
- Stains should be dried carefully in front of the furnace door so they do not run or bleed.
- When simulating a "check line" or microcrack with surface stains, apply a broad line first with the chosen shade of stain (Figure 8.12A). Using a flat edge of the brush, carefully wipe away each side of the line until the desired thinness is achieved (Figure 8.12B). After inserting additional characterization as needed, fire the crown according to instructions (Figure 8.12C). Similar effects can be created with white microcracks instead of brown (Figure 8.12D). This can be helpful in younger patients.
- The guides for staining to alter shades and add characterization (Tables 8.2 and 8.3) should serve as a reference to help solve esthetic problems or to improve results. Some of the techniques can make the difference between unenthusiastic patient acceptance and complete satisfaction.

Too many firings may cause the restoration to lose its original vitality and alter shading. However, Barghi[3] states that repeated firings (up to nine) do not normally affect the porcelain shade but that repeated firings could cause reduction and loss of

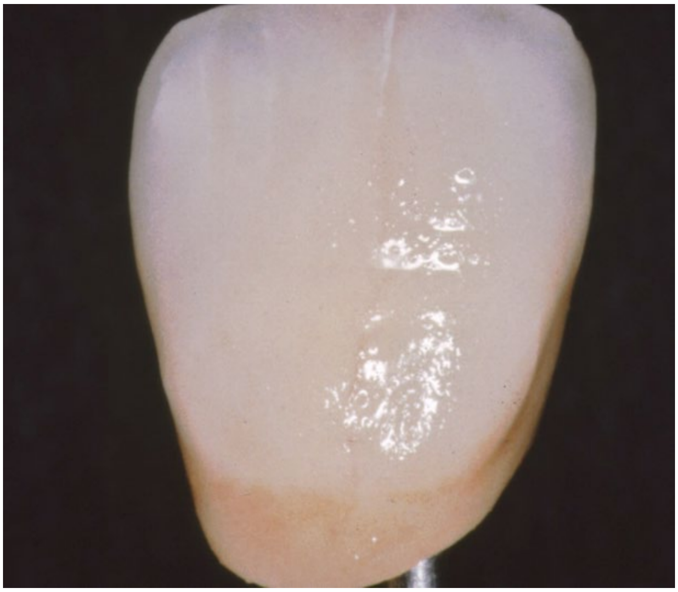


Figure 8.10 **(A)** A combined glaze and stain technique is shown here at the try-in appointment. The restoration has been checked for fit, shape, and occlusion.

Figure 8.10 **(B)** The appropriate shade of stain is mixed to a thick, creamy consistency.

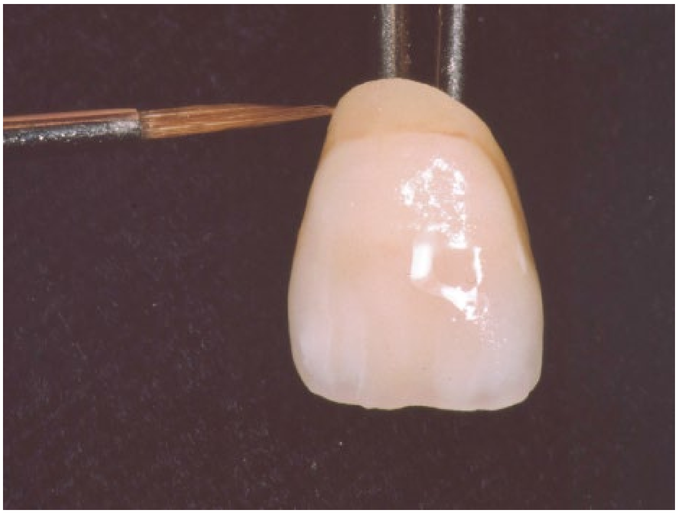


Figure 8.10 **(C)** The stain and glaze mixture is applied to the restoration.

Figure 8.10 **(D)** The final result after firing. Note how the contrast between orange, brown, and blue can help create a more natural look.

autoglaze in porcelain. Nevertheless, try to incorporate as much staining as possible into the original bake and glaze. Place stains on the tooth and fire the restoration at a temperature slightly less than for glazing until all the desired effects are achieved. Then glaze at the proper temperature. Multiple staining effects are better achieved in this fashion.

Communication with the laboratory

Proper communication with your laboratory is essential if you expect to receive an accurate rendition of your esthetic concept. One of the most frequent complaints dentists have is that their laboratory did not return a finished product that had the anticipated esthetic qualities. There are five basic ways to achieve proper communication:

1. Computer imaging can provide a good idea of what the final result should look like. This is especially true if the images are taken by an intraoral camera, which allows occlusal and labial views to be included. Thus, the correction can be visualized on two or more planes. Eventually, computer-aided design/computer-aided manufacture (CAD/CAM) will provide the most useful information to the technician. If your technician does not have a direct link to your computer but has a similar system, you can arrange an email or file transfer with your intended results; otherwise, send a printout.
2. A waxed model may be sufficient to illustrate to you, your technician, and your patient the suggested changes.
3. Another effective way to let patients visualize just how their esthetic correction will appear is to apply ivory wax directly

Figure 8.11 **(A)** The final close-up smile shows the two new ceramometal crowns combined with porcelain veneers.

Figure 8.11 **(B)** This photograph of two central incisor crowns taken under black light demonstrates that they did not fluoresce like the adjacent natural enamel, causing the crowns to appear different under various light conditions.

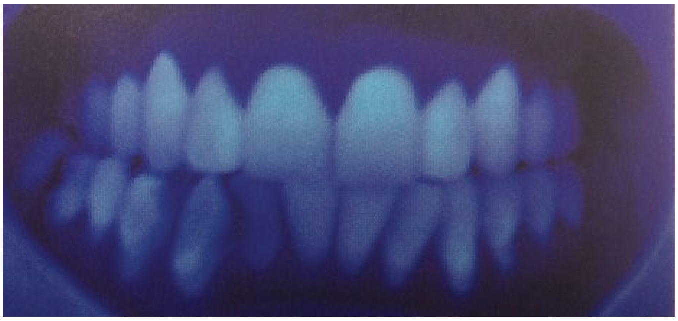


Figure 8.11 **(C)** Black light helps to show how naturally the new crowns and porcelain veneers fluoresce.

to the teeth. Use cotton rolls or plastic retractors to keep the teeth dry, and place a 2 × 2 gauze over the lower lip to protect it in case the hot wax accidentally drips. Flow tooth-colored or ivory-type wax onto the incisal edges of the teeth, shape with a wax carver, and then show your patient the anticipated result. Be sure to remind the patient to hold the mirror at arm's length to get the proper illusion.

4. The same effect can also be achieved by using the vacuform matrix/composite resin technique. Take a diagnostic cast and wax-up the intended correction. Make a plaster model of the corrected wax-up and then make a vacuform matrix of this. Fill the inside with old or outdated composite resin and place in the mouth without polymerizing. An alternative is to line the inside of the vacuform matrix and polymerize only after eliminating undercuts by trying in the matrix several times.
5. To assure that a restoration will have the desired shape, contour, and size when it is returned from the laboratory, detailed instructions must be written. Written communication may be the only source of information or may be a secondary

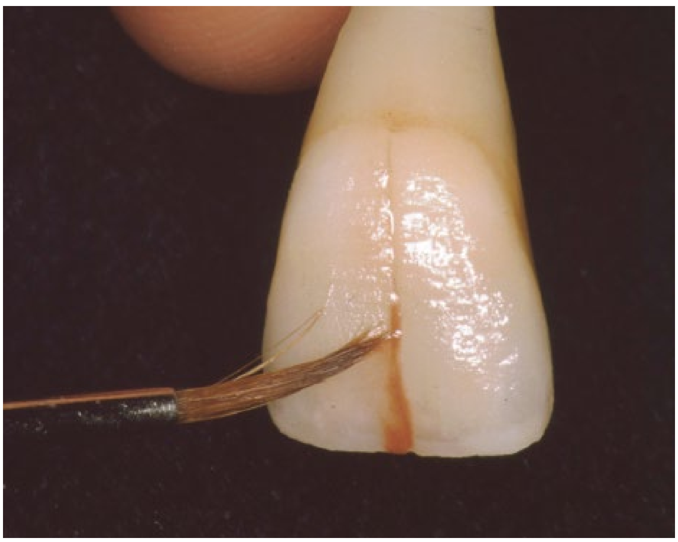


Figure 8.12 **(A)** A "natural-looking" microcrack is added by first applying a broad band of the selected shade of stain.

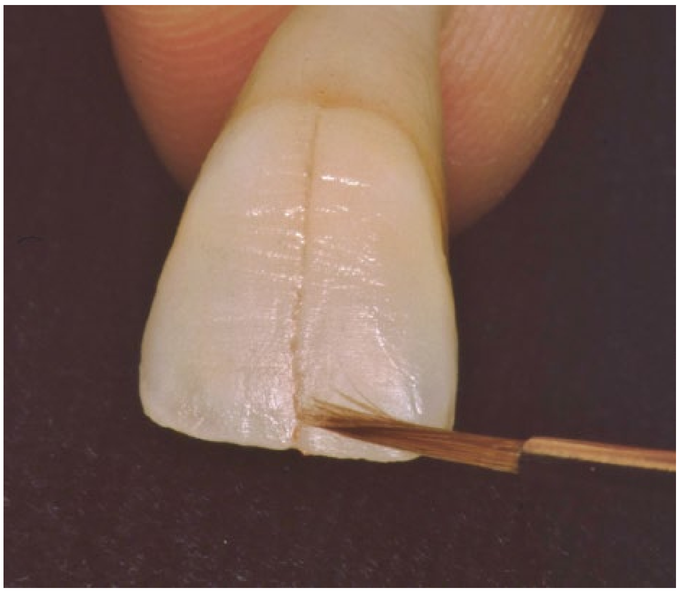


Figure 8.12 **(B)** The flat edge of the brush is used to achieve the desired thinness.

Figure 8.12 **(C)** The final result including additional "characterizations" after firing gives the appearance of realism.

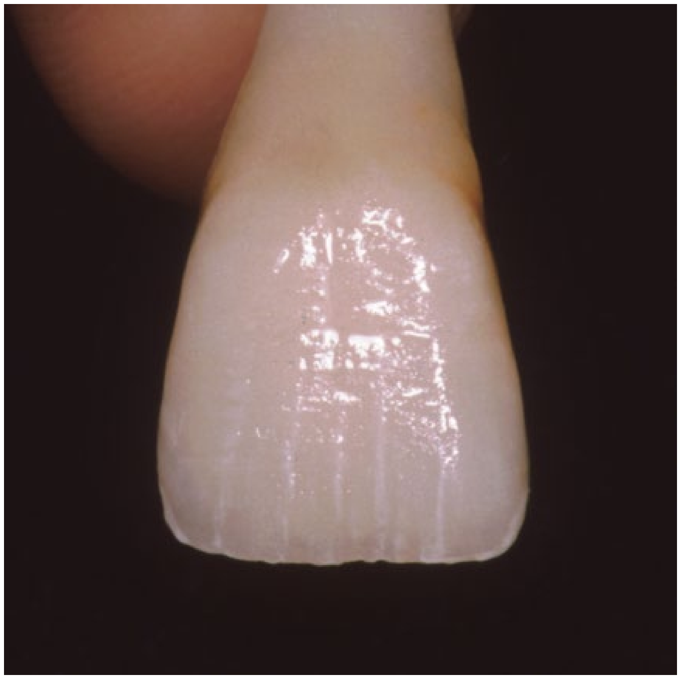


Figure 8.12 **(D)** These white "microcracks" may be more esthetically pleasing, especially for a younger patient.

source. Carefully written instructions are essential and leave no room for misinterpretation. For example, in the case of a diastema, the technician should be instructed to carve the contact areas to the lingual surface in order to diminish the apparent width of the crowns. This kind of communication makes it more likely that you can achieve the desired results before the restoration is even tried in the mouth.

In cases of illusion through arrangement, a diagram on the prescription blank is most helpful. If you want a tooth overlapped, rotated in labio-or linguoversion, or in any other position not commonly used by the laboratory, planning must be done at the outset. If you desire the ultimate in esthetics, then spend the necessary time to write a detailed, graphic laboratory prescription.

Providing your technician with digital photographs of whatever you need to communicate can help the technician better understand both your patient's esthetic problem and what you want to accomplish in the restoration. Try taking a close-up photograph holding the chosen shade tab against the area to be restored. Often, even slight differences in chroma and value can be seen. The more pictures you take, the better the technician will be able to visualize what he or she must do to help achieve the desired esthetic result.

Shade guide

One of the biggest frustrations for the ceramist is interpreting what both the dentist and patient visualize. Unfortunately, typical shade guides fail to show the range of special inlaid effects that natural teeth possess. One such system has been developed by Kahng (Chairside Shade Guide, LSK121) (Figure 8.13A). Because of different translucencies, transparencies, dentin overlays with enamel, and enamel modifications, a traditional shade tab cannot match natural dentition. It is merely to be used as a guide. The Kahng shade system takes into consideration the theory behind these colors, looking at natural teeth but also the synthetic made colors we see when patients bleach their teeth. The Chairside Shade Guide ceramic shade tabs are divided into different categories, with 20 tabs in each grouping.

- Shade guide 3.0
  - Cosmetic (six colors)—historically, there has not been an extensive tool to guide dentists in the area of cosmetic color. Many patients want, specifically, bright color with translucency, light with warm tones. The tabs are created with that in mind.
  - Early Age (14 colors)—occlusal two-thirds area includes white calcification and opal blue, more dentin color and less translucency. For the incisal one-third bright color with deep translucency is provided (Figure 8.13B).
- Shade guide 4.0
  - Middle Years (20 colors)—includes variation of color in enamel, a 20–30% reduction compared to 3.0 in between the dentin and enamel. The tabs in this grouping consider outside enamel, translucency, and dentin. Expect to see 50% enamel and 50% translucency in these shade tabs. There are included three white calcification possibilities and a variety of translucency with mamelon (Figure 8.13C).
- Shade guide 5.0. Later Years (20 colors)—in the mouth, there is more intensive color saturation with deep dentin, translucency, and transparency, as well as a variety of

Table 8.2 Guide for Staining to Alter Shade

Objective	Color of Stain	Formula	Application	Rationale
Reduce real translucency	White	White as a base		
Make coping invisible	Gray black or blue	Match value level with gray, black and blue	Match value level of incisal area	Method maintains value, chroma, hue, and blend
Masking small flaws and dirt specks	Orange	Gingival effect with orange		
Control apparent translucency				Complementary hue lowers value (grays) and reduces chroma (weakens)
Incisal edge				
To intensify translucency	Blue/ blue violet/blue-green	Use complementary color to neutralize orange, yellow, or pink	Brush lightly over labioincisal or linguoincisal area 0.5 mm from edge in an irregular pattern	Complementary hue lowers value (grays) and reduces chroma (weakens)
	Orange/orange-brown/ brown		Apply orange adjacent to incisal area and feather lightly into proximal contact areas. Applying thin area to incisal edge helps increase translucency and makes tooth appear more natural.	(Same as above) and complementary hues applied adjacent to one another enhance each other; also helps to create third dimension
To decrease translucency	Orange/red/yellow/ gray/white	Add complementary color to compensate for the increased value due to the white	Add white sparingly; adjust value with orange, red, yellow If necessary to lower value further, use gray	Complementary hue can alter value or chroma
Incisal-gingival blend				
To increase incisal translucency	Violet	If yellow body shade, use a violet stain	Add small increments brushing lightly	Use a hue that complements the body shade
	Blue	If brownish-orange body shade, use a blue stain (others hues similar procedure)		
To eliminate green	Pink		Add to body color as stain	A yellow body color with a gray opaquer results in a green cast Red complements green
Control chroma (strength)				
Thin areas (gingival third)	Yellow or orange	Use opaquer of the same hue desired in thin areas		Color of thin area greatly influenced by the color of opaquer
Between abutment and pontic	Select desired hue		The final buildup and opaquer of the abutments and pontic should be of equal thickness	Thickness of area will influence chroma

Increase chroma (strength)	Red/yellow/blue	Add three primary colors in equal amounts; emphasis on hue to be strenghtened		Addition of the three primary colors will not change the shade (extremely difficult procedure)
Decrease chroma	Clear		Add clear material sparingly	Do not use white; it will increase the value (brilliance of the shade)
Reduce value (brilliance)				
Match a too-light (too-bright) crown with the natural dentition	Complementary hue of desired shade		Add sparingly	Graying the shade by using a complementary hue reduces value
Example: yellow shade	Violet			
Increase value (This is practically impossible to do with stains.)				Choose a shade of higher value, if necessary

Table 8.3 Guide for Staining to Add Characterization

Effect Sought	Color of Stain	Formula	Application	Rationale
Random discoloration	White/orange/brown-blue/yellow	Combine small amount of white with body shade	Randomly intensify chroma over labial surface (adds dimension)	Cervical and interproximal discoloration can tolerate some opacity
Labial mottling	Same		Same as above	
Fissures and apertures				
Sulci and proximal aperatures	Orange to brown	Use lighter yellow-orange in young people; deeper burnt orange as aging progresses	Apply thin lines asymmetrically	
Worn enamel and exposed dentin (incisal edge lower anteriors of the aged)	Orange to brown		May take two bakes	
Exposed dentin of smoker	Orange-brown or brown, blue		Vary shading, reduce incisal surface in center of teeth; increase incisal translucency at interproximals	
Incisal wear/erosion	Yellow-brown	One part yellow/one part brown/two parts diluent (medium)	Strain center area of incisal edge. Undiluted or slightly diluted brown may be placed centrally to depict exposed and heavily stained dentin. Mix with orange to radiate from center.	Adds depth and feeling of naturalness to incisal edge if worn
Enamel cracks (young patients)	Gray (distal)/white (mesial)/yellow/black	Use thick consistency	Strain runs 3–5 mm (1/3 length of crown) (gray-white) to the incisal edge	Add depth to surface (third dimension)
			Place brush tip in the center of the crown, with a fast light stroke bring to incisal edge	
			Apply thicker line with correct shade	
			Wipe away mesially and distally until desired thickness is achieved. Create shadow effect by abutting the (gray/white) stain with black. Apply only a faint line.	
Check-lines	Brown/black/yellow/orange	Brown with a small amount of black or yellow/four parts stain/one part diluent (medium)	A wide strip of stain is applied, this is brushed until a very fine sometimes not continuous line remains. These lines can slant mesial or distally towards the embrasure terminating at the incisal edge.	
Grooves and pits (on the occlusal of posterior teeth and lingual surface of anteriors)	Brown/black/orange/blue	Brown with a small quantity of black or orange for a young person	Stain as fine lines, except in occlusal pitting.	Creates lifelike appearance to the tooth
			Combine pitting and grooves with bluish enamel staining of adjacent ridges.	

Decalcification/ hypocalcification	Opaque white yellow/brown/gray	Opaque white alone or with a trace of yellow, brown, gray	Use a thick layer of opaque applied irregularly in various areas. Effective if used on several teeth evenly in gingival area. Otherwise, vary	Used to match adjacent teeth. Note area and intensify
Cervical stain/gingival erosion	Brown/yellow/gray or line-green	Three parts brown/one part yellow or gray/four parts diluent (medium) or lime-green	Blend with body shading where it begins. Occasionally dark brown spots may be placed using the feathered edge of a brush.	Ditching possible to actually create an eroded area
Existing silicate or composite				
			Paint the outline form using brown/gray/orange It should fade out irregularly	
Stained outline	Orange/brown/ gray	Limit diluent added to stain	Place the inside portion with opaque white	
		Opaque white with small amounts of any combination using gray, yellow or brown		
Restoration itself	Opaque white			
	Gray/yellow/brown			
Amalgam stain	Gray/black/blue	Match adjacent teeth	Gray or bluish stain on the proximal angle over a distance of 2 mm on the labial surface	
Gold inlay	Gold pottery stain		Superglaze surface to be stained. Paint a thin layer of gold stain over super glaze. Fire the layer and then coat with two thin layers of white glaze.	

Figure 8.13 **(A)** The Chairside Shade Guide ceramic shade tabs are divided into different categories, with 20 tabs in each grouping. Figure courtesy of Lukus S. Kahng.

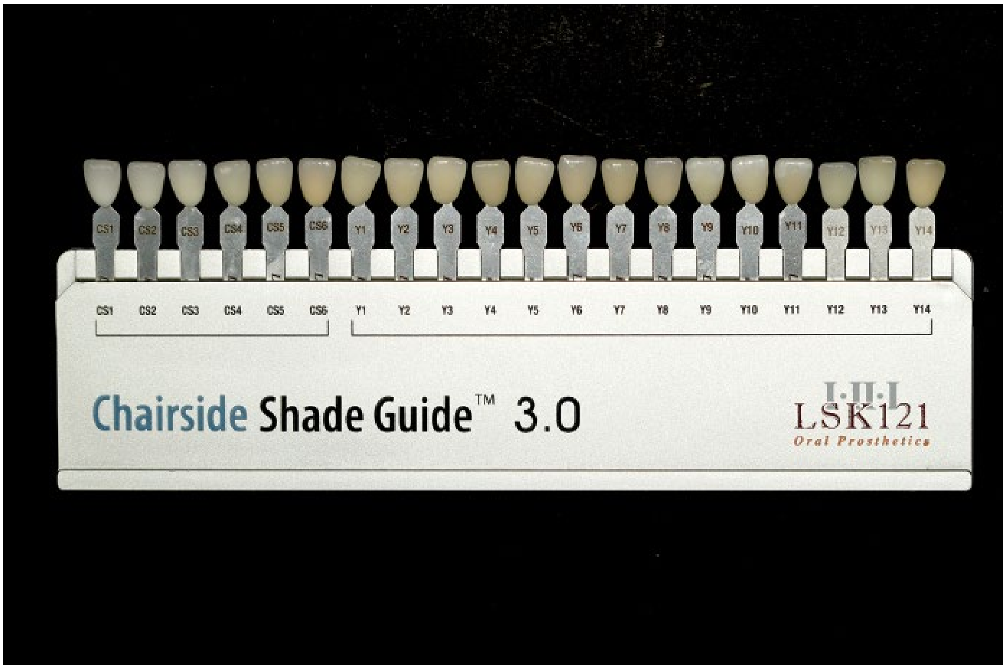


Figure 8.13 **(B)** Early Age (14 colors). Shade tabs range from bright to warm colors with different degrees of translucency. Figure courtesy of Lukus S. Kahng.

enamel translucencies. The shade tabs mimic those colors (Figure 8.13D).

- Shade guide 6.0: Pre-molar (five), Molar (10), and Canine (five) selections with two-thirds occlusal enamel along with occlusal stain, gray, tan, opal, and blue enamel and a variety of canine enamels, with consideration also given to the incisal one-third (Figure 8.13E).
- Shade guide 7.0: After Preparation Color (10) mimics natural teeth color and after preparation from implant to veneer cases and dark after-prep colors. Surface Texture (four) includes vertical, vertical horizontal, misty, and natural polish. Surface texture relates to anterior cases because without the proper texture application, the restoration will tend to have a fake appearance. Gingival Color (six) includes

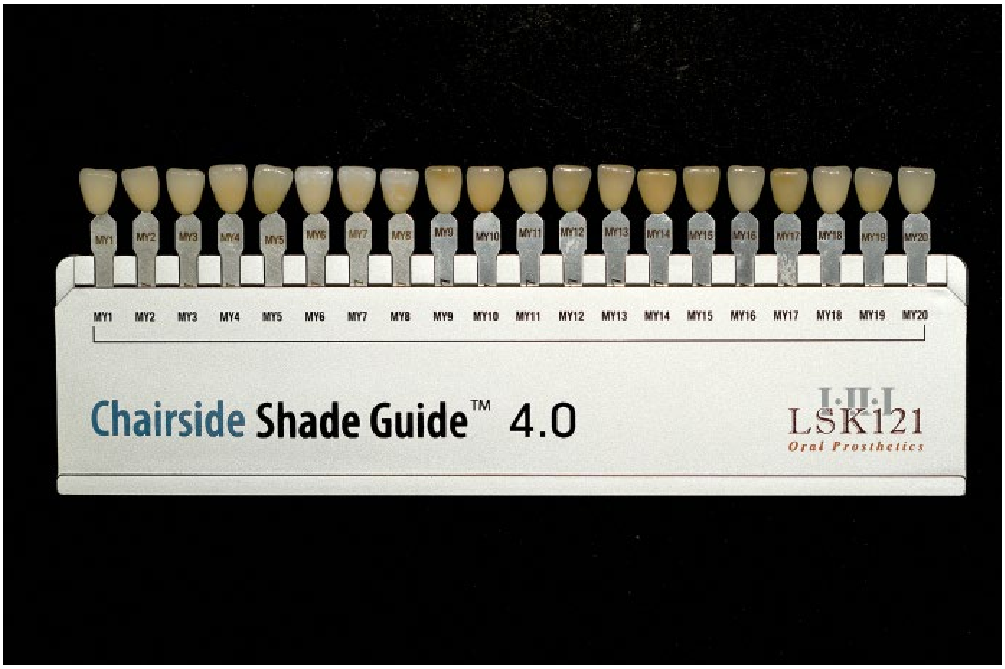


Figure 8.13 **(C)** Middle Years (20 colors) include variation of color in enamel in ratios of 50% enamel and 50% translucency with three white calcification possibilities. Figure courtesy of Lukus S. Kahng.

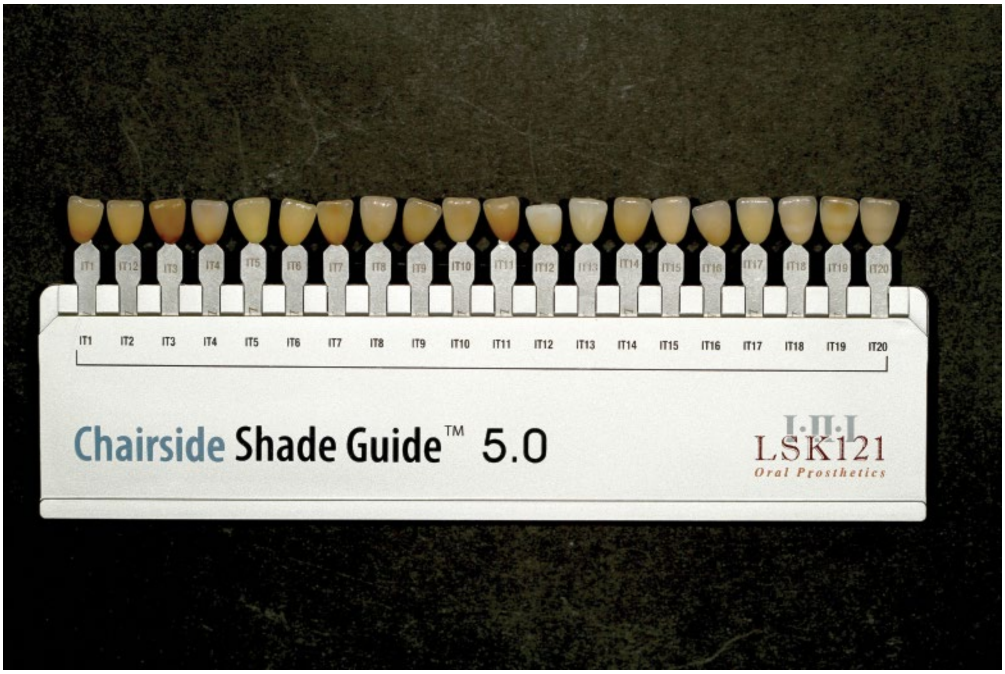


Figure 8.13 **(D)** Later Years (20 colors) include intensive color saturation with deep dentin, translucency, and transparency, as well as a variety of enamel translucencies. Figure courtesy of Lukus S. Kahng.

a variety of pinks with enamel overlay included in the color. This is especially important for implant and edentulous cases because the tissue color can create an unnatural appearance if it does not match the natural dentition (Figure 8.13 F).

These shade tabs are based on the theory behind custom shade matching and are each overlaid with different enamel colors so that they harmoniously match with natural teeth. A traditional 1–3 solid color shade tab opposes natural dentition and enamel, serving merely as a guide to color matching. It is also important to properly photograph the shade tabs with the teeth to be matched to show the ceramist any shade discrepancies (Figure 8.13G and H).

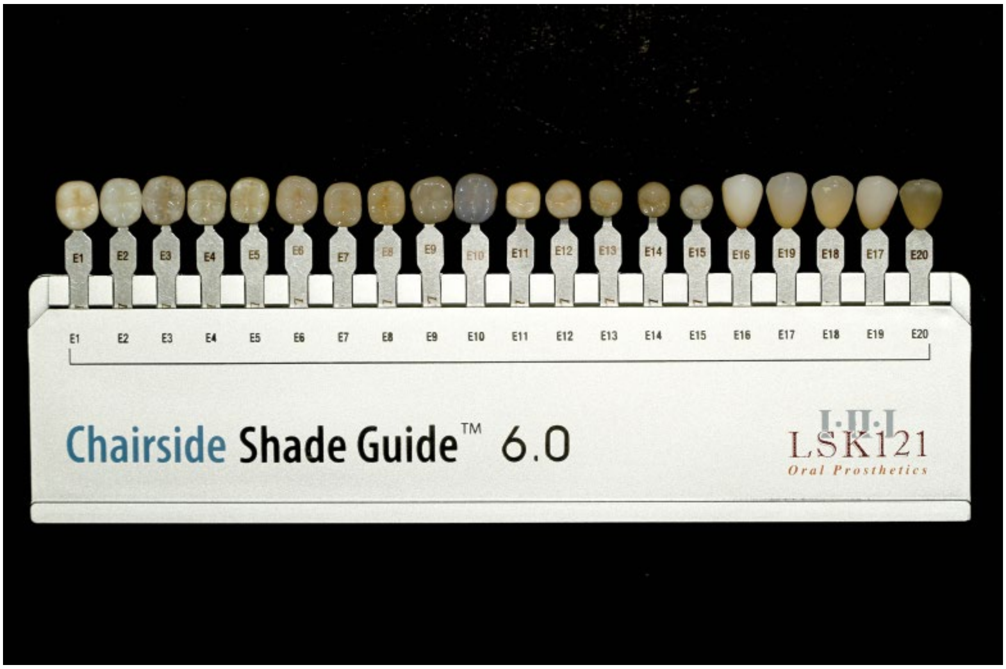


Figure 8.13 **(E)** Pre-molar (five), Molar (10), and Canine (five) selections show a variety of occlusal stains as well as canine enamel incisal variance. Figure courtesy of Lukus S. Kahng.

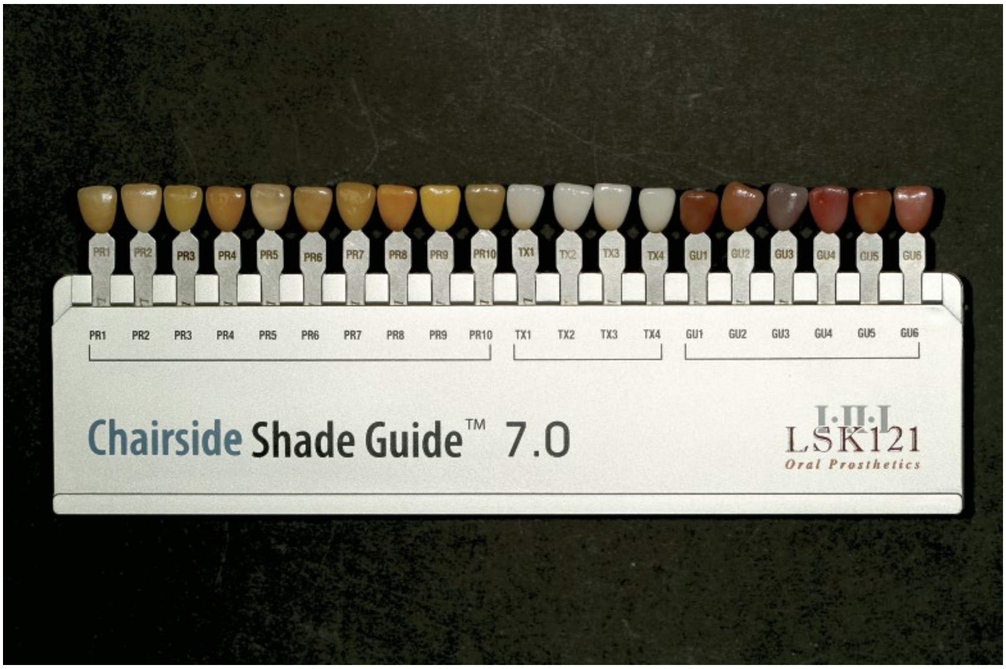


Figure 8.13 **(F)** After Preparation Color (10)—shows a variety of colors of prepared teeth. Surface texture (four) is also seen as well as a variety of pinks with enamel overlay. Figure courtesy of Lukus S. Kahng

Techniques for resolving various problems

The most commonly encountered problems that can be corrected through illusions are discussed below.

Space available is wider than the ideal replacement tooth

This problem is typically encountered either when space was present between the teeth prior to extraction or when drifting has occurred to widen the space. If the space is to be restored

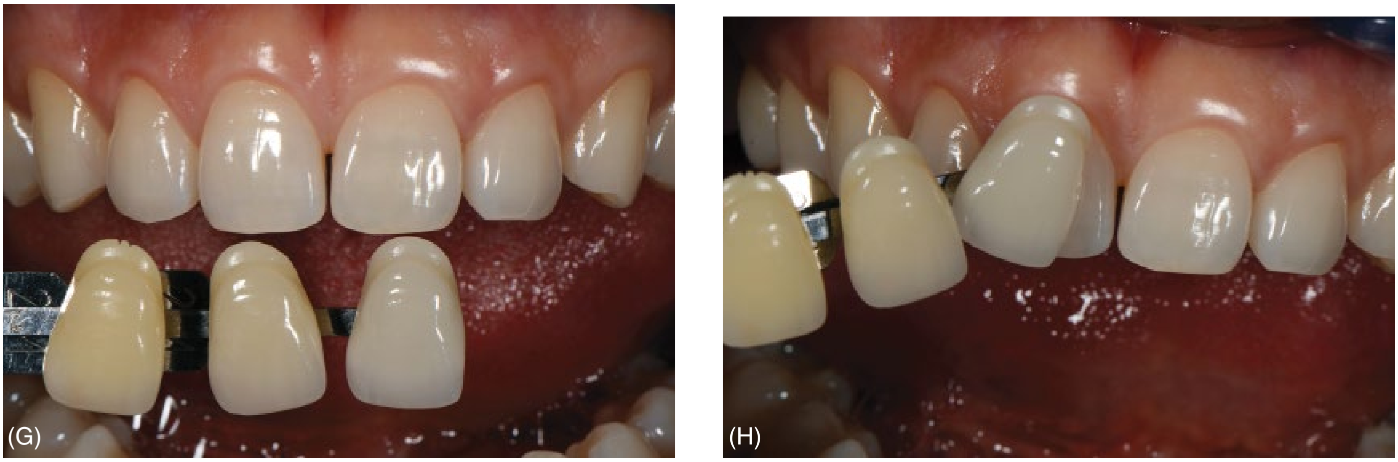


Figure 8.13 **(G and H)** Shade tabs position in photograph is critical for communicating color property. Shade tabs should be placed below and in the same plane as teeth.

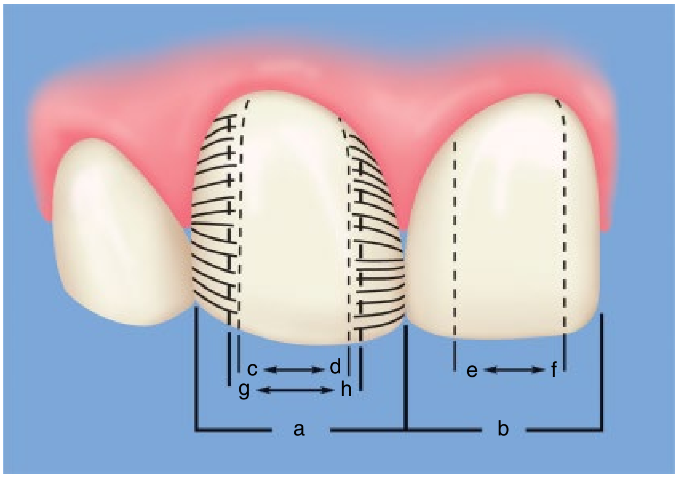


Figure 8.14 Tooth "a" is made to appear thinner than it actually is by carving the mesial and distal line angles to the lingual, thus presenting less labial surface.

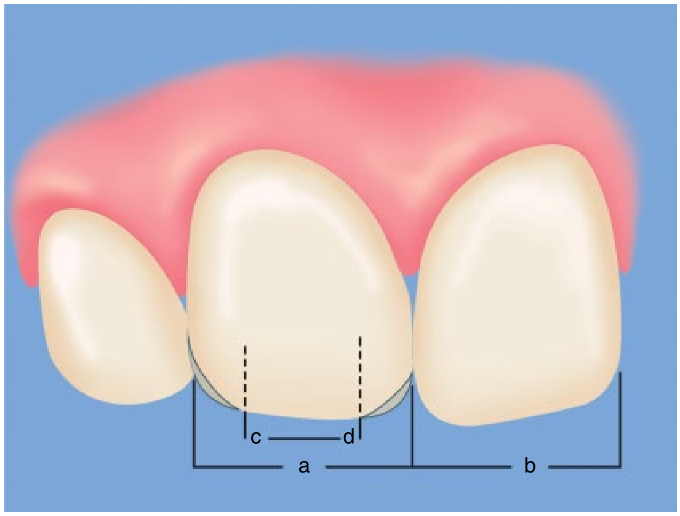


Figure 8.15 Gentle curving of the mesioincisal and distoincisal edges, as well as a slight indentation at the midincisal edge, alters visual perception.

with the correct number of teeth and tooth contact is to be re-established, avoid horizontal lines, edges, and characterizations, and incorporate as many vertical ones as possible into the restoration.

Shaping and contouring illusions

The width of the replacement tooth or teeth will have to be wider than ideal; therefore, various illusions achieved through shaping and contouring should be used. The width needed to close the space is gained in the areas of contact.

Illusions for incisors

The extra width can be disguised by placing the contact areas more lingually and cervically. In Figure 8.14, the diameter of tooth "a" is larger than that of tooth "b", but by carving the mesial and distal line angles to the lingual the tooth appears thinner. One reason for this illusion is the reflection created by shaping and contouring the tooth. Light usually reflects from the flat labial surface. Line angles "e" and "f" usually reflect light and give the appearance of width to the tooth. The corresponding lines on the right central would be "g" and "h". By moving the mesial and distal line angles slightly to the middle of the tooth, new line angles "c" and "d" are created and thus a less flat labial surface remains. This reduction in the reflective surface makes the tooth appear narrower than it really is. Although these should be subtle carvings, at times labial prominences can be created to actually catch light rays. In this manner, more precise distance can be interpreted by the observer.

In summary, the mesial and distal line angles in Figure 8.14 are moved toward the center of the labial surface (c and d). The mesial and distal surfaces are then made more convex, curving from the line angles into the areas of contact. The shape of the incisal edge can abet the illusion of decreased width. The mesioincisal corner is rounded, and a gentle curve is created from the middle third of the incisal edge to the distal contact (Figure 8.15). The incisal edge can be notched slightly to break

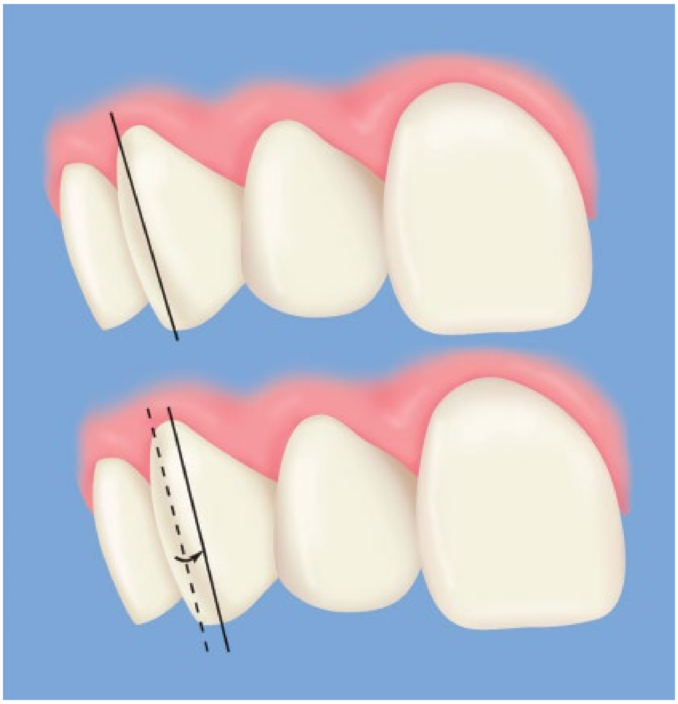


Figure 8.16 This figure illustrates a too‐wide cuspid. The buccal ridge is carved to the mesial to disguise the excess width in the cuspid.

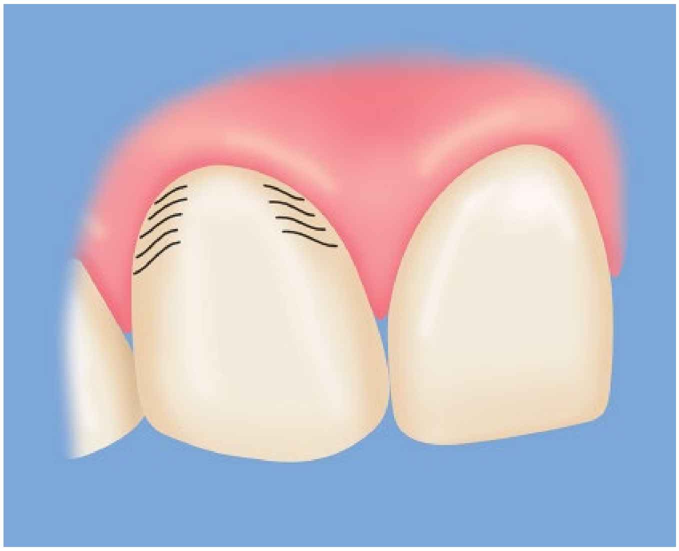


Figure 8.17 Shallow developmental grooves which break up the smooth labial reflecting surface make the tooth appear less wide.

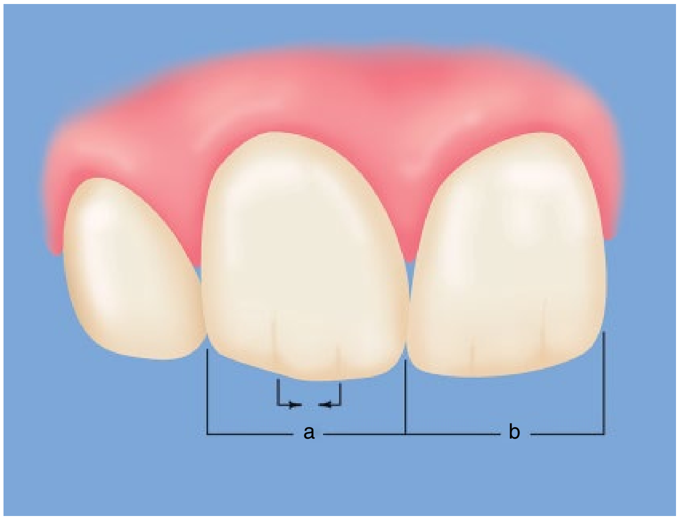


Figure 8.18 A more pronounced curve carved into the cemento-enamel junction which is in a more incisal or occlusal position is another technique used to make the tooth appear thinner.

up the horizontal line. Even a slightly curved indentation, a wave result, will alter visual perception and create a more pleasing effect. The eye tends to wander away from a horizontal line, and the curves provide relief. Only a limited amount of mesioincisal rounding is permitted, mainly due to the possibility of creating asymmetry in the restoration by overdoing it. It is possible, however, to create the illusion of a slight incisal diastema by moving the mesial contact of the larger tooth gingivally. This produces an entirely different effect than a complete diastema. The open incisal diastema can be natural in appearance and quite effective in balancing space variations. More incisal shaping is possible from the distal side. Since the observer sees the patient mainly from straight ahead, it is possible to achieve much of the space illusion by opening the distoincisal embrasure. The distance c and d is also re-emphasized by carving mainly from this point, both mesially and distally. At times, it may even appear as if a diastema is placed distally, depending on how much the contact is placed gingivally. This is still a much better esthetic choice than having an oversized contralateral central incisor.

Illusions for cuspids

Extra width can be disguised by moving the visual center of the labial or buccal surface more to the mesial by carving the buccal ridge to the mesial (Figure 8.16). The cusp tip should then be moved mesially if this is compatible with functional requirements. Contact areas should also be moved lingually and cervically.

Illusions for anterior or posterior teeth

The developmental grooves are moved closer together (Figure 8.17). These grooves do not have to be deep to be effective. Shallow grooves will give the desired shadows. To further this illusion, any characterizations ground into the labial or buccal surface should be vertically oriented. By breaking up the smooth unbroken labial or buccal reflecting surface with characterizations, you make the tooth appear less wide. The curve of the cementoenamel junction carved into the restoration can be made more pronounced and brought into a more incisal or occlusal position in the interproximal gingival embrasure areas (Figure 8.18). When shaping the restoration, the opposite tooth should be kept in mind as the ideal. Slight concavities in the gingival third also give the illusion of a narrower tooth. Special attention should be paid to duplicating ridges and depressions that reflect light (Figure 8.18). One should remember that it is the individual

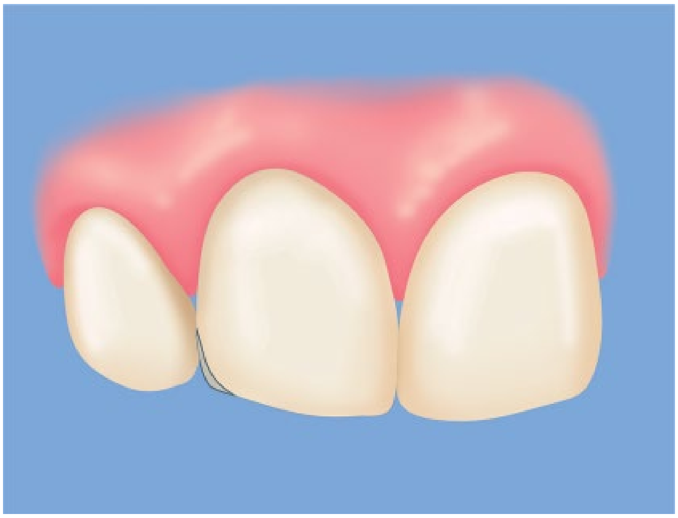


Figure 8.19 All three shaping special effects are combined on this restoration to produce the illusion of a thinner tooth.

pattern of light and color reflection that determines tooth character. Figure 8.19 shows all the shaping effects combined to produce the illusion of a thinner tooth.

Staining to mask tooth size

For masking a large tooth, color can be used to advantage in one of several ways. By selecting a body color barely darker than that of the approximating teeth, the larger tooth appears less prominent. The mesial and distal thirds of the labial or buccal surface can be stained grayer (Figure 8.20A and B) than the middle third. The gray color disappears in the mouth and the appearance of size is transmitted to the glancing eye by the normally colored area. Note how much thinner the teeth appear in Figure 8.20B after using the above technique. The developmental grooves and characterizations ground into the surface can also be emphasized with gray stain. Indefinite, barely perceptible, vertical lines can be incorporated to accent the vertical aspects of the tooth. This is done by using a stain slightly lighter than the body color and by running it from the tooth body to the incisal or occlusal edge. To further highlight the lighter lines suggested earlier, an opaque white, yellow, orange, or brown stain can be used to create vertical check or microcrack lines.

Arrangement of teeth can create the illusion of decreased width

The position or arrangement of the teeth can create the illusion of decreased width. When a tooth is placed in linguoversion, not only is its real width masked by the more prominent approximating teeth but also the effect of the increased shadowing masks its size (Figure 8.21). Rotation of a tooth from its normal labiolingual position will accomplish several illusions. Through rotation, the normal perception of the tooth is changed, and the tooth loses some of its identity. Depending upon the degree of rotation, the tooth can be made to appear less wide. In Figure 8.22A, the right central appears wider than the left central; actually the left central is rotated distally, so it looks thinner (Figure 8.22B). When the mouth is viewed from midway between the rotated and nonrotated teeth, the teeth look much the same width (Figure 8.22C). When two central incisors are replaced, the distal aspects of the wide crowns are rotated lingually, thereby narrowing the area that reflects light forward and decreasing the apparent width (Figure 8.23). You can create a diastema to avoid widening the replacement teeth. Position the teeth so that the space left on the distal aspect of the restoration is not prominent (Figure 8.24).

If the space to be filled is much wider than the replacement teeth, the only reasonably esthetic solution may ultimately be the addition of an extra tooth. This method of handling the extra space works especially well when replacing the lower anteriors. (See Chapter 26 on restorative treatment of diastema.)

Space available is narrower than the ideal replacement tooth

This problem is usually encountered when extraction was not immediately followed by replacement and the adjacent teeth drifted or tilted to encroach upon the space. If the space is to be

Figure 8.20 **(A)** These two central incisors appear too wide with respect to the other teeth in the patient's dentition.

Figure 8.20 **(B)** To accomplish thinner looking central incisors the ceramic restorations were made slightly longer and more translucent stains were used in both mesial and distal proximal areas to give the appearance of thinner-looking teeth.

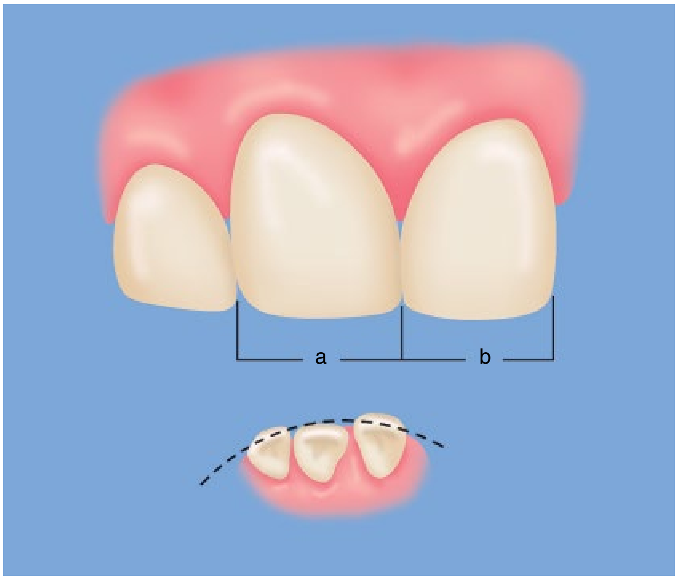


Figure 8.21 Placing the wider tooth in linguoversion masks its real width by diminishing its prominence with the adjacent teeth and adding shadowing.

restored with the correct number of narrower teeth, avoid vertical lines, edges, and characteristics, and incorporate as many horizontal lines as possible.

Shaping

Before the replacement crowns are shaped, the proximal surfaces of the adjacent teeth should be reduced slightly to increase as much as possible the space available. Most or all of the needed space can be obtained in this fashion. If this procedure is used, the reduced enamel surfaces must then be refinished (see Chapter 11). By altering the contour of the labial or buccal surface and the incisal or occlusal edge, an illusion of width can be achieved, even when the actual tooth is narrowed.

Illusion for incisors

The contact areas are moved labially and incisally, as illustrated in Figure 8.25. In this case, the right central is narrower than the left central and needs to be made to appear wider. By extending the contact areas both labially and incisally, the apparent width of line angle "X" is increased and helps make the right central look wider than it really is. If the previous technique is used in conjunction with flattening the entire labial surface and the proximal line angles, the overall effect will be lengthening of the incisal edge and development of a broad labial surface for light reflection. Both of these effects heighten the illusion of width (see Figure 8.25).

Another technique is to leave the incisal edge as flat and as horizontal as is compatible with adjacent teeth (see Figure 8.25). It may also help to reshape the incisal edge of the adjacent teeth slightly to help make the entire effect more esthetically harmonious. The adjacent central incisor can be shaped to look narrower by carving its distoincisal edge gingivally.

Illusions for cuspids

The narrowness of the crown can be disguised by moving the visual center of the labial or buccal surface (Figure 8.26) more distally. This is accomplished by carving the buccal ridge to the distal. The cusp tip should be moved distally if this is compatible with functional requirements, and the contact areas should be moved labially and incisally to accent the horizontal aspects of the narrow tooth.

Illusions for anterior or posterior teeth

The curve of the cementoenamel junction can be influential. It should be at the same level as the curve on the adjacent natural teeth but should have a flatter appearance (Figure 8.27A). To further accentuate the horizontal, additional grooves can be carved gingivally on the original one (see Figure 8.27A). However, if the adjacent natural teeth have strong vertical lines, this cannot be done effectively; therefore, the effort should be directed toward de-emphasizing as much as possible any vertical lines or edges. If there are only a few vertical lines on the adjacent natural tooth, it may be possible to cosmetically contour the labial surface on that tooth to diminish their effect.

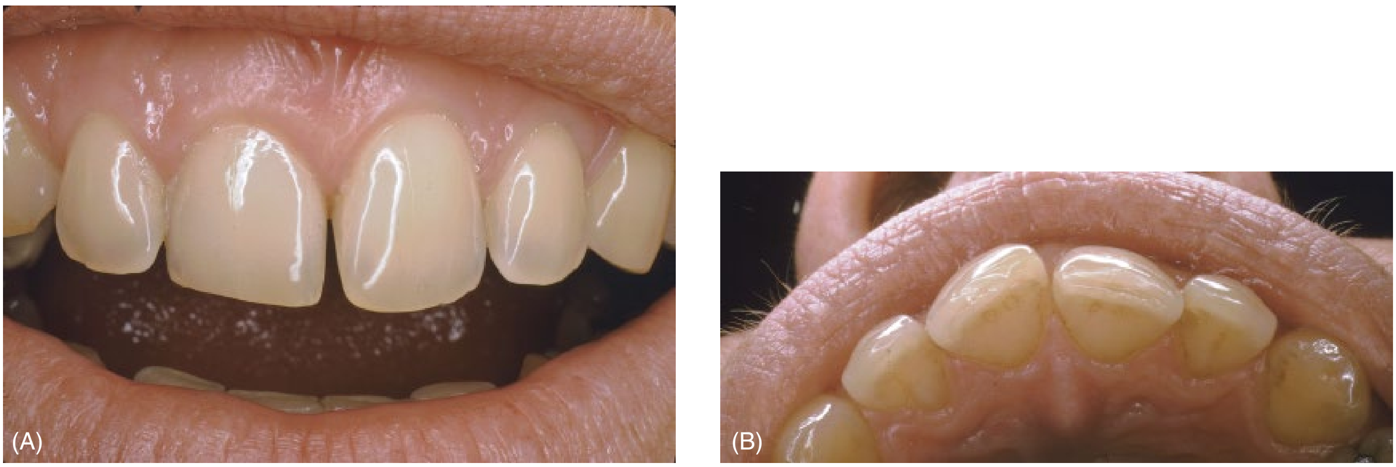


Figure 8.22 **(A and B)** Although the right central appears wider than the left central, the left central is actually rotated distally, which causes it to look thinner.

Figure 8.22 **(C)** When the patient is viewed from a different angle (halfway between the rotated and non-rotated teeth) the teeth look proportional.

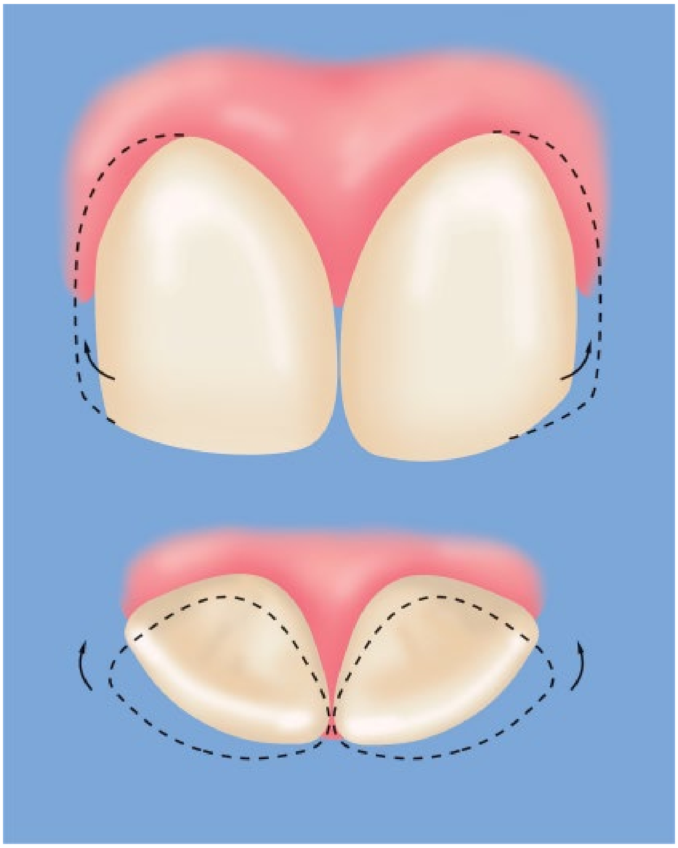


Figure 8.23 The distal aspects of both the replaced central incisors are rotated, which narrows the light‐reflecting surface and decreases width perception.

By eliminating developmental grooves and lobes, the labial surface can be carved to develop a broad, flat surface to provide an area for unbroken light reflection. This area will appear broader than the same area that has the surface broken with grooves and characterizations that scatter the reflections (see Figure 8.27A).

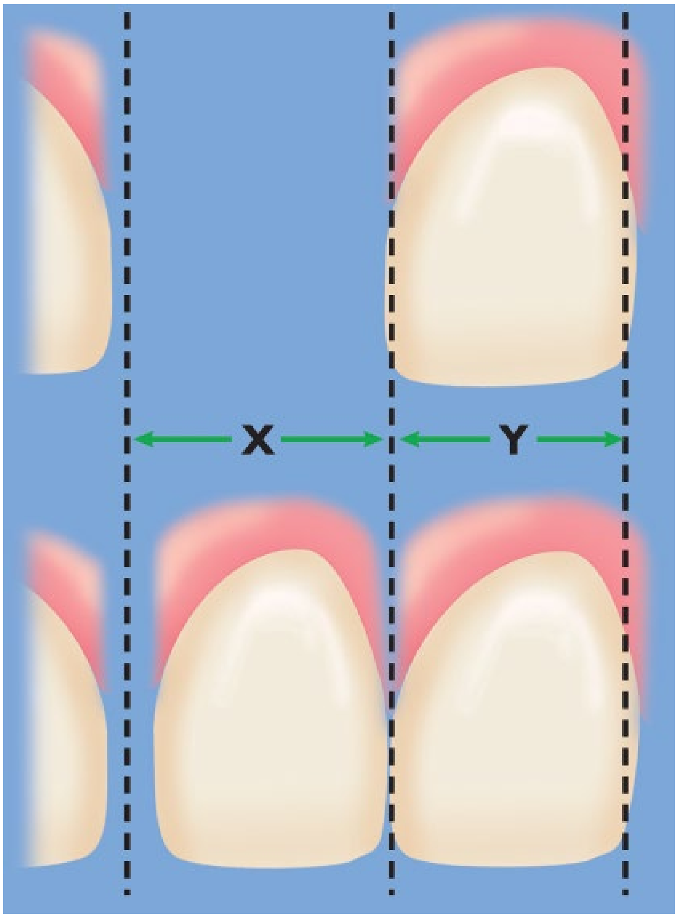


Figure 8.24 When a space is too wide (X) a distal diastema is preferable to making the replacement tooth too wide (Y).

Staining

Color can also be used to increase the illusion of width. For instance, when a body color is selected that is slightly lighter than that of the adjacent teeth, the narrow tooth will appear more prominent and therefore wider. The mesial and distal thirds can be stained a shade lighter than the middle third, to highlight the proximal aspects and the width of the tooth. Any horizontal grooves or lines that have been carved into the labial surface can be accentuated with a light stain. Definite, barely perceptible, horizontal lines can be created to accentuate width. This is done by choosing a stain slightly lighter than body color and running it from mesial to distal. To further accentuate these lines, a light, thin orange, yellow, brown, or white opaque line can be placed on the labial surface (Figure 8.27B).

Another way to accentuate width is to simulate multiple decalcification spots running horizontally across the middle third of the tooth (Figure 8.27C). Other horizontal lines can be created by using staining to indicate one or two anterior restorations that have been carried out onto the labial surface. If adjacent teeth show cervical erosion, this erosion should be either restored or reproduced in the replacement tooth (Figure 8.27C). Staining can also be used to create an illusion of incisal erosion (Figure 8.27D). Finally, shade modification can and should be done when patients want to have a more natural look (Figure 8.27E).

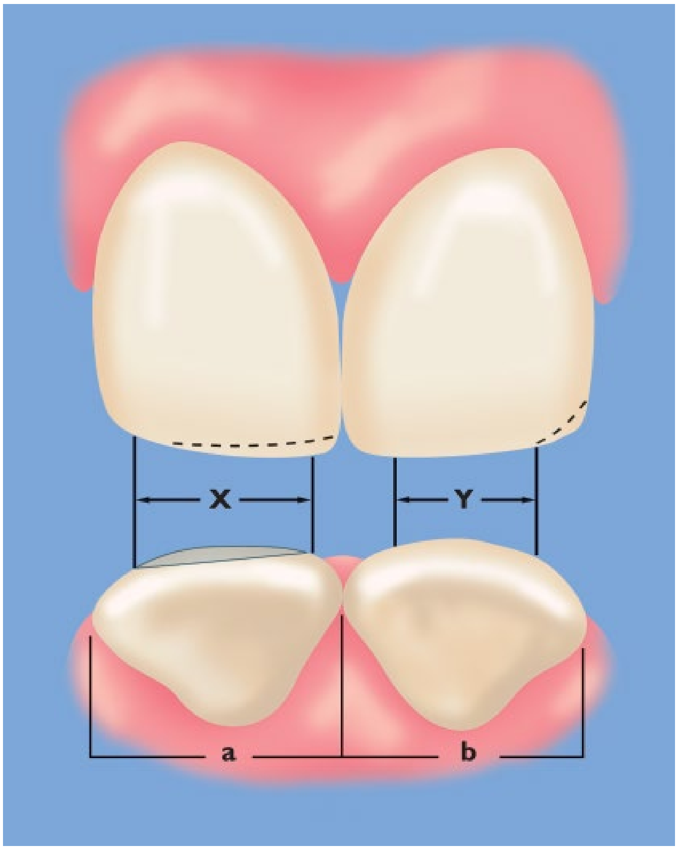


Figure 8.25 The narrow right central incisor needs to appear as wide as the left central incisor. The line angle "X" is extended labially and incisally, making the right central appear wider. If necessary, the distoincisal angle of the wide incisor can be reshaped, making it appear slightly narrower (Y).

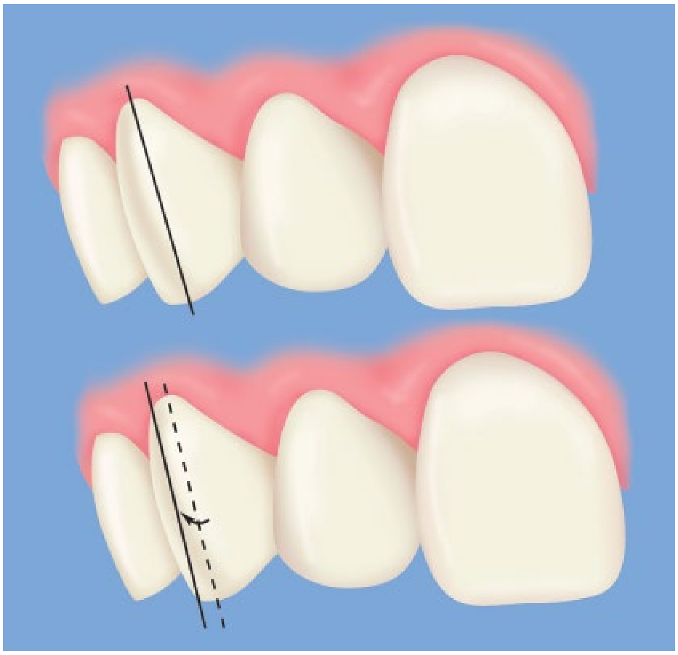


Figure 8.26 When the crown of the cuspid is too narrow, move the visual center of the labial surface distally by carving the buccal ridge distal to the usual position if this remains compatible with functional requirements.

Arrangement

The most simple and direct solution for inadequate space is to rotate and overlap the replacement crowns or teeth without reducing their ideal widths. If rotation and overlapping are unacceptable or impossible, and if the encroachment on the space has

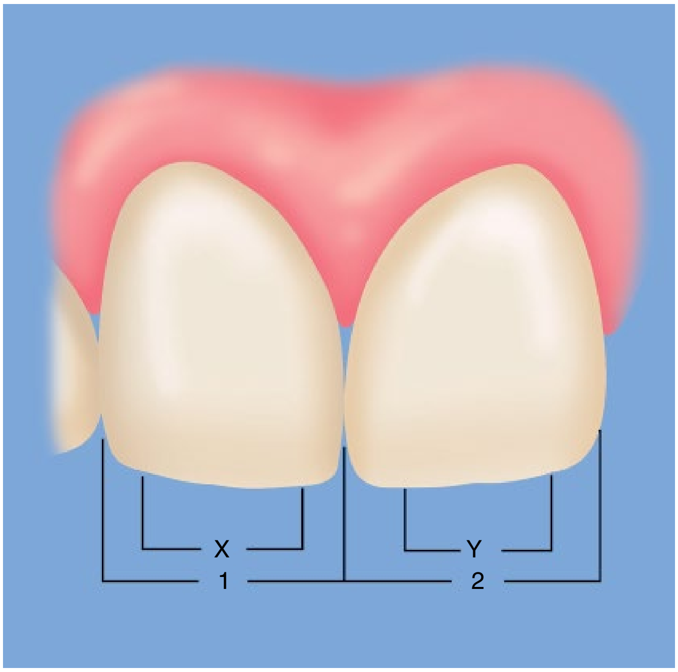


Figure 8.27 **(A)** Horizontal grooves were carved into the right central (1) to give it a wider appearance.

Figure 8.27 **(B)** Light, thin, orange and yellow opaque lines were placed on the surface to further enhance the carved horizontal lines.

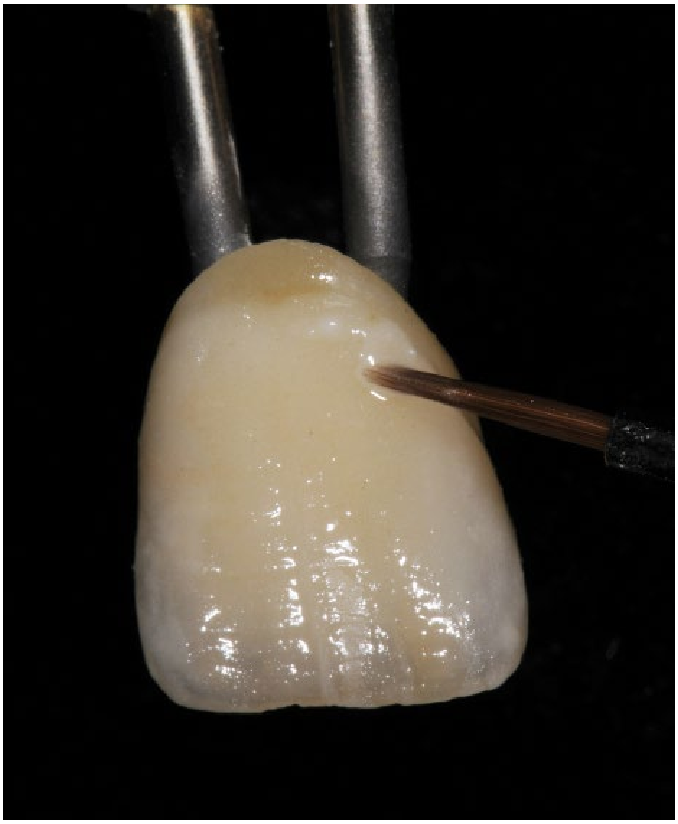


Figure 8.27 **(C)** White calcification spots running horizontally across the middle third of the tooth further accentuate width.

Figure 8.27 **(E)** This photo of a ceramometal splint shows the ability to modify shades to the patient's natural looking teeth.

been severe, it may be possible to eliminate one tooth entirely with good results, especially in cases involving lower anteriors. In cases where the maxillary central incisors are involved, the distal aspects can be rotated labially, making these teeth appear more prominent and wider (Figure 8.28). The principle involved here is to create prominent distolabial line angles to create more horizontal reflections.

When the problem involves both maxillary central and lateral incisors, the centrals can be placed normally and the laterals can

Figure 8.27 **(D)** Staining used to create the illusion of incisal erosion to match adjacent teeth also emphasizes width if the crown is horizontal and flat.

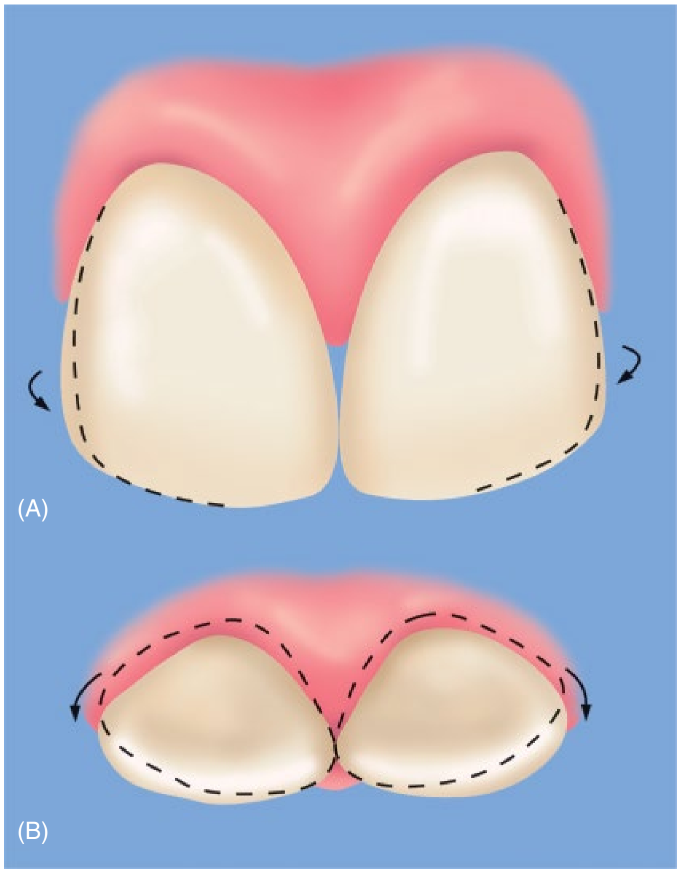


Figure 8.28 For an inadequate space involving central incisors, the teeth can be slightly rotated labially and lapped rather than reducing their ideal width, making them appear wider and more prominent.

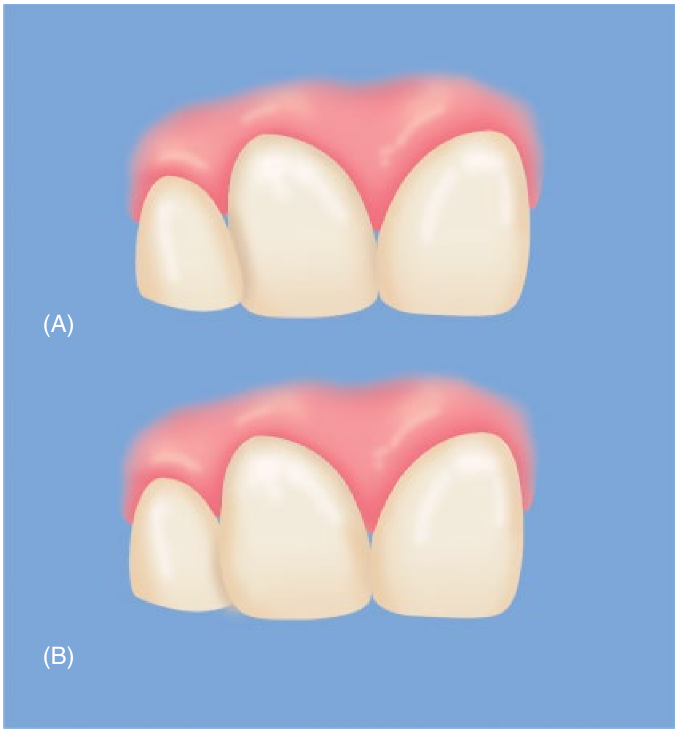


Figure 8.29 **(A)** For a female, the mesial aspect of the lateral incisor is rotated labially and lapped in front of the centrals to increase a soft, feminine appearance without increasing the space needed for the replacement teeth. **(B)** The mesial aspect of the lateral incisor of this male patient is rotated and lapped lingually behind the central to project width and boldness without requiring additional space.

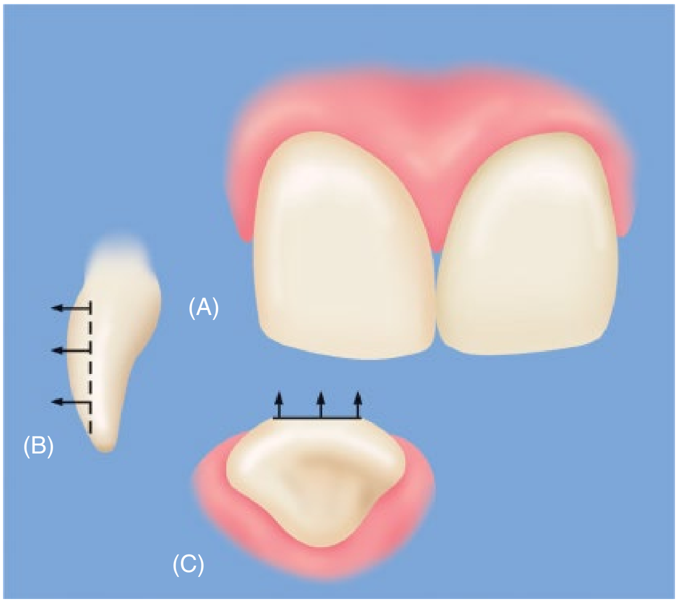


Figure 8.30 Narrowing a too-short tooth mesiodistally at the gingival one-third creates the illusion of length **(A)**. To further this illusion, vertically flatten the labial middle third (B, C).

be rotated. In the case of a male, the mesial aspects of the laterals are rotated and lapped lingually behind the centrals increasing the overall appearance of width and boldness and decreasing the amount of space needed (Figure 8.29A). In the case of a

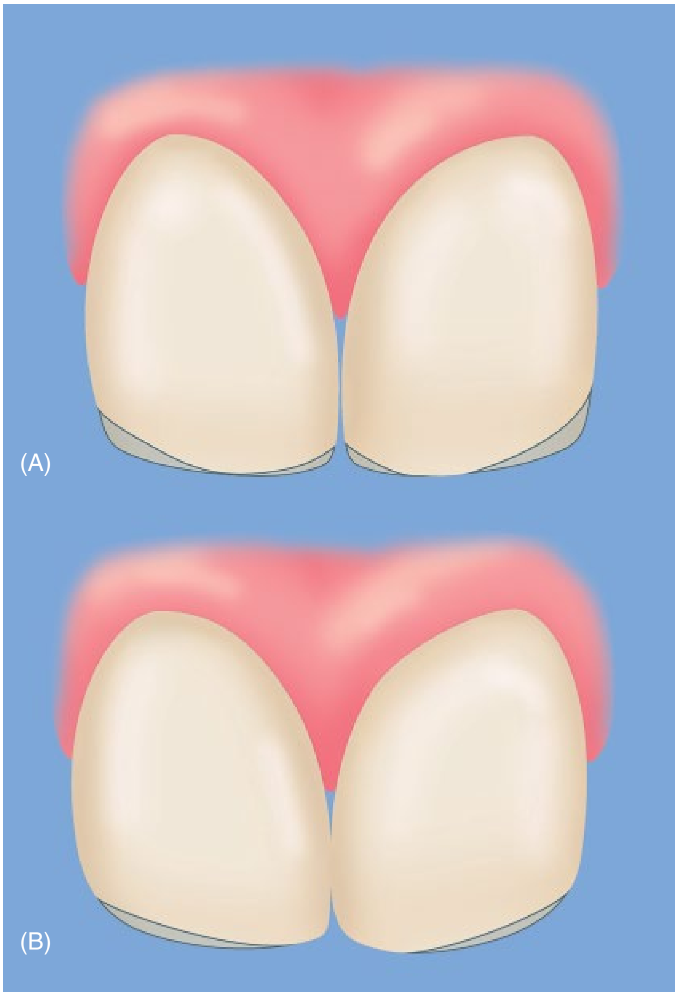


Figure 8.31 **(A)** An illusion of length can be created by gently sloping the mesial and distal halves of the incisal edge toward the gingiva from the midline to the contact areas. **(B)** If two adjacent anterior teeth need to appear longer, each incisal edge should be made to slope gingivally away from the approximating common incisal angles, lending the illusion of length.

female, the mesial aspects of the laterals are rotated labially and lapped in front of the centrals, increasing the feminine appearance (Figure 8.29B).

The too-short tooth

If a tooth appears too short, as is likely if it is wider than normal, several techniques can be used to create the illusion of length.

Shaping

If the gingival third is narrowed mesiodistally, the tooth will appear more tapered and longer (Figure 8.30A). This illusion can be further enhanced by having a vertically flat labial middle third to increase the vertical reflecting surface (Figure 8.30B and C).

The shape of the incisal edge can be altered to create an illusion of greater length in the anterior region. For each involved tooth, the mesial and distal halves can be sloped gently toward the gingiva from the midline to the contacts (Figure 8.31A). In the specific case of the central incisors, each incisal edge can be

Figure 8.32 **(A)** Microcracks, decalcification, and interproximal restoration staining has produced the illusion of length.

Figure 8.32 **(C)** A more youthful look was attained with all ceramic restorations consisting of slightly altering vertical dimension to be able to lengthen teeth. Interincisal distance was re-established and incisal embrasures restored.

made to slope gingivally away from the approximating common incisal angles, lending the illusion of length (Figure 8.31B).

Staining

The main principle to remember when using staining to increase height is that stains of higher value (whiter) make the area to which they are applied more noticeable. A fine, opaque, white check line running from the body of the tooth to the incisal edge accentuates the height. A white decalcification spot placed close to the incisal edge also increases the height illusion. Staining can be used to duplicate the appearance of a long, vertical interproximal anterior restoration, which increases the illusion of length (Figure 8.32A).

Arrangement

If the maxillary six anterior teeth have worn unnaturally, producing noticeably shorter teeth, vertical dimension may need to

Figure 8.32 **(B)** This 49-year-old patient had an extreme case of bruxism resulting in an older-looking smile.

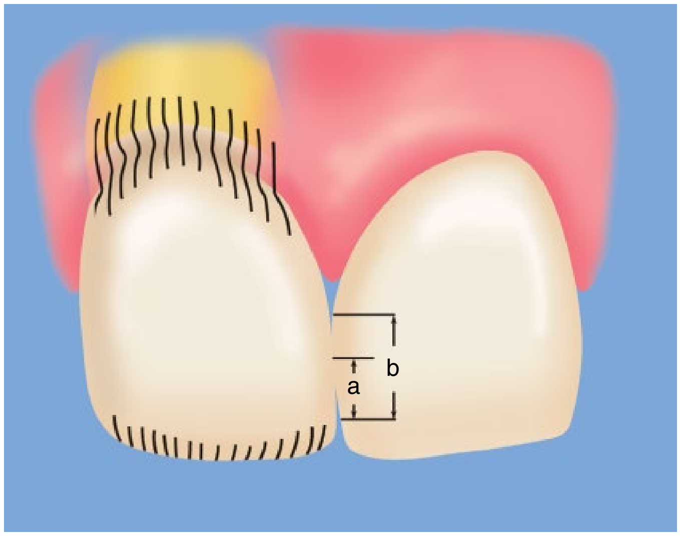


Figure 8.33 For the too-long tooth, increase the vertical contact area ("a" to a wider contact "b"), keep the embrasures as narrow as possible, and lingually incline the cervical and incisal one-fifth areas.

be altered to be able to lengthen the teeth and reopen the incisal embrasures (Figure 8.32B and C). Be careful of using too much incisal staining, otherwise the teeth may still appear too short.

The too-long tooth

When alveolar or gingival recession has been severe, the length of the pontics or crowns must be made to appear shorter. Basically, vertical grooves or lines should be diminished and horizontal lines emphasized. This can be accomplished by several methods.

Shaping

The areas of contact can be lengthened as much as is physiologically acceptable while the gingival embrasures are kept as narrow as possible (Figure 8.33). The cervical portion and the incisal one-fifth of the pontic or crown should be inclined lingually (Figures 8.33 and 8.34). By changing the inclination of these

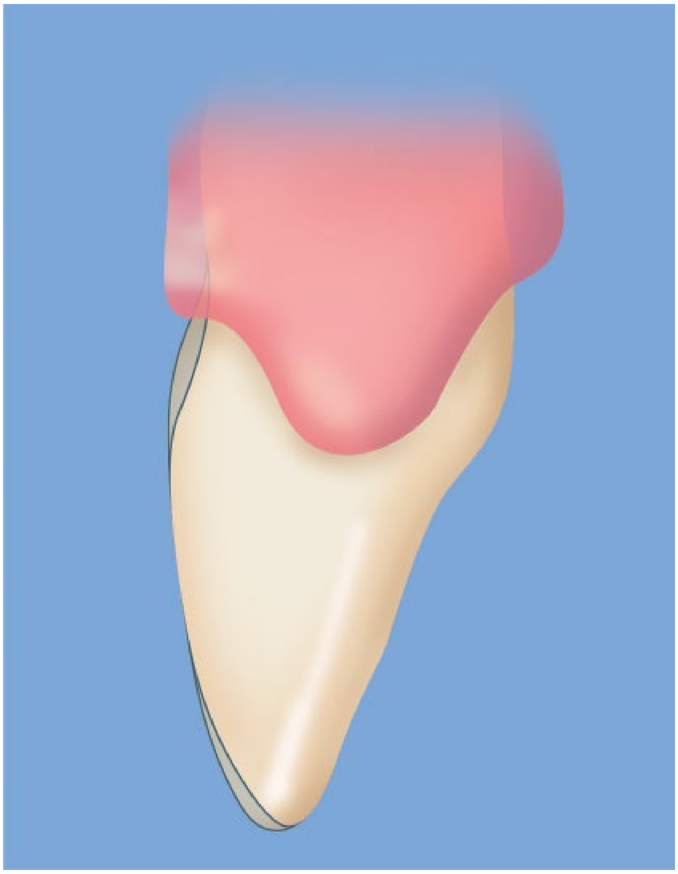


Figure 8.34 A lateral view demonstrating the lingual inclination of the cervical and incisal one-fifth areas which decreases the appearance of length.

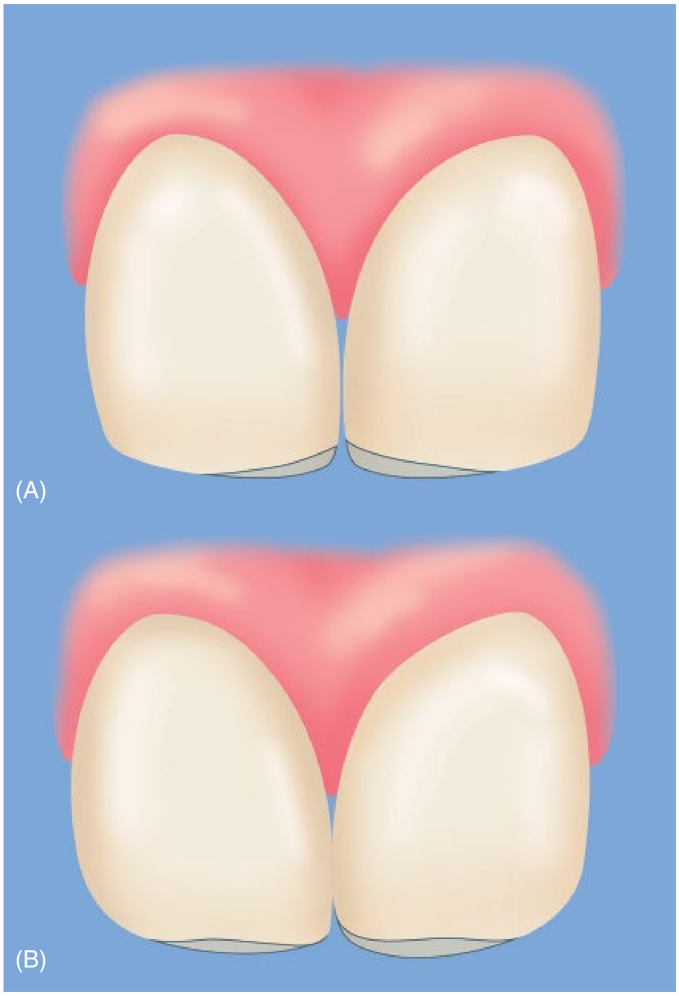


Figure 8.35 When two teeth are involved, reduce the incisal edges to converge gingivally at the proximal common contact **(A)**. The length of the tooth will appear to decrease by the notching of the center of the incisal edge **(B)**.

surfaces, the effective reflecting surface is shortened, decreasing the appearance of length. The incisal edge may be shaped to seemingly decrease length by notching the center (Figure 8.35B). If there are two adjacent teeth that need to appear shorter, grind the incisal edges to converge gingivally at the proximal contact (Figure 8.35A).

Staining

A definite demarcation at the cementoenamel junction decreases the apparent length, and this can be carved into the restoration and further accentuated with stain. The color of the cervical portion should be deepened by staining it either a deeper body or cervical shade.

To mask the height of extremely long teeth, either stain the gingival portion of the crown or pontic pink (to simulate gingival tissue) or use a combination of tissue-colored porcelain stains when baking the crown.

Creating optical illusions with form and color

Modifying shape and form, along with the color and shade of teeth can create a myriad of special effects or illusions (Figure 8.36A–L). Table 8.4 and accompanying photographs provide real-world examples of these special effects in action.

Need to disguise long-axis inclinations

When restoring a severely tipped tooth, it may be impossible to achieve correct alignment simply by altering the preparation. In these cases, the use of illusions can confer the appearance of good alignment.

Increasing mesial inclination

In an anterior tooth (Figure 8.37), the distal contact is moved cervically and the mesial contact is moved incisally. The distal line angle is carved toward the center of the incisal edge. To help complete this illusion, the incisal edge is pointed on the mesial and notched toward the distal. In a posterior tooth, the distal contact is moved cervically and the mesial contact is moved occlusally. The buccal ridge is carved to curve from the distogingival to the mesio-occlusal. The cusp tip can be moved mesially if this is compatible with functional requirements.

In both anterior and posterior teeth, the illusion of mesial inclination can be increased by incorporating light lines, by

Figure 8.36 **(A–C)** Modifications of form and color can create illusion of better proportion of teeth.

Figure 8.36 **(D–F)** Darker gingival color and root formations create shorter tooth appearance.

Figure 8.36 **(G–I)** Pink gingival ceramics used to re-establish correct proportions of teeth and gingival levels.

Figure 8.36 **(J–L)** Designing darker proximal wings and adjusting line angles gives a smaller/narrower appearance of the restoration. This is useful in diastema closure cases with excessive space to maintain the illusion of proper tooth proportion.

staining, that follow the distal line angle, or buccal ridge, or that run approximately parallel to them.

Increasing distal inclination

To increase the perception of a distal inclination, reverse the preceding instructions on mesial inclination. In an anterior tooth, the mesial contact is moved cervically and the distal contact is moved incisally. The mesial line angle is carved toward the center of the incisal edge. The incisal edge is pointed on the distal and notched toward the mesial. In a posterior tooth, the mesial contact is moved cervically, and the distal contact is moved occlusally. The buccal ridge is carved to curve from the mesiogingival to the disto-occlusal. The cusp tip can be moved distally if this is compatible with functional requirements. In both

Table 8.4 Form and Color to Create Optical Illusions

Shape and Form	Desired Effect	Color and Shade
Pink ceramics (Figure 8.36A–C)	Long teeth	Darker root form
Vertical grooves and ridges (Figure 8.36D–F)	Make longer	Long vertical crack lines
Horizontal grooves and lines (Figure 8.36G–I)	Make shorter	Horizontal hypocalcification bands
Proximal wings (move in line angles) (Figure 8.36 J–L)	Wide teeth	Darker, more chroma in proximal
Line angles out	Larger teeth	High value, bright, opacious
Line angles in	Smaller teeth	Low value, darker, translucent

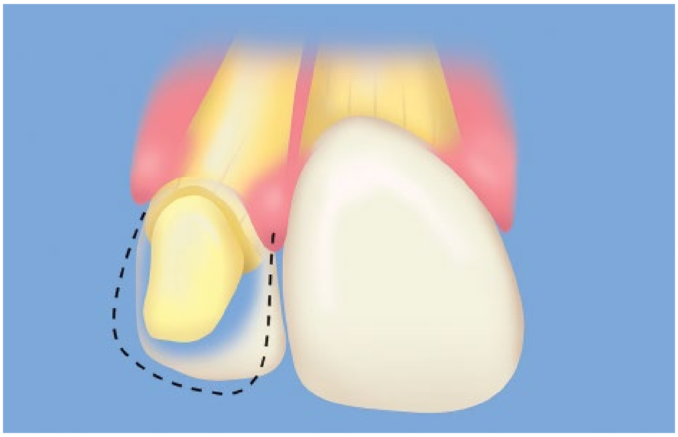


Figure 8.37 Increasing the mesial inclination on a severely tipped tooth is an illusion that increases the appearance of good alignment.

anterior and posterior teeth, the illusion of distal inclination can be increased by incorporating lightly stained lines that follow the mesial line angle or buccal ridge or that run approximately parallel to them.

Insufficient differentiation between teeth

Special problems occur in the attempt to achieve a natural appearance in the multiple unit anterior ceramometal restoration. The major objective is to give the illusion that the teeth are actually separate and not a connected series. This can be accomplished by placing the proximal connector as lingual as possible to allow for maximum interdental separation between the teeth. Staining should be used to give the teeth the appearance of individual units. Most restorations appear artificial because of stains that are too light or the absence of stains between the teeth. By the use of darker stains, the interproximal areas can be shaded where they curve into the embrasures. This will add an illusion of interproximal depth and separateness. Use an orange-brown

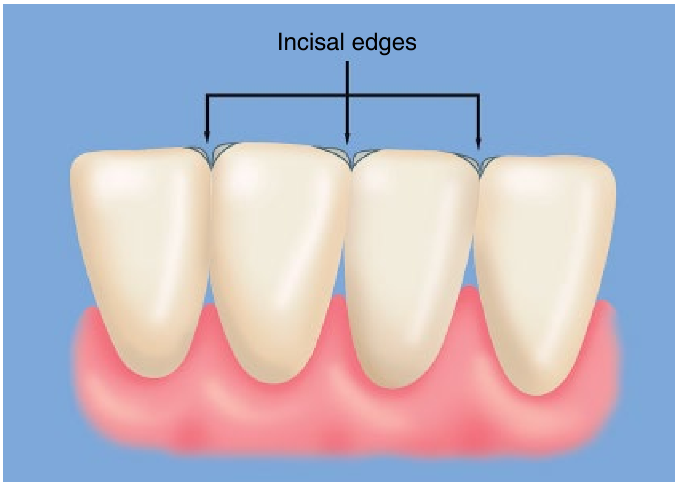


Figure 8.38 In addition to staining the interproximal areas where they curve into the embrasures, the incisal edges are slightly curved to create differentiation between teeth.

or gray-green combination, whichever approximates the color of the adjacent or opposing teeth.

Sometimes, it is still difficult to obtain the desired illusion of separation in crowded lower anterior units. An alternative technique is postsoldering when multiple crowns are involved. The actual separation between the crowns, even though minimal, may create an individual, natural-looking restoration. Make certain not to create too much space between the crowns. Complete visualization of the result should occur before the final soldering. It is advisable to examine the framework and try to picture the degree of separation before the porcelain buildup. A slight depression in the framework strut in the contact area will also increase the illusion of separation by allowing a deeper depth-cut in the porcelain veneer. The incisal edge (ie) can also be curved into the interproximals, heightening the illusion (Figure 8.38).

Arch irregularity

On smiling, an arch irregularity can cause exposure of more crowns or more of the crowns on one side of the mouth than on the other (Figure 8.39A and 8.40A). You need to discuss this problem with the patient before treatment, explaining that the crowns will not be bilaterally symmetrical in the final restoration. All other unusual conditions should be noted at the second appointment during the esthetic diagnosis. Pre-restorative photographs should be taken to preserve a good record of both smiling and lip-retracted positions. It is a good idea to give a copy of these photographs to the laboratory as well.

Treatment for arch irregularity usually involves gingival raising, tooth shortening and/or lengthening, or a combination to help achieve the illusion of a more balanced arch (see Figure 8.39A–C). In addition, an artificial tissue insert can be made (Figure 8.40D–G) or tissue-colored ceramic composite be applied.

Influencing facial shape

In general, the oval is considered the ideal facial shape. If the face is too long, shortening long teeth will help to add width. Reduce the interincisal distance (the vertical height between the central

Figure 8.39 **(A)** This lady has a maxillary arch that drops down on the right side.

Figure 8.39 **(C)** After contouring, the patient's smile shows a balanced arch.

incisal edges and the lateral incisal edges) if the central incisors are extra long or extended. Also, horizontal lines and characterizations can be added or emphasized. The reverse procedure can be used on the round face by emphasizing tooth length, and using vertical lines and characterizations.

Incorporating age characteristics

Once the correct form and function have been achieved in a crown or pontic, the wear and stains that normally accumulate with age should be incorporated into the new restorations to blend with the appearance of the remaining natural teeth. Foods and various filling materials leave stains and discoloration. A clean, new, perfect tooth would be quite noticeable if set among

Figure 8.39 **(B)** The teeth are outlined with an alcohol marker to show where they will be contoured.

others with worn incisal edges, multiple restorations, and tobacco stains. Overall, teeth are generally lighter in young people than in the aged, and rarely are all of the teeth uniform in shade in the older dentition.

Nature incorporates in each tooth many colors that usually become more pronounced with age; for example, the gray and yellow tones. A prosthesis prepared for an older individual should be stained to simulate the color variations found in the remaining natural teeth. For example, the presence of Class III restorations can be simulated with stains (see Figure 8.32A). If the patient desires, actual gold restorations may be placed in artificial replacement teeth to increase the illusion of age and realism.

Careful shaping and polishing can effectively mimic abrasion and imply advancing age. Wear on the incisal edge accumulates with increasing age, shortening the anatomic crown by abrading its translucent edge. This aging is simulated by carving the incisal edges and cusp tips to simulate accumulated abrasion. The grinding should not be a flat reduction in height but should simulate natural, angled wear facets produced by opposing teeth. Note in Figure 8.41A, how incisal wear can occur in natural teeth, and in Figure 8.41B and C, how cuspids can wear. To maintain harmony of appearance, if there is cemental erosion or erosion on the gingival one-third of the remaining teeth, carving and staining a similar pattern into the replacement tooth is indicated. Tooth migration, shifting, or rotation may also occur with aging. If the long axes of the remaining teeth are variable and if some of the teeth are rotated, a row of straight, perfectly aligned pontics or crowns will stand out. A slight rotation or shift of the long axis can mean the difference between an artificial appearance and a natural one (Figure 8.42). Although most patients request a younger look, never assume that this is what all patients prefer.

Reducing age effects on the smile

Many patients are motivated to seek esthetic dental treatment to make them look younger. They want to eliminate the aging effects just described. This is usually possible by the use of various restorative techniques. A too-light shade will look false, so avoid the temptation to follow the patient's wishes for "white teeth." When patients look at a single tooth tab from a shade guide, their inclination may be to choose the lightest color. What

Figure 8.40 **(A)** When this patient smiles she reveals more tooth length on the maxillary right side than the remainder of the arch.

Figure 8.40 **(B and C)** After periodontal surgery and full ceramometal crown restoration, the maxillary crowns are extremely long.

Figure 8.40 **(D and E)** An artificial tissue insert was made to mask the extra tooth length.

Figure 8.40 **(F and G)** The final result shows how wearing the artificial tissue insert enhances this woman's smile.

Figure 8.41 **(A)** This patient has uniform incisal and occlusal wear on all of the teeth due to bruxism (LSK121 Oral Prosthetics).

they usually fail to understand is that multiple teeth of a lighter shade will appear even whiter in the mouth when they are all together. The shade can be lighter, but vary the intensity of body color when staining the tooth. Use a deeper gingival shade that blends to the incisal edge. Avoid too much incisal shading. To make the tooth appear natural, the incisal edge should be mostly body colors, with bluish translucency appearing on the mesial and distal edges where the enamel may have worn thin. A bluish incisal surrounded by light opaque orange on the incisal edge intensifies the color, creating a halo effect, and helps give a much younger look (Figure 8.43A and B).

Aging wears down the incisal edges, usually drastically shortening the central incisors. Increasing the interincisal distance by making the centrals again longer than the laterals can help make the individual appear younger.

Most aged individuals show either too little tooth structure or none at all. If occlusion permits, make the entire anterior segment of teeth longer. Consider bevelling or cosmetic contouring on the lower anterior teeth to permit lengthening the upper incisors. In certain patients, it may even be possible to restore lost vertical dimension after which you can lengthen the upper anteriors. If this is attempted, begin with a removable or fixed interim appliance for several months to make sure your patient is comfortable with the new occlusal position. Then temporarily restore the teeth with veneers, crowns, or bonding that incorporate the new length. It is best to keep the patient in these temporary restorations for an additional 3 months before constructing the final restorations to allow for any occlusal adjustments, should your patient develop any temporomandibular joint (TMJ) discomfort.

Incisal embrasures

The incisal embrasure is the triangle formed between the edges of two adjacent anterior teeth. The incisal embrasures should display a natural, progressive increase in size or depth from the central incisor to the canine (Figure 8.44A and B). This is a function of the natural anatomy of the front teeth and, as a result, the contact point moves further toward the gum line as the teeth proceed from the centrals to the canines. This mimics the smile line and failure to provide adequate depth and variation to the incisal embrasures will make teeth appear too uniform and make contact areas too long, which will impart a box-like appearance to the teeth (Figure 8.44C and D). The individuality of the incisors will be lost if their incisal embrasures are not properly created. Also, if the incisal embrasures are too deep it will tend to make the teeth look unnaturally pointed. Incisal edge wear can eliminate the incisal embrasures, a characteristic identified with the elderly. Carving the embrasures into the restoration helps create a younger look (Figure 8.45A and B).

- **Problem**—This case shows the effect of discolored irregular teeth on a 67-year-old female (Figure 8.45E). Unfortunately, the teeth did nothing but create an even older appearance. No amount of makeup or any other cosmetic improvement could disguise the feeling of old age one got from her smile. Lipstick only helped to call attention to this.
- **Treatment**—Treatment consisted of full-mouth reconstruction with a fixed porcelain fused-to-metal prosthesis.
- **Result**—For purposes of this chapter, the patient illustrates the importance of the final esthetic result, particularly its effect on the lip line. With proper restoration, a more youthful look has been created by lengthening the central incisors and producing a more feminine (rounded) appearance in the anterior teeth. Note the overall improvement achieved by the use of a harmonious shade (Figure 8.45 F).

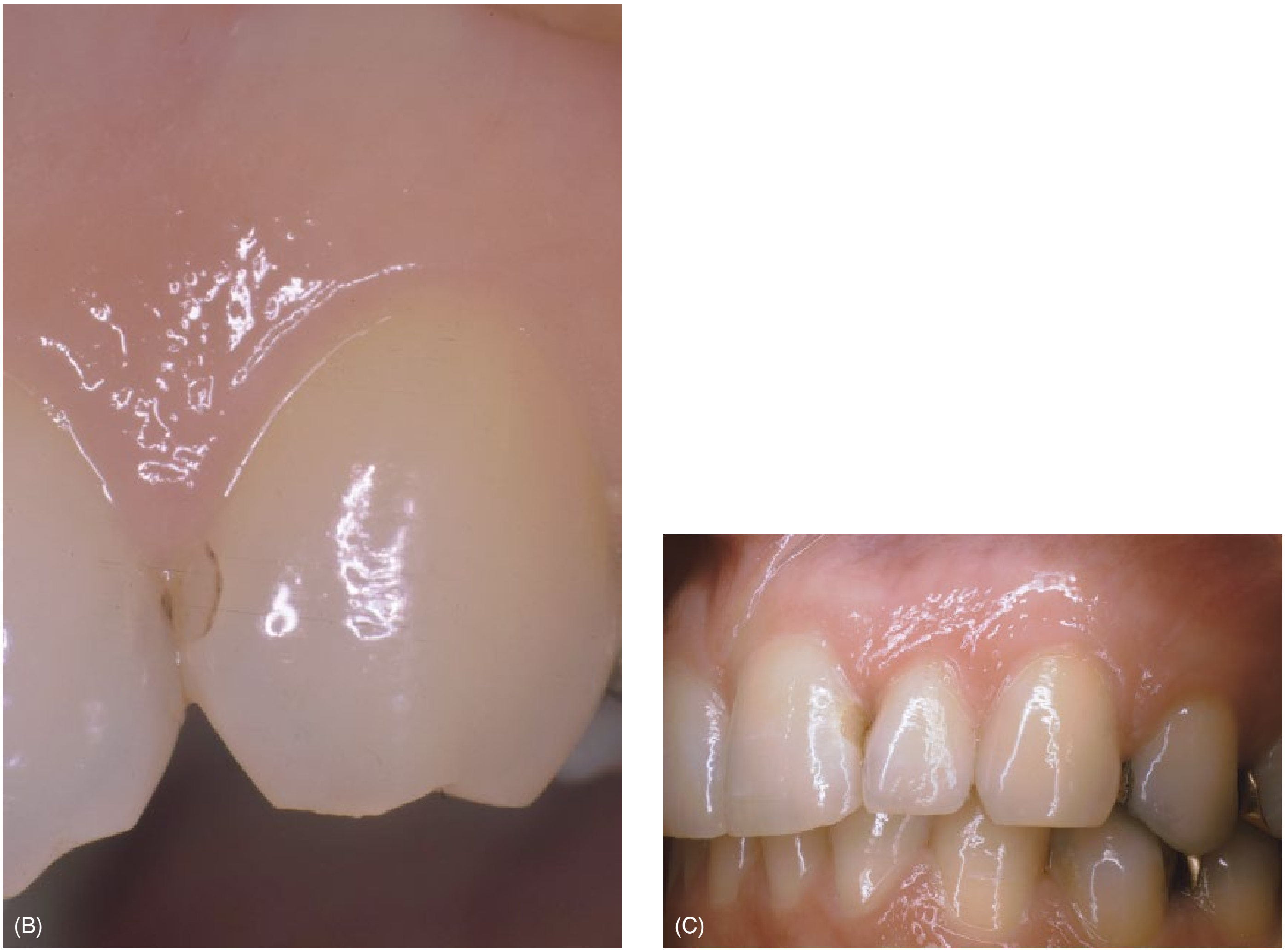


Figure 8.41 **(B and C)** These are examples of individual incisal tooth wear that often occurs in cuspids.

Figure 8.42 The slight rotation of the long axis of some teeth in a prosthesis can result in a more natural look. Figure courtesy of Magna Laboratories, Richard E. Resk.

Figure 8.43 **(A and B)** The bluish tint at the incisal edge surrounded by light opaque orange is applied to an anterior crown, producing a halo effect and giving a younger-looking appearance to the teeth.

How color affects the way we perceive teeth

See Table 8.5 for examples of how color affects our perceptions of teeth and aging.

Incorporating sexual characteristics

Wear of incisal edges eliminates certain sex characteristics. When teeth are contoured or crowns carved, you may need to incorporate either feminine or masculine characteristics. The remaining teeth should be observed to see if the replacement tooth is in harmony. We tend to interpret a female mouth as one where the contours and lines are more rounded and curved than those in the male, which are usually flatter, sharper, and more angular. By rounding angles and edges, a more feminine appearance can be achieved (see Figure 8.45B). By squaring angles and edges, a more masculine feeling is created (Figure 8.46 and 8-47). The idea of masculinity can be further enhanced by slightly abrading the incisal surface. Staining the prosthesis to simulate tobacco, coffee, or tea stains can also aid this masculine illusion, as will the incorporation of light microcrack lines. Figure 8.48A and B show stained characteristics used to obtain a more masculine look, accomplished in Figure 8.45C and D. Note the simulated restorations and hypocalcified areas. Staining of women's teeth could consist of adding a touch of blue to the incisal edge (Figure 8.43A and B).

It is not always necessary to match adjacent, natural, untouched teeth. In fact, many times the opposite should be the case. During the planning stage, a decision should be made about the type of esthetic result desired by the patient. Since it is possible to alter the patient's masculine or feminine appearance through conservative procedures such as cosmetic contouring, bonding, or laminating on the adjacent teeth, determination should first be made about the extent of the masculine or feminine character that is desired before creating the final restorations. For example, for a female who has worn her incisal edges until they now appear angular and masculine, you may elect to recontour her natural dentition before carving the new restoration.

This is not to say every female should have a soft, curvaceous look to her mouth, or every male should look sharp and angular. The degree of femininity or masculinity is dependent on the patient's personality, habits, and (most of all) desire. Patients have an unquestionable right to help choose what type of appearance they will eventually have. The dentist must be sensitive enough to go beyond the patient's apprehensions about being considered vain and find out their true desires.

Figure 8.44 **(A and B)** Natural, progressive increase in incisal embrasures (Naperville).

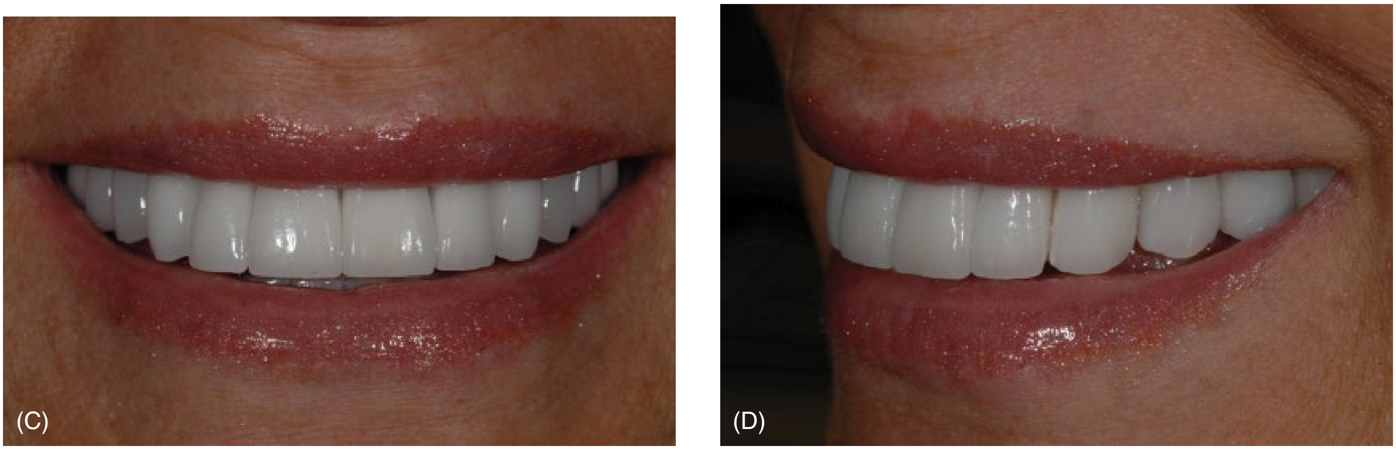


Figure 8.44 **(C and D)** Unnatural, too uniform incisal embrasures, described as "chicklets."

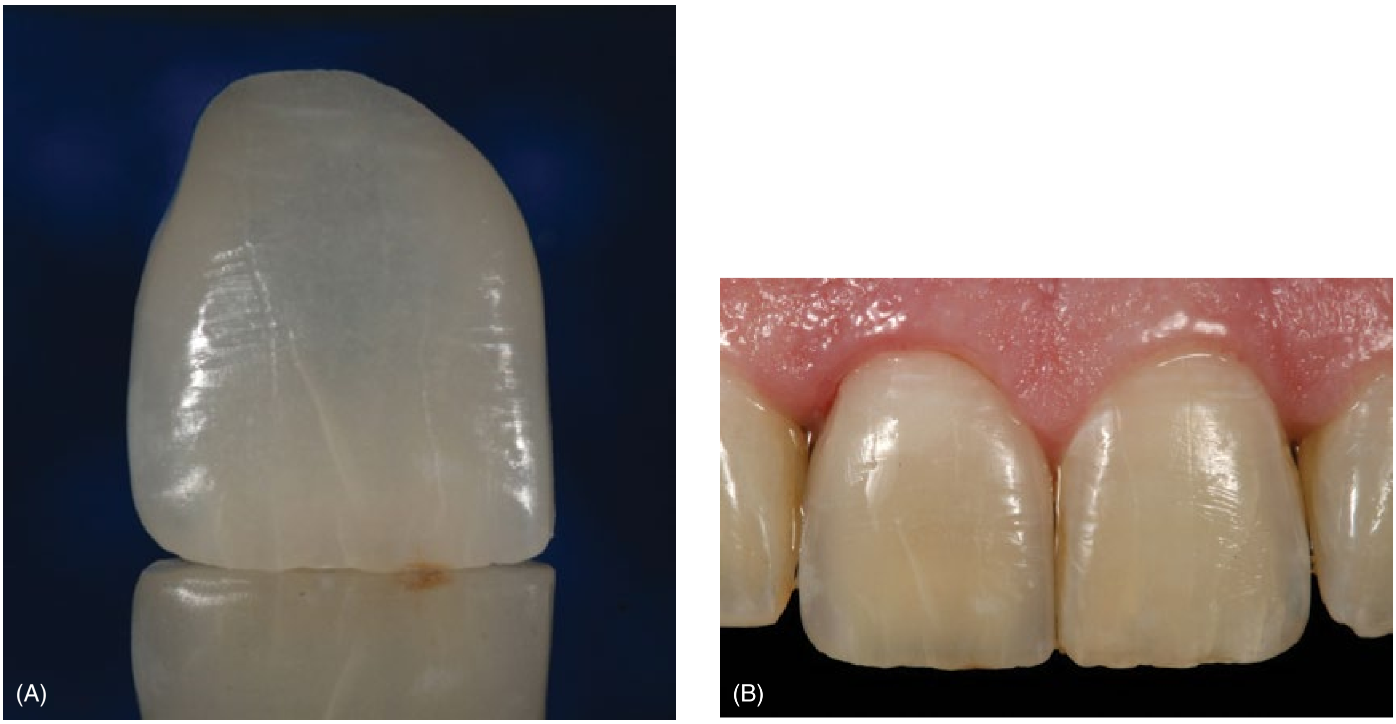


Figure 8.45 **(A and B)** Older, more mature tooth reproduction.

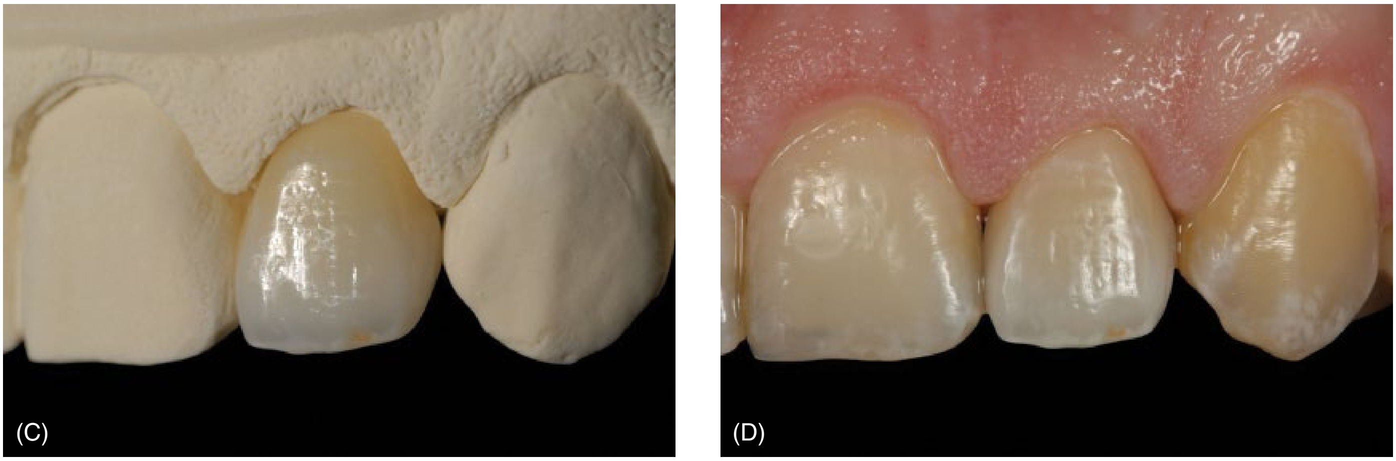


Figure 8.45 **(C and D)** Youthful tooth reproduction.

Figure 8.45 **(E)** Irregular and discolored teeth contribute to an older-appearing smile.

Figure 8.45 **(F)** A younger-looking appearance achieved by restoring the teeth with rounded, even, more feminine lines and a more uniform and harmonious shade.

Table 8.5 Color and Our Perception of Teeth

Younger-Looking Teeth	Older, More Mature-Looking Teeth
White hypocalcification	Yellow/orange staining
High texture	Low texture (surface polishing)
Include mammalons	Include signs of wear (flat edges)

* Some of these characteristics illustrated in Figure 8.43A and B.

Incorporating the personality of the patient

A delicate personality can be differentiated from the vigorous one by the degree of characterization, coloring, and arrangement of teeth. Overaccentuation of color, bold characterization, and nonuniform arrangement are compatible with an aggressive personality. The mild, demure personality is associated with less starkness and less color differentiation. The patient and his or her teeth should be evaluated carefully to achieve the desired final effect.

Many patients wish to improve the appearance of their teeth and want a very bright shade but fear a too-perfect look might alter their image. They want a natural appearance that retains their personality. An example was seen in a 47-year-old female patient (Figure 8.49A and B) who wanted a younger-looking, more feminine smile with a very bright shade. A combination of periodontal crown lengthening, full crowns, porcelain veneers, and even composite resin bonding created the final result. Figure 8.49B shows the patient's choice for a natural, youthful appearance.

Loss of interdental tissue

Minimizing the loss of interdental tissue and concealing the fact that it is missing are problems that intrigue both the periodontist and the general practitioner, as well as the prosthodontist. Patients who have had periodontal surgery resulting in the loss of interdental tissue that then created holes or spaces between the teeth can be miserable about their appearance. Occasionally, surgical techniques can be altered to include either a lingual approach or other procedure that does not expose as much root surface.

Both the restorative dentist and the periodontist should always examine the patient's smile line to see exactly how much

Figure 8.46 **(A)** Worn, irregular and discolored teeth contribute to an older-appearing smile in this 52-year-old man.

Figure 8.46 **(B)** An improved appearance was achieved by restoring the teeth with more masculine-shaped, lighter-colored ceramic crowns. Note the central incisors are a little longer than the lateral incisors, creating a greater interincisal distance and resulting in a younger-looking smile.

tissue would be exposed by each of several different procedures. If no compromise is possible, then a special effect may have to be created after the tissue has healed. There are generally four solutions to this problem: (1) a removable artificial interdental tissue appliance, (2) composite resin bonding or porcelain veneers, (3) full crowning, or (4) fixed porcelain interdental addition (Figure 8.40A–G).

Figure 8.47 Squared angles and edges create a more masculine look.

Composite resin bonding or porcelain veneers

It is possible, by use of an acid-etch composite resin technique, to proportionally bond composite resins to each tooth so that the space is closed. This method is perhaps the easiest, and certainly the quickest, to perform. When doing so, it is important to add the material mainly from the linguoproximal surface, so that the size of the tooth is not changed appreciably (Figure 8.50A). The lingual, proximal, and mesiolabial surfaces of both central incisors were etched, and the composite resin was placed. The final attractive result was achieved by not overbuilding the tooth and yet hiding the unsightly spaces left by the missing interdental tissue (Figure 8.50B). When using this technique, it is important to take as much time as necessary for shaping and forming the composite resin. For this reason, a light-polymerized composite

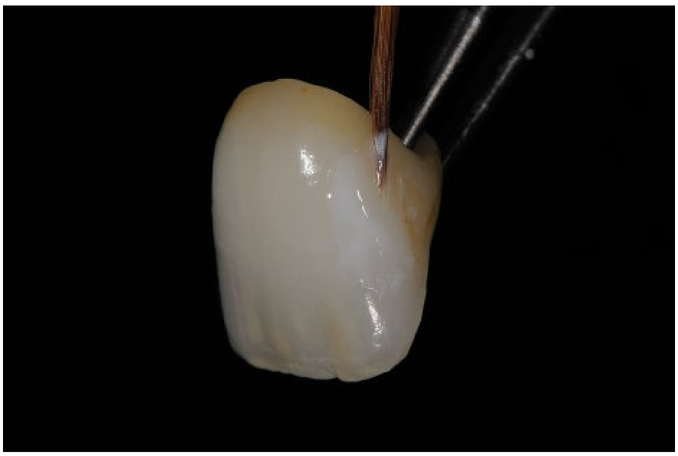


Figure 8.48 **(A)** Light microcracks, simulated restorations, and hypocalcified areas can help create a more natural and youthful look.

Figure 8.48 **(B)** Yellow/orange staining is a natural characteristic of the older dentition.

Figure 8.49 **(A)** This 47-year-old female wanted to restore her teeth and have a more attractive smile.

Figure 8.49 **(B)** A combination of crown lengthening, full crowns, porcelain veneers and composite resin bonding were done to create the final result.

Figure 8.50 **(A)** The loss of interdental tissue has resulted in a dark, unattractive space between the two central incisors.

Figure 8.50 **(B)** Conservative composite resin bonding of the lingual, mesial, and labial surfaces of both central incisors hides the space while not overbuilding the teeth.

Figure 8.51 **(A)** Interdental spaces from periodontal surgery plus severe cervical erosion may require more than the usual conservative treatments of bonding or laminating.

Figure 8.51 **(B)** An unsightly dark space was clearly visible between the central incisors in the before-treatment smile.

Figure 8.51 **(C)** Full-arch splinting with a telescopic prosthesis allowed for both raising the contact area gingivally and the addition of material lingually to lessen the space. After treatment, the interdental space is not evident, and the patient now has a more attractive smile line.

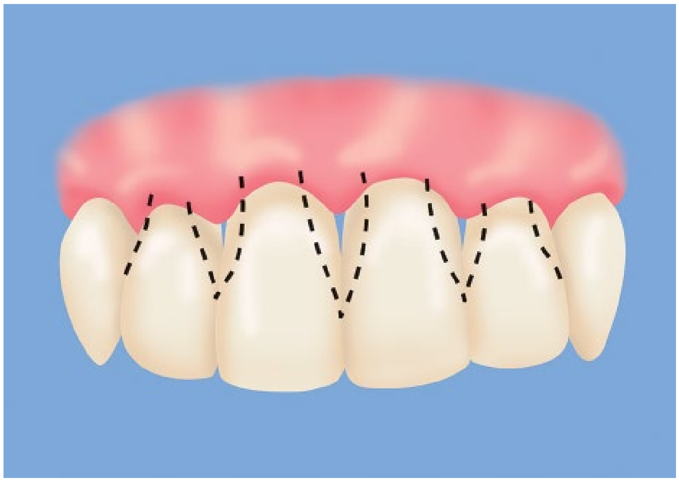


Figure 8.51 **(D)** This illustrates where to add porcelain so that the spaces are masked and the restorations do not appear too bulky.

Figure 8.52 **(A and B)** This 45-year-old female presented with older, discolored porcelain veneers with slight loss of interdental papilla.

Figure 8.52 **(C)** New all-ceramic crowns were made and splinted together due to her cleft palate. However, a fixed pink ceramic insert was chosen to replace the missing interdental papilla.

resin is best. Adequate time is then available to fully carve each tooth to obtain a good esthetic result. An alternative to this technique is to use porcelain veneers to mask the spaces. If this is done, make sure the proximal surfaces of the teeth are prepared deeply into the embrasure space.

Full crowning

Full crowning can also be used to mask the loss of interdental tissue; however, it is generally not advised unless the teeth also need to be restored. In Figure 8.51A and B, we see a patient after periodontal surgery left him with unsightly interdental spaces. Since individual gold telescopes plus full-arch splinting were necessary, closure of these spaces could be adequately handled with the fixed prosthesis. By raising the contact areas gingivally

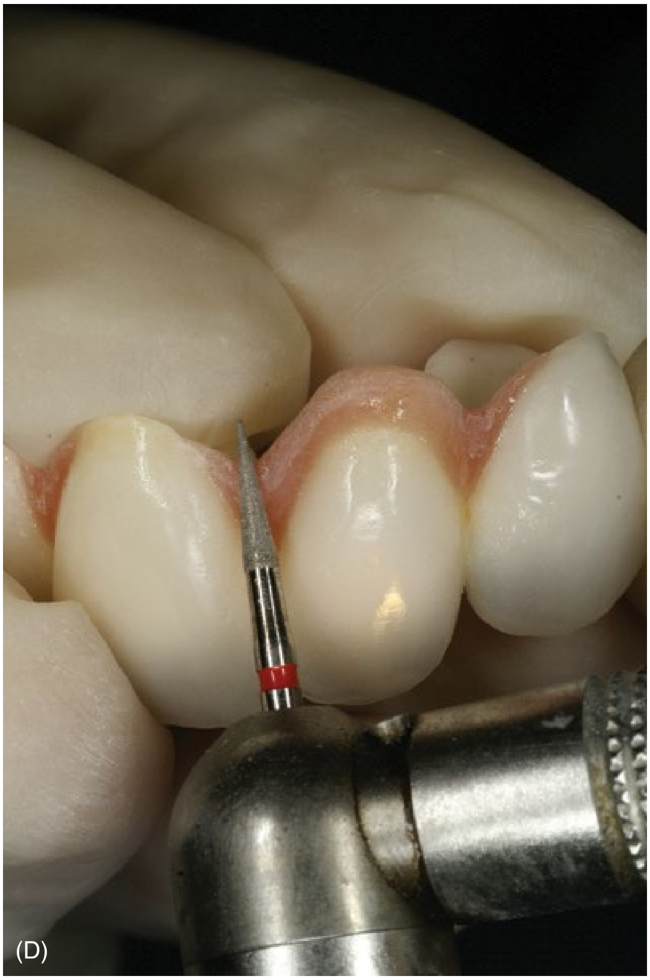


Figure 8.52 **(D–F)** A fixed pink ceramic was applied to the four-unit fixed bridge to replace the missing interdental papilla.

and by adding additional porcelain lingually to close the interdental spaces, an improved smile line is created (Figure 8.51C). Figure 8.51D shows graphically where the porcelain is added to hide the spaces and keep the crowns from looking too bulky. Note that the visible gold bands at the gingival margins are concealed by the patient's medium lip line.

Fixed porcelain interdental addition

An alternative solution to the interdental space problem is adding a gingiva-colored porcelain insert attached to the fixed partial denture. This method works well when there are missing anterior or posterior teeth and extreme ridge resorption. The following case illustrates the technique for construction. A female patient, aged 45, presented with an older, discolored anterior restoration (Figure 8.52A and B). The patient was conscious of her unattractive smile and tried to hide it by keeping her upper lip as far down as possible. Her main problem was loss of interdental tissue. The treatment included a fixed splint with a fixed pink ceramic interdental insert (Figure 8.52C–H).

Lost interdental tissue can be effectively and esthetically treated with the above techniques. However, another type of porcelain addition has been suggested by Cronin and Wardle.[4] They describe a cantilevered porcelain papilla that features a convex gingival form, which can be easily cleaned with dental floss. Treatment could also consist of a combined therapy including orthodontics to erupt the central and cuspid, bringing the tissue level down to balance the opposite side, followed by ridge augmentation as necessary, and completed with a single-tooth implant replacement or a conventional three-unit bridge.

Another alternative to the fixed porcelain interdental tissue is to use a fixed composite resin addition. A major advantage to composite resin is the ease of masking the add-on and the ability to repair it in the mouth (Figure 8.53A–N).

Porcelain veneer alternate construction techniques

There are times when preparation for a porcelain veneer might result in insertion problems with too much bonding cement in undercut areas. Therefore, master ceramist and artist Nasser Shademan has developed a two-tier quattro veneer construction that can be seen in Figure 8.54A–V.

Figure 8.52 **(G and H)** Note a more attractive smile line was created by full crown restorations and using the pink porcelain addition to replace her missing papilla.

Figure 8.53 **(A)** This patient was concerned about the interdental space between her centrals.

Figure 8.53 **(B)** After implant placements make spaces where interdental papilla will be missing.

Figure 8.53 **(C)** Wax-up of the proposed implant bridge and gingival papilla. Note how Siltek matrix will be used in the design.

Figure 8.53 **(D)** Zirconia framework.

Figure 8.53 **(E)** Porcelain buildup following the Siltek design.

Figure 8.53 **(F)** Final restorations in place on the model.

Figure 8.53 **(G)** Checking the pink shade.

Figure 8.53 **(H)** After the implant was seated the patient's concern turned to the missing gingival papilla between her natural central incisors.

Figure 8.53 **(I)** An EMAX white tooth fragment was constructed with a pink composite resign gingival papilla bonded to the porcelain.

Figure 8.53 **(J)** Air abrasion was used to help clean and etch the enamel. This procedure also corrected the provisional defect.

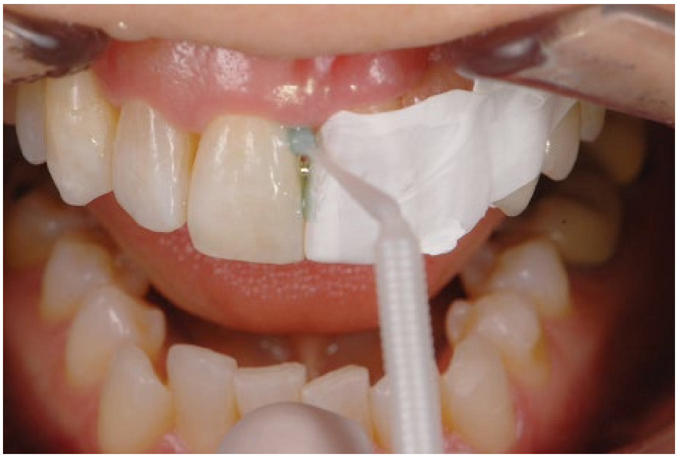


Figure 8.53 **(K)** Teflon tape was used to protect the adjacent tooth as etch is applied to the other central incisor.

Figure 8.53 **(L)** The final central incisor tissue insert and the implant bridge are in good health.

Figure 8.53 **(M and N)** Extraoral close-up photos show how esthetics look 2 years postoperatively. Figure courtesy of Guilherme Cabral.

Figure 8.54 **(A)** All-ceramic quattro veneers on the maxillary central incisors are a new solution to allow intimate marginal adaptation and a perfect fit. This may eliminate excessive tooth reduction especially with triangular tooth shapes. Figure courtesy of Nasser Shademan.

Figure 8.54 **(B–G)** Porcelain buildup process performed using multilayer technique, to allow sufficient amount of masking the yellow color of the tooth beneath, while at the same time displaying natural translucency on layers closer to the labial surface on refractory dyes. Figures courtesy of Nasser Shademan.

Figure 8.54 **(H–K)** The porcelain buildup is completed and the ceramic surface is glazed and manually polished under the microscope. Figures courtesy of Nasser Shademan.

Summary

This chapter has presented a variety of methods to help make artificial teeth look more realistic. Selecting material with optical properties closest to the natural dentition in all light conditions is a good start. The ceramometal crown can be just as realistic as the all-ceramic crown. Splinted teeth can look just as individual as single units. However, in the final analysis, the quality of the result is directly proportional to good communication and the ability and artistry of the dental ceramist (Figure 8.55A and B).

Natural tooth positions, contours, surface characterizations, and blemishes can be quite esthetic. Asymmetry is a normal occurrence. Neither dentist nor patient may wish to reproduce that which is grotesque, but the classic ideal may be just as unesthetic. All or some of these factors must be analyzed and resolved before an esthetic result can be achieved. There is an obligation to the patient to restore not merely healthy function but the esthetics that are so important to a healthy personality. Through the use of illusion, this end can often be achieved, despite seemingly impossible esthetic problems.

Figure 8.54 **(L and M)** The maxillary central incisor after removal of the refractory dye material that was sand blasted earlier shows a thickness of less than 0.5 mm. Figures courtesy of Nasser Shademan.

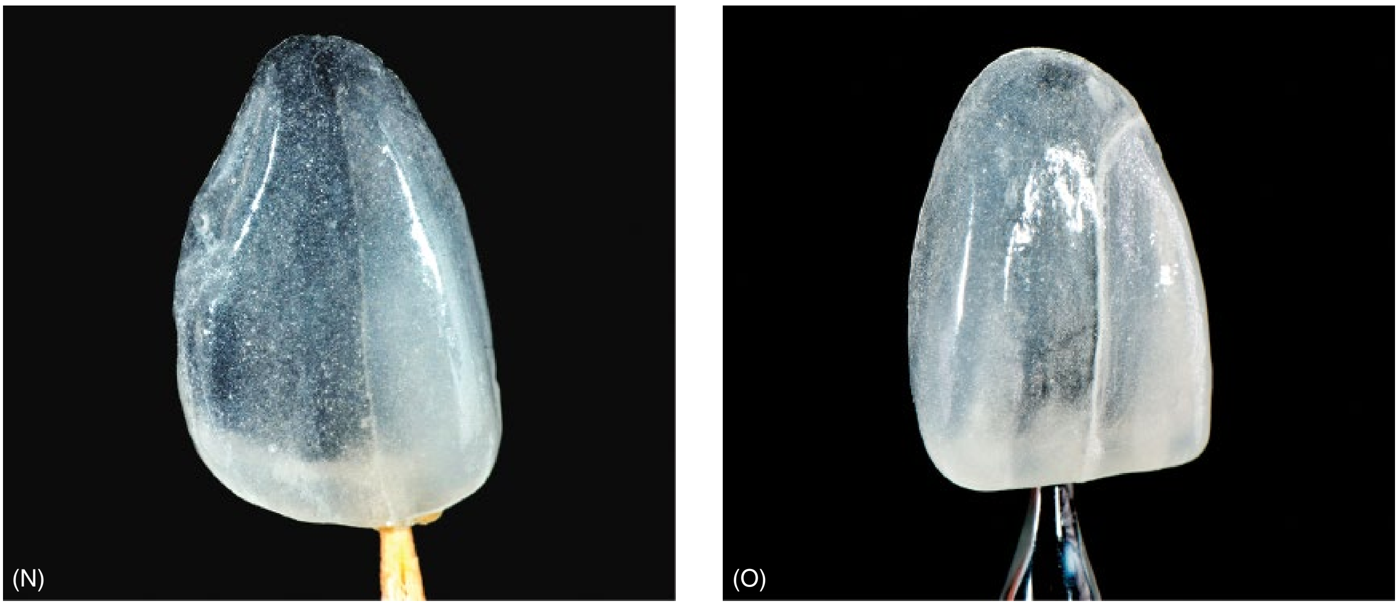


Figure 8.54 **(N and O)** Using a well-sharpened ceramic cutting bur the vertical groove was created from inside the veneer under the microscope, outlining the design of a dual-section veneer. Figures courtesy of Nasser Shademan.

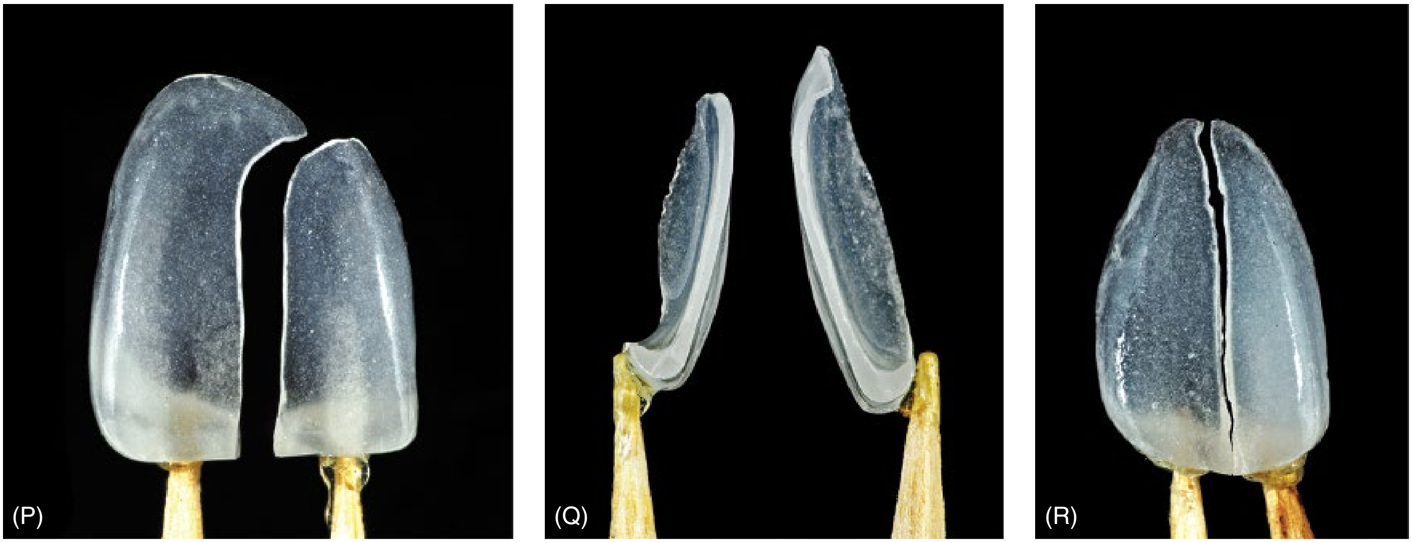


Figure 8.54 **(P–R)** With a little pressure the single porcelain veneer is now separated into two sections, just as planned. Figures courtesy of Nasser Shademan.

Figure 8.54 **(S)** The preoperative close-up image shows the triangular interproximal shape as well as excessive yellow staining on the canine. Figure courtesy of Nasser Shademan.

Figure 8.54 **(T)** Postoperative close-up image from the same patient after insertion of all-quattro veneers. Figure courtesy of Nasser Shademan.

Figure 8.54 **(U and V)** The patient's smile before and after images. Figures courtesy of Nasser Shademan.

Figure 8.55 **(A)** A preoperative view of the patient's existing left central incisor crown shows a lack of (1) color match, (2) proper tooth form, (3) luster, and (4) texture. Figure courtesy of Guilherme Cabral.

Figure 8.55 **(B)** A new all-ceramic crown was fabricated to better mimic the natural dentition. Note the type of shade characterization, the density of calcified spots, and the finishing texture and luster which give the illusion of a natural tooth. Figure courtesy of Guilherme Cabral.

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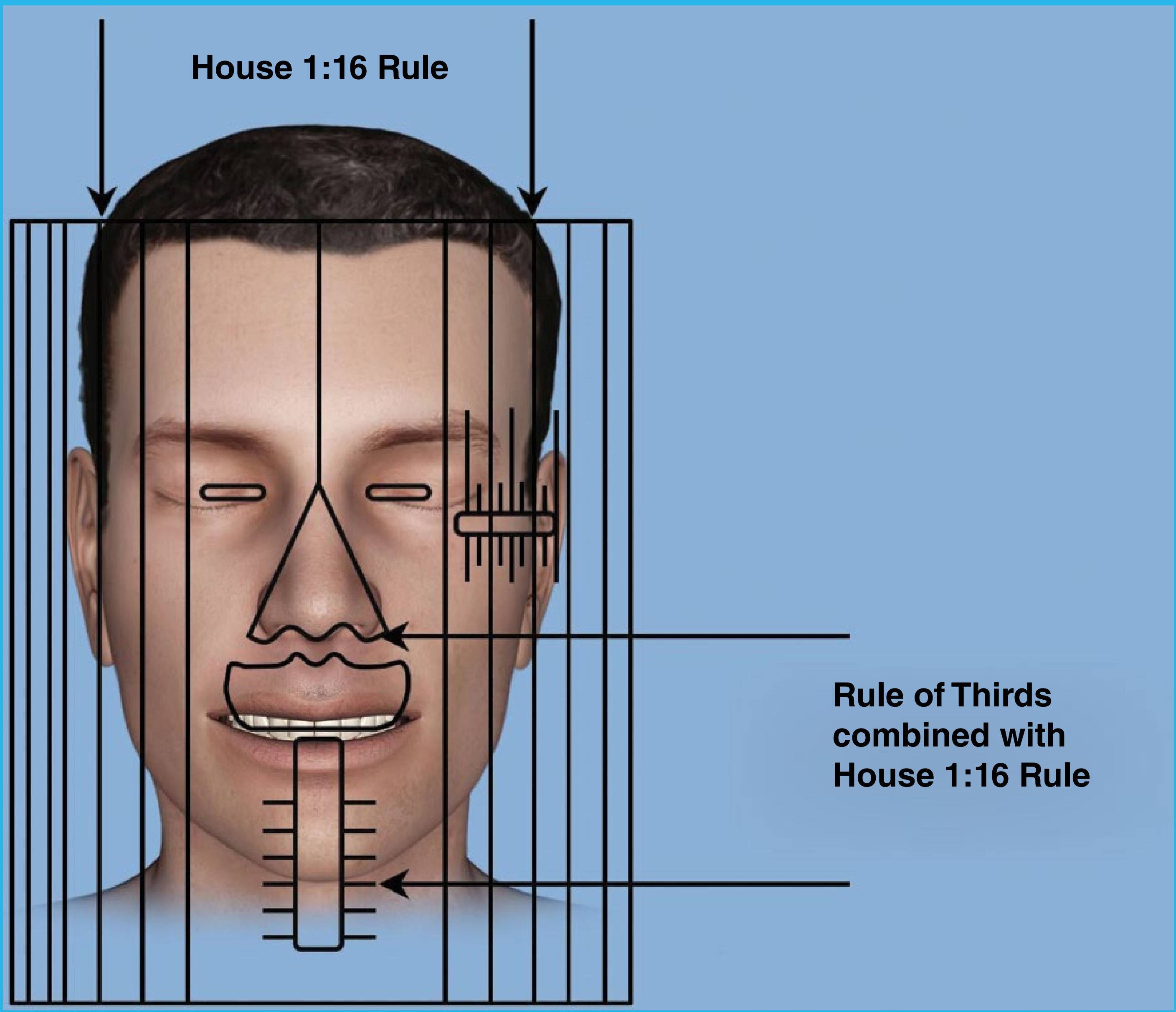
House 1:16 Rule
Rule of Thirds
combined with
House 1:16 Rule

Chapter 9 Proportional Smile Design

Daniel H. Ward, DDS, Stephen J. Chu, DMD, MSD, CDT, and Christian F.J. Stappert, DDS, MS, PhD

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The modern paradigm of dentistry merges an esthetic element with a functional restorative component. An analytical approach in conjunction with a stylistic expression of smile design is essential to balance the artistic and scientific aspects of the discipline. A few gifted operators have the ability to internally visualize the potential outcome of a smile without formal analysis. This subjective approach may be effective for the most experienced and talented professionals, but a more objective method for evaluating and predetermining the final outcome is essential for the majority of dentists. Some professionals may feel this diminishes the creativity of their efforts, but in today's consumer-oriented environment, patients often demand a clear visualization of the end results. On closer evaluation and study, specific characteristics and patterns of what is considered esthetic become evident. Certain key proportions emerge as being present in smiles considered to be pleasing to the eye.

The golden proportion

Balance, symmetry, and proportion are essential to create the perception of beauty and harmony in objects viewed as esthetic (Figure 9.1). The concept of beauty and its correlation with nature and mathematics was a central theme in the development of the "golden proportion." Attributed to Phidias in ancient Greece over 2000 years ago, it has been believed by many to possess mystical powers.[1] Leonardo da Vinci denoted the presence of the golden proportion in his book of illustrations depicting the human body (Figure 9.2). The golden proportion occurs when the length of two objects have a special relationship in which the proportion between the shorter to the longer is the same as the proportion of the longer to the sum of the shorter plus the longer (Figure 9.3). The proportion in which this occurs is 0.618:1 or 62%. The golden proportion has been observed to

Ronald E. Goldstein's Esthetics in Dentistry, Third Edition. Edited by Ronald E. Goldstein, Stephen J. Chu, Ernesto A. Lee, and Christian F.J. Stappert.

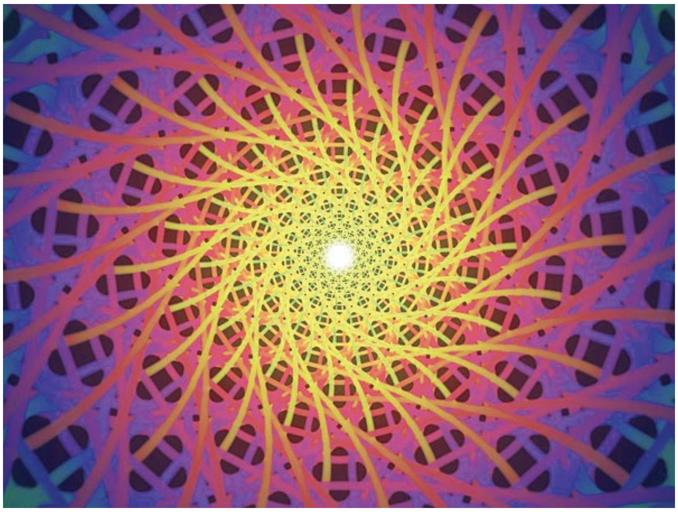

Figure 9.1 Esthetic balance and symmetry.

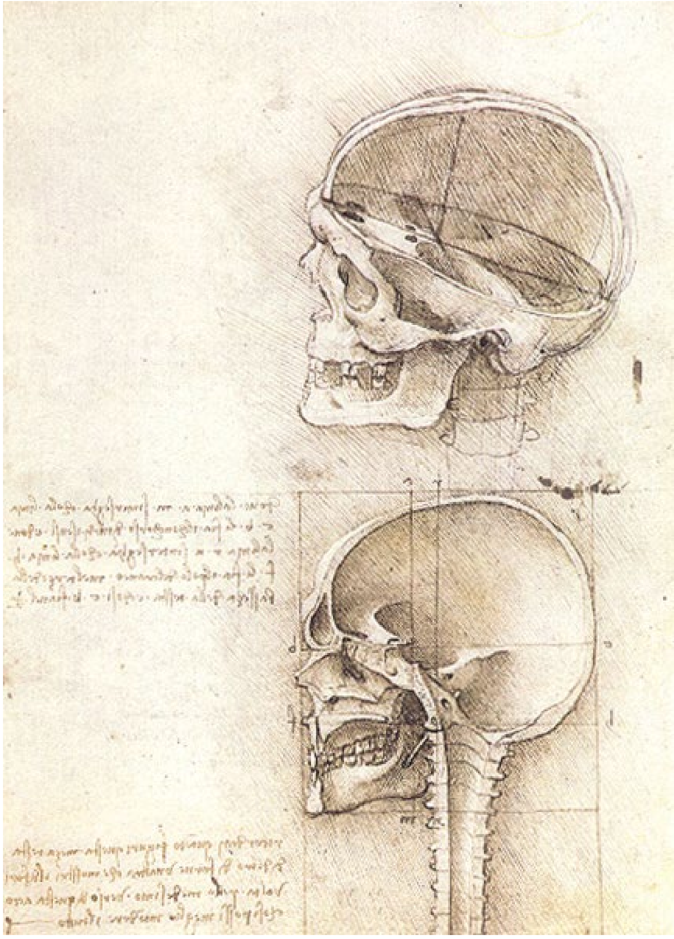

Figure 9.2 da Vinci drawings.

be present in nature in the growth of many organisms (Figure 9.4). It is interesting to note that the reciprocal of the golden proportion is equal to the sum of 1 plus the golden proportion (Figure 9.5). Authors have described various proportions of body parts as being golden (Figure 9.6).[2] Ricketts suggests that

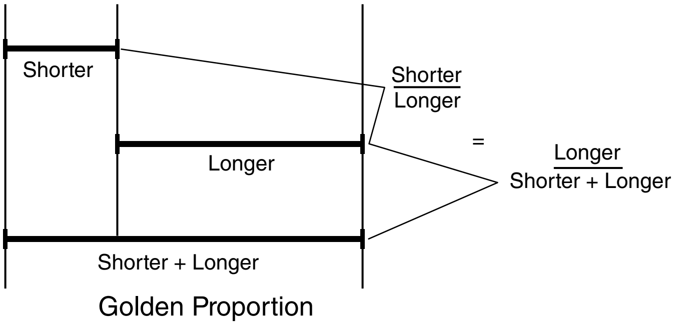

Figure 9.3 Lines in golden proportion.

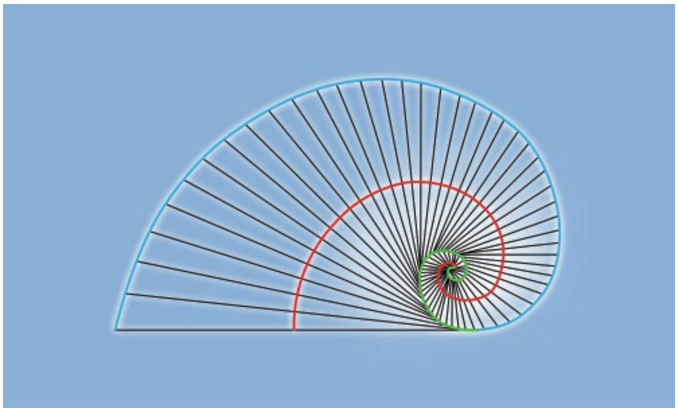

Figure 9.4 The golden proportion is observed in many organisms, such as a snail's shell.

$$\text{Golden Proportion} = \frac{\text{Shorter}}{\text{Longer}} = \frac{\text{Longer}}{\text{Shorter + Longer}} = 0.62 = \left(\frac{\text{Shorter + Longer}}{\text{Longer}} - 1\right)$$

Figure 9.5 Unique golden proportion mathematical properties.

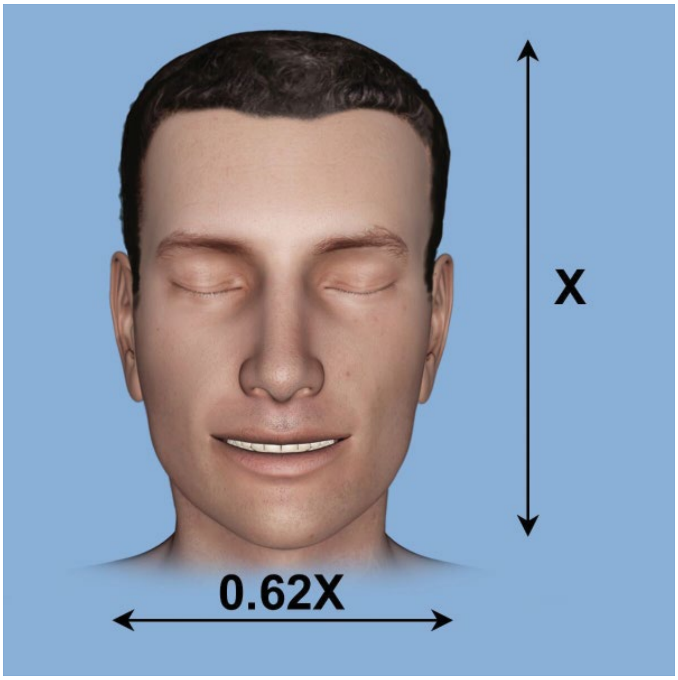

Figure 9.6 Width and length of face in golden proportion.

the golden proportion registers in the mind at the subconscious level and provides beauty, comfort, and pleasure to the senses.[3]

Proportions of the esthetic face

Other proportions have been reported to be present in humans. Modeling agencies often have measured their models in search of esthetic proportions deemed to be desirable for employment. A common lay observation has been that models are often tall. The average head is one-seventh of the total body height, yet the desired ratio by some modeling agencies is one-eighth (Figure 9.7) (L. Guthrie, personal communication, 1992). Artists have defined the facial rule of sevenths: the hair comprises the top seventh, the forehead the next two-sevenths, the nose two-sevenths, the space between the nose and mouth one-seventh, and the chin the final seventh (Figure 9.8).[4] Plastic surgeons speak of the rule of facial thirds and the rule of facial fifths.[5] Vertically, the esthetic face can be subdivided into approximately equal thirds. The superior third is from trichion to glabella, the middle third from glabella to subnasale and the inferior third from subnasale to menton. Of further interest to dentists is if the inferior third is equally divided into thirds, the incisal plane is generally located at the junction of the superior and middle thirds (Figure 9.9). It is interesting to note that these facial proportions may change as a patient ages, suggesting that certain proportions may be age-specific or age-appropriate (Figure 9.10). Similarly, plastic surgeons have noted the esthetic face can be divided into approximately equal fifths horizontally with one-fifth being the width of an eye (Figure 9.11).

Smile design principles

Every culture has its own esthetic preferences. The definitions reported are generally accepted standards for North America and may not be applicable worldwide. The original definitions of an esthetic smile were relative to the fabrication of

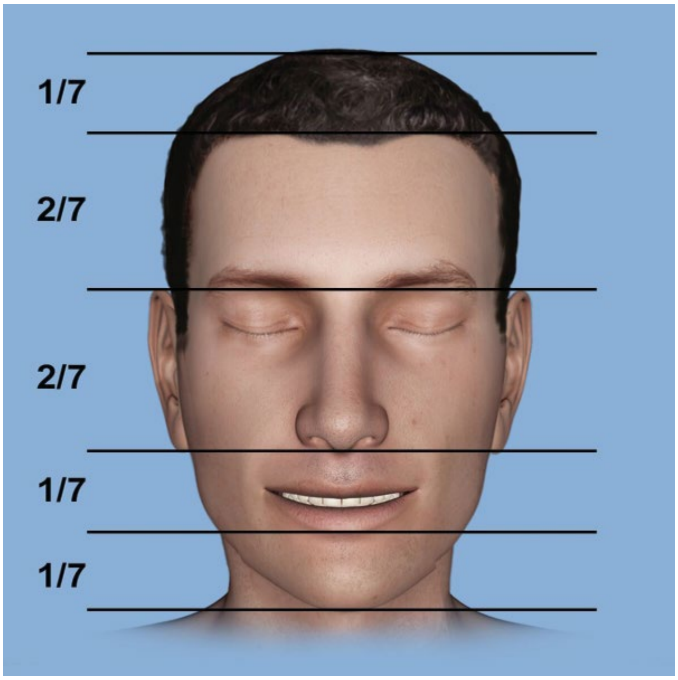

Figure 9.8 Facial rule of sevenths.

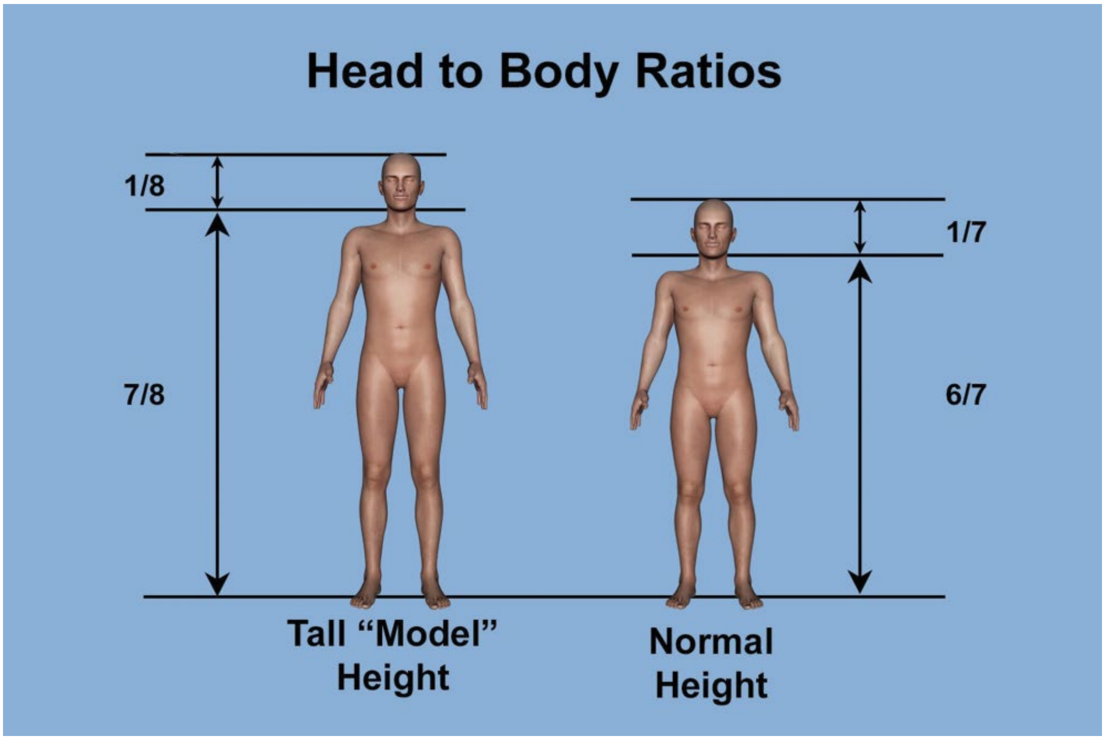

Figure 9.7 Head to body ratios.

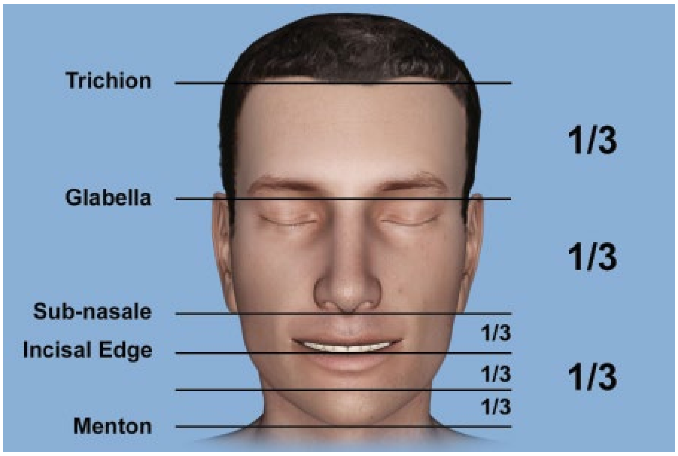

Figure 9.9 Facial rule of thirds.

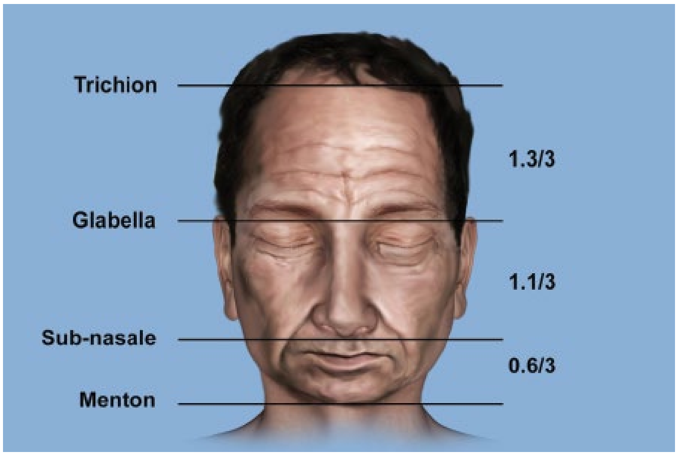

Figure 9.10 Aging facial proportions.

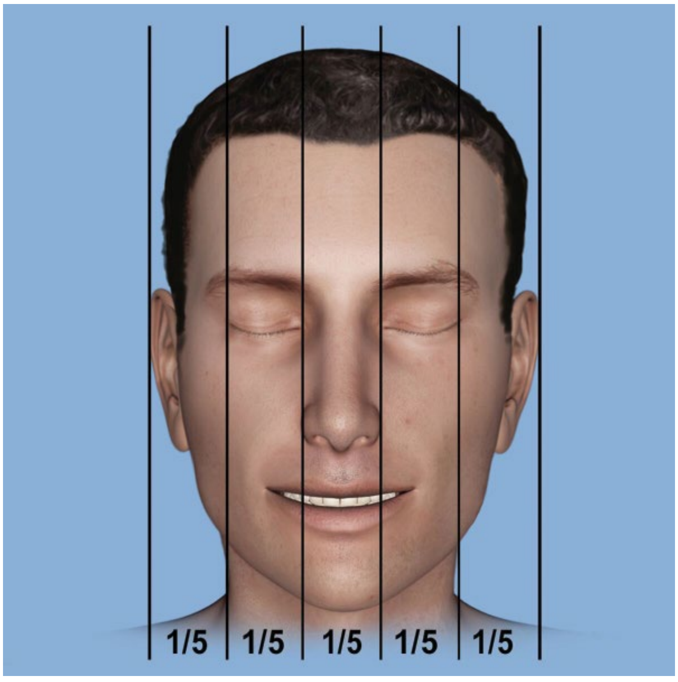

Figure 9.11 Facial rule of fifths.

complete dentures. Many classic and still often cited papers helped to define much of smile design as we know it today. "Dentogenics" was defined over 60 years ago as the art, practice, and techniques used to achieve esthetic results in dentistry.[6] No individual smile ever follows all these rules, nor would it look natural if all were followed, but a basic definition of an ideal smile is an important reference.

Determinants of incisal edge position

The starting point for smile evaluation is the position of the incisal plane. It should be parallel to the interpupillary line and the midline centered with the philtrum (Figure 9.12).[7] The superior/inferior position of the incisal plane can be selected by the use of four determinants.[8] The first determinant of incisal plane placement is esthetics. The incisal edges should follow the curvature of the lower lip (Figure 9.13).[9] The position of the buccal cusp tips of the teeth should progressively move apically

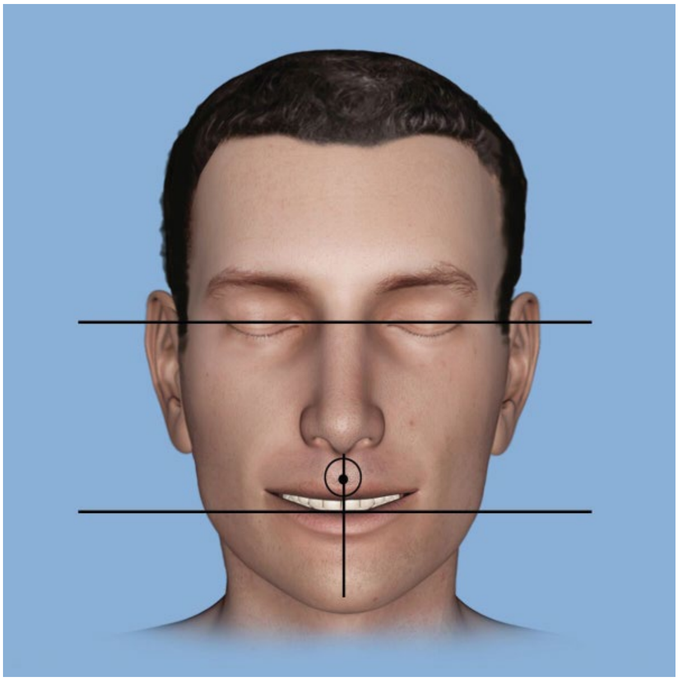

Figure 9.12 Incisal plane parallel to interpupillary line and the midline centered with the philtrum.

Figure 9.13 Incisal edges follow curvature of lower lip.

as you move distally. This curvature has been referred to as the curve of Spee (Figure 9.14).[10] The opposite of this curvature is referred to as a "reverse smile curve" and is considered to detract from the overall appearance of the smile (Figure 9.15).[11] The clinical crown should be outlined by the upper and lower lip and the marginal gingival display should be confined to the interdental papilla (Figure 9.16).[12] The second determinant of incisal edge position is phonetics. The incisal edges of the incisors should meet at the junction of the wet and dry zone when the fricative ("f" and "v") sounds are pronounced (Figure 9.17).[13] Words that begin with "th" can be pronounced by the patient and the relative ease and sound of the enunciation can help to evaluate the superior/inferior position of incisal edge placement. The third determinant of incisal placement is occlusion and anterior guidance. Anterior guidance is the key to protecting the posterior teeth while developing the esthetics of the smile. The lingual surfaces of the maxillary anterior teeth should disclude the posterior teeth immediately on forward movement of the mandible.[14] The fourth determinant is condylar border movements. The maxillary anterior teeth should meet the mandibular anterior teeth in full protrusive movements. The angle the lingual surfaces of the maxillary teeth disclude the mandibular teeth should be slightly greater than the angle of the eminentia.[15] The requirements of esthetics, phonetics, and adequate anterior guidance greater than the angle of the eminentia must be satisfied for long-term success.

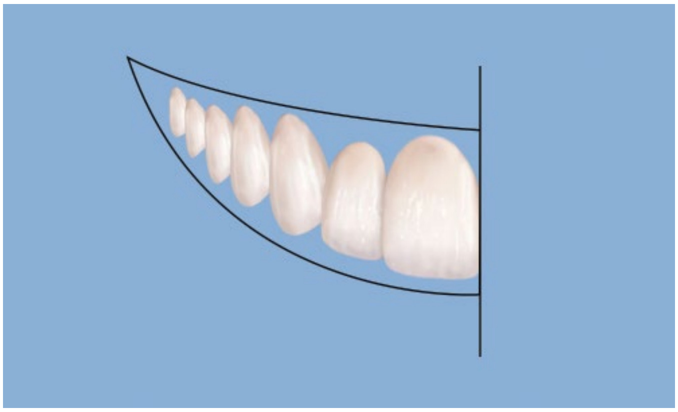

Figure 9.14 Curve of Spee.

Figure 9.15 Reverse smile curve.

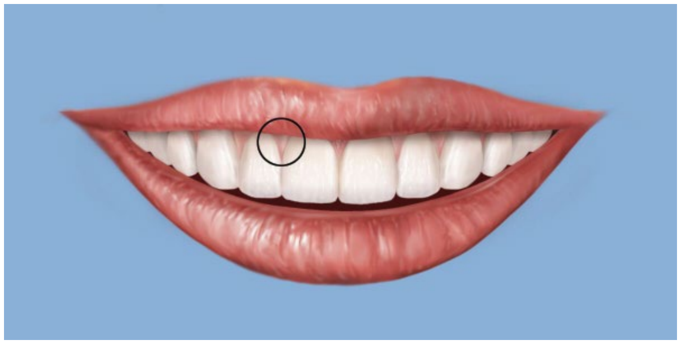

Figure 9.16 Marginal gingival display should be confined to the interdental papilla.

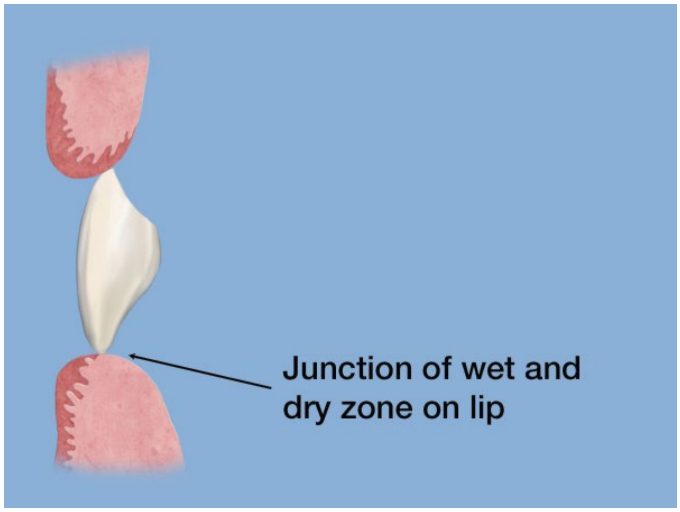

Figure 9.17 The incisal edges should meet at the junction of the wet and dry zone when the fricative ("f" and "v") sounds are pronounced.

Embrasures

The shape of the incisal edges as they blend into the interproximal area at the incisal embrasures is important to the overall smile and may change due to aging, trauma, or biting patterns.[16] The incisal embrasures should become larger as you move distally (Figure 9.18). The mesial-incisal line angle of the maxillary incisors should be more of a right angle whereas the distal-incisal line angle should be more acute and rounded.[17] The location of the contact points between adjacent teeth should move apically as you move distally.[18] The amount of perceived contact between adjacent teeth has been referred to as the "connector area" and decreases as you move distally in the anterior area. The connector area between the maxillary central incisors should be 50% of the incisal length of the teeth. The connector area should be 40% between the central and lateral incisor and 30% between the lateral incisor and canine (Figure 9.19).[19] The incisal edges and embrasures are an important factor in the visual age perception of a patient.[20] As a patient ages and the incisal edges become worn, the incisal embrasures become smaller.

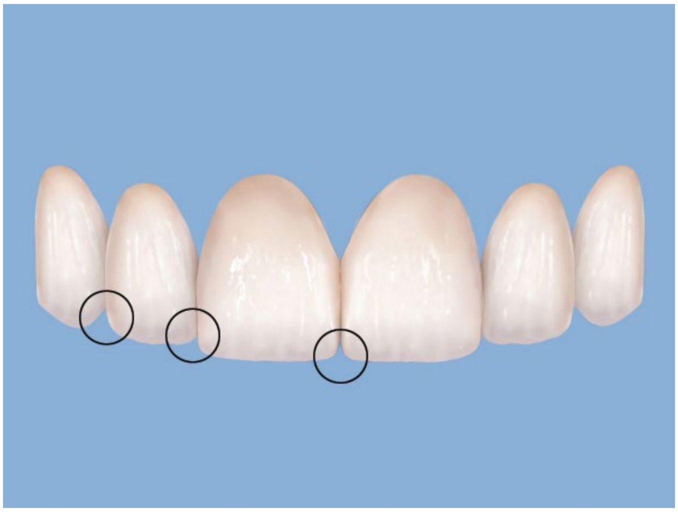

Figure 9.18 The incisal embrasures should become larger as you move distally.

Figure 9.20 Central incisor SPA factor reflects age.

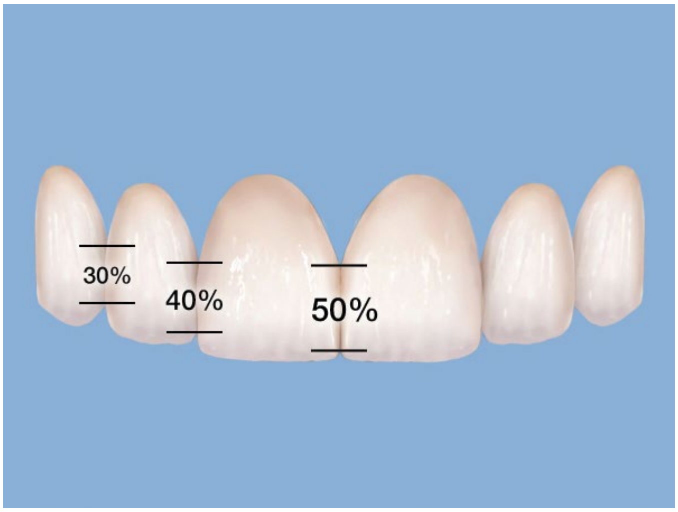

Figure 9.19 Connector area should be 50% between the central incisors, 40% between the central and lateral incisor, and 30% between lateral incisor and canines.

Size and shape of individual teeth

The individual teeth have certain characteristics associated with their form. The shapes of the maxillary anterior teeth have been associated with the "SPA" (sex, personality, age) factor.[6] The incisal edge wear of the maxillary central incisor may coincide with the age of the patient since it may shorten and flatten as a patient ages (Figure 9.20).[21] There is a gradual reduction of maxillary central incisor exposure with an increase in age accompanied by a gradual increase in mandibular tooth exposure.[22] To impart a younger appearance to a smile, distinct angular embrasures may be created along with incisal indentations coinciding with the developmental lobes. The outline form of the central incisor has been recommended to be the inverted facial form of the patient.[23] A person with a square jaw would exhibit a square central incisor and a person with a tapered jaw would have a tapered central incisor (Figure 9.21). The shape of the maxillary lateral incisor may be associated with the sex of a patient.[24] A female lateral incisor exhibits more rounded line angles and curved facial surfaces. The length of the lateral incisor may be less in the feminine form (Figure 9.22). The masculine lateral incisor has sharper line angles, is more similar in length to the central incisor, and has a flatter facial profile. The maxillary canine may coincide with the personality of the patient.[25] A more aggressive personality is projected by a prominent and pointed canine whereas a more passive feel is imparted by a rounded cusp tip (Figure 9.23). The SPA factors should be considered as a guide when designing a smile to satisfy the desired persona projected by the patient.

Apical tooth forms

The shapes and angles of the apical portions of the tooth may be a factor in the esthetic appearance of a smile. In situations where the lip is lifted above the clinical crowns of the teeth upon smiling, the form of the free marginal gingival becomes visibly important. The free gingival margin outlines of the respective contralateral maxillary central incisors and canines should be mirror images of each other and symmetrical. Slight variations of the maxillary lateral incisors are permissible and often desired to give variation. The free gingival margins of the lateral incisors should be located slightly coronal to lines connecting the free gingival margins of the central incisors and canines.[26] A more feminine appearance is portrayed when the free marginal gingivas of the lateral incisors are positioned 0.5–1.0 mm coronal to this line. A more masculine appearance is present when it is more in line (Figure 9.24). The apical zeniths of the maxillary central incisors should be located approximately 1 mm distal and the lateral incisors 0.4 mm distal to the midline of the long axis of the teeth. The apical zeniths of the canine teeth should be nearly in line with the long axis of the tooth (Figure 9.25).[27] The apical angulations of the long axes of the maxillary anterior teeth should become more inclined toward the distal as you move distally (Figure 9.26).

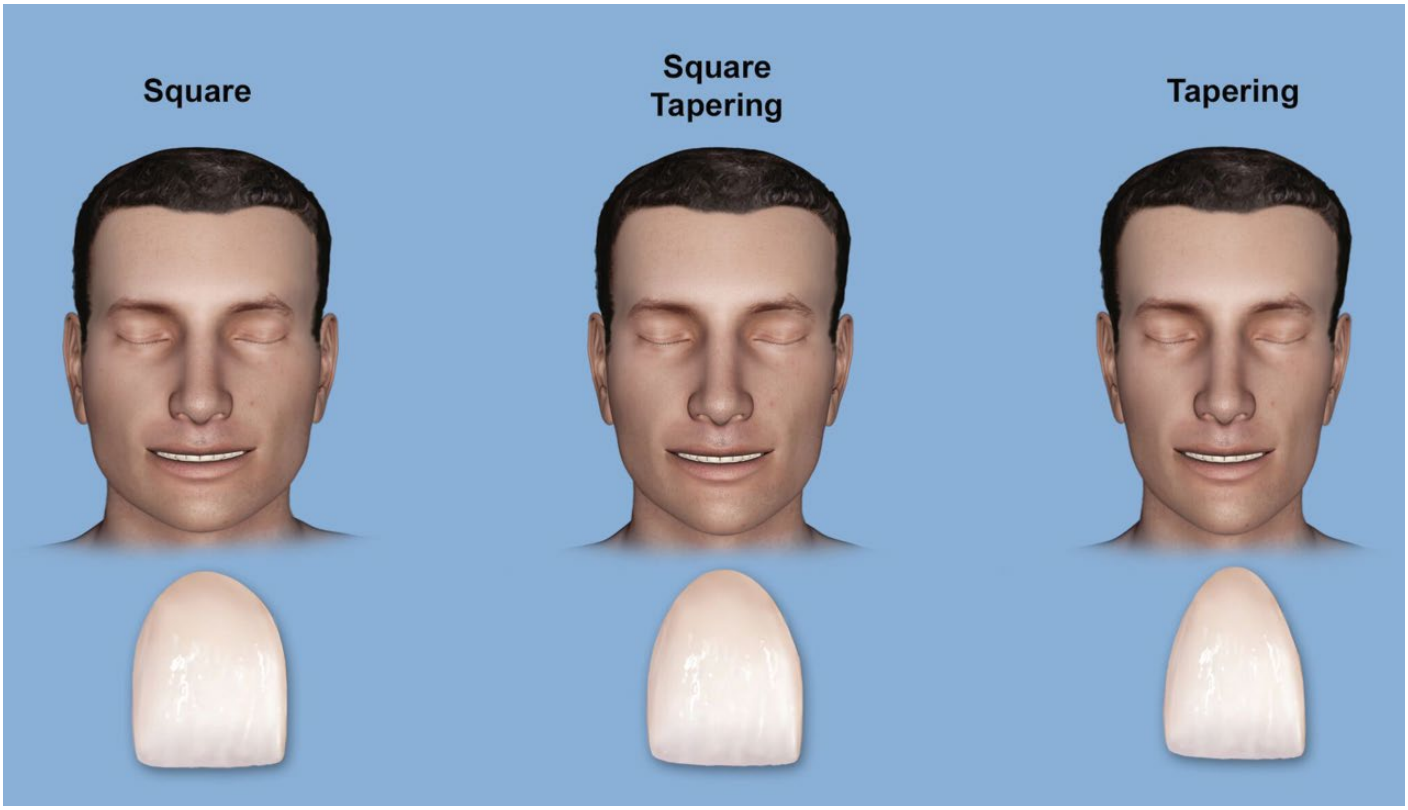

Figure 9.21 Central incisor is inverted face form.

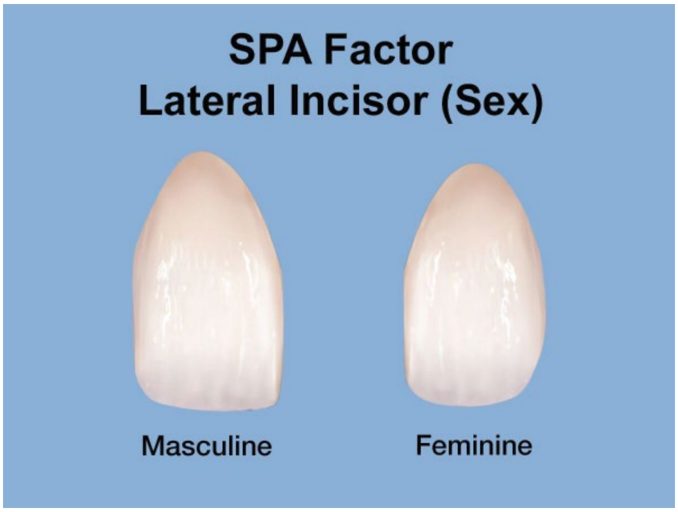

Figure 9.22 Lateral incisor SPA factor reflects sex.

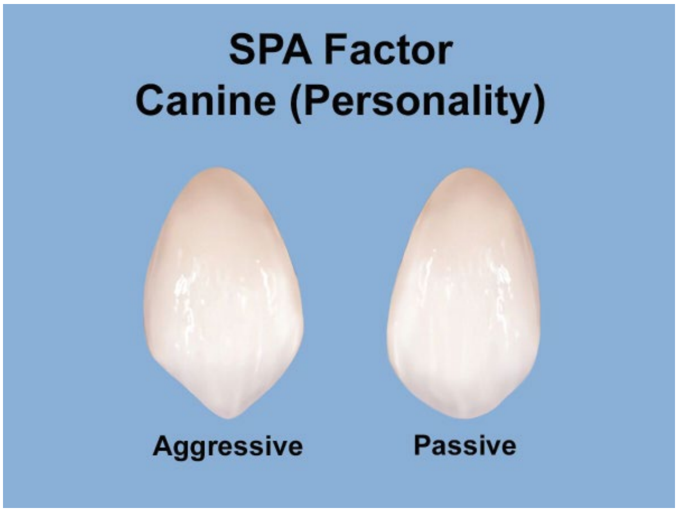

Figure 9.23 Canine SPA factor reflects personality.

Proportion of tooth size to face size

One of the earliest references correlating the proportion of tooth size to face size states the ideal length of the central incisor should be 1/16 the length from trichion to menton (Figure 9.27).[28] Similarly, the ideal width of the central incisor should be 1/16 the interzygomatic width (Figure 9.28). A manufacturer of denture teeth combined the concepts of the rule of thirds with the 1/16 proportion to produce a clear plastic guide which can be placed over the face to determine the appropriate dimensions of the central incisor relative to the size of the face. Position the guide over the face by lining up the nose and eyes in the slots. The recommended length and width can be read by recording the corresponding numbers aligned with the lowest aspect of the chin and the widest part of the zygoma on the guide (Figure 9.29). House and Loop[28] also reported that the interzygomatic width divided by 3.3 gave the approximate width of the maxillary anterior six teeth as viewed from the frontal (Figure 9.30). Others have recommended that the width of the maxillary anterior six teeth (the intercanine width, ICW) as viewed from the frontal

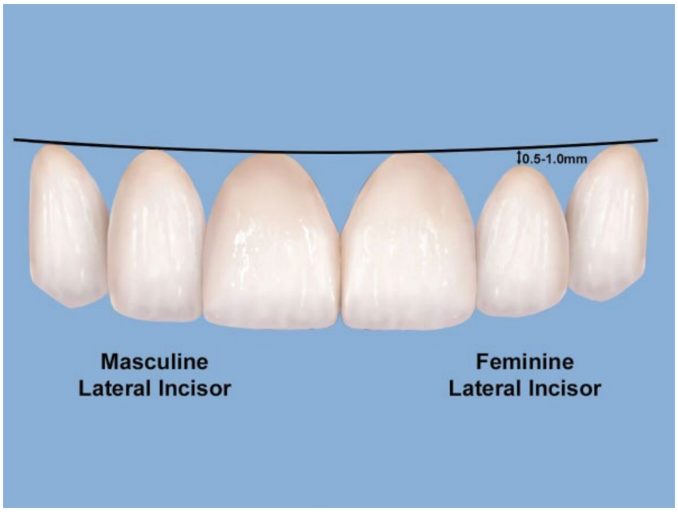

Figure 9.24 Gender differences in lateral incisor shape and length.

Figure 9.25 Location of apical zeniths of the maxillary anterior teeth.

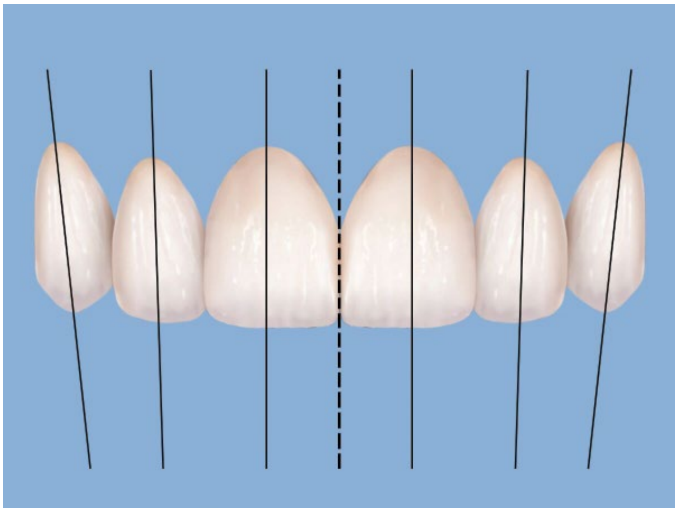

Figure 9.26 Long axes of the anterior teeth diverge apically as you move distally.

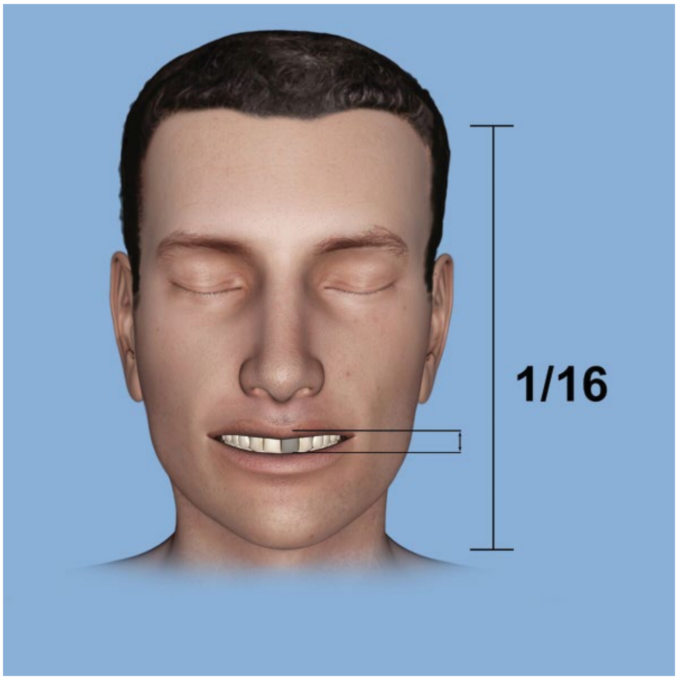

Figure 9.27 The vertical 1/16 rule.

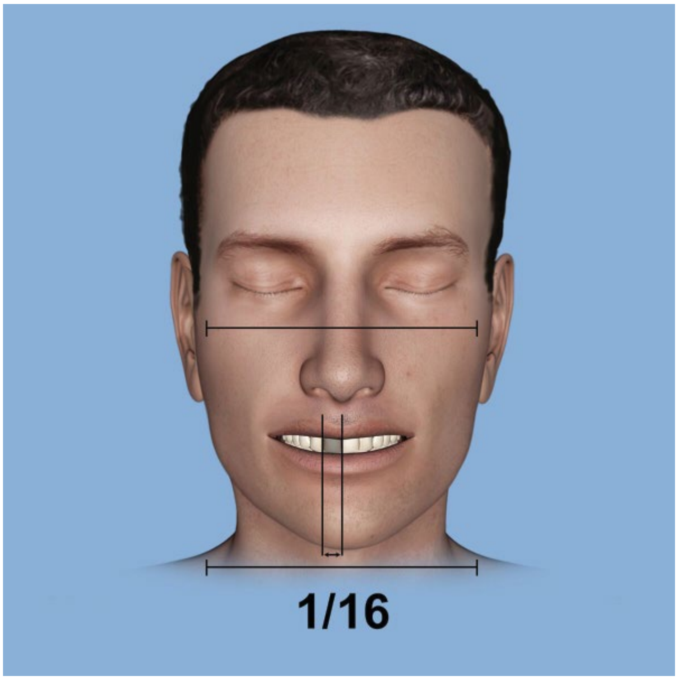

Figure 9.28 The horizontal 1/16 rule.

should be in golden proportion to the intercommisural width when smiling[29] (Figure 9.31).

Recent studies have reported that the average width of each maxillary anterior tooth as measured parallel to the facial surface of each tooth to be 8.5 mm for the central incisor, 6.5 mm for the lateral incisor, and 7.5 mm for the canine (Figure 9.32).[30] It is interesting to note that in this study 80–84% of all teeth measured ranged within ±0.5 mm of the average size. A majority of males exhibited tooth measurements between the average

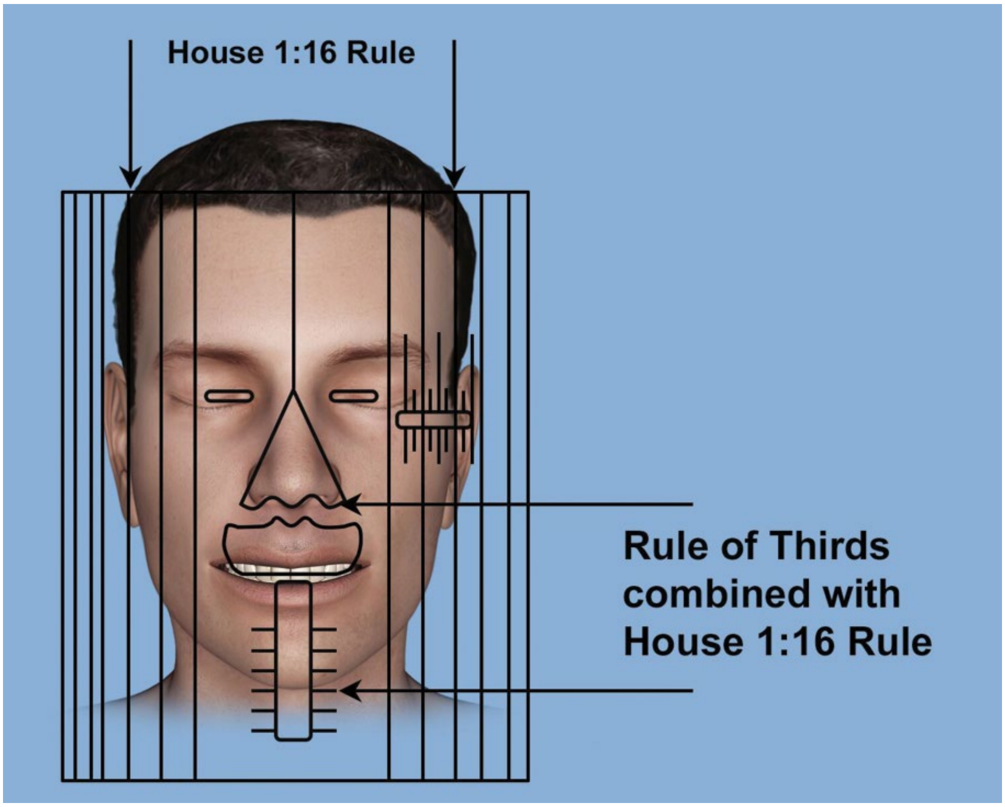

Figure 9.29 The Dentsply tooth size facial guide.

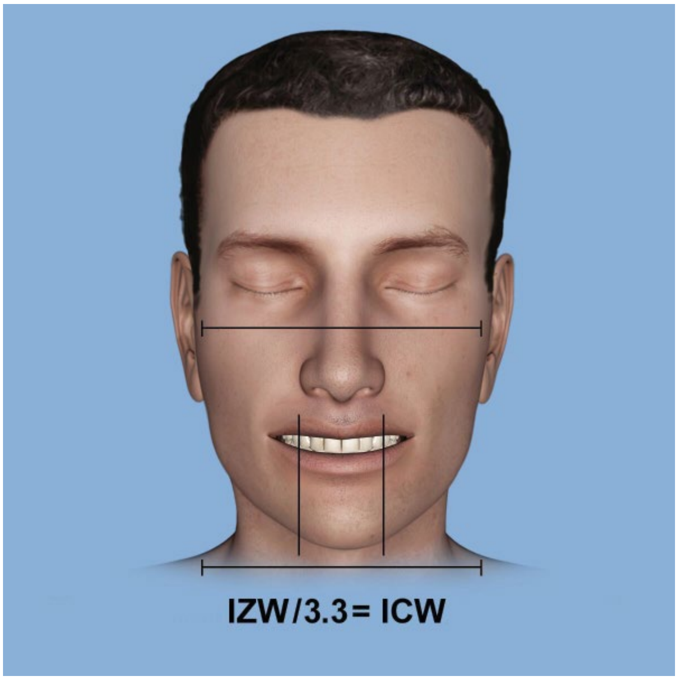

Figure 9.30 Interzygomatic width (IZW) divided by 3.3 equals intercanine width (ICW).

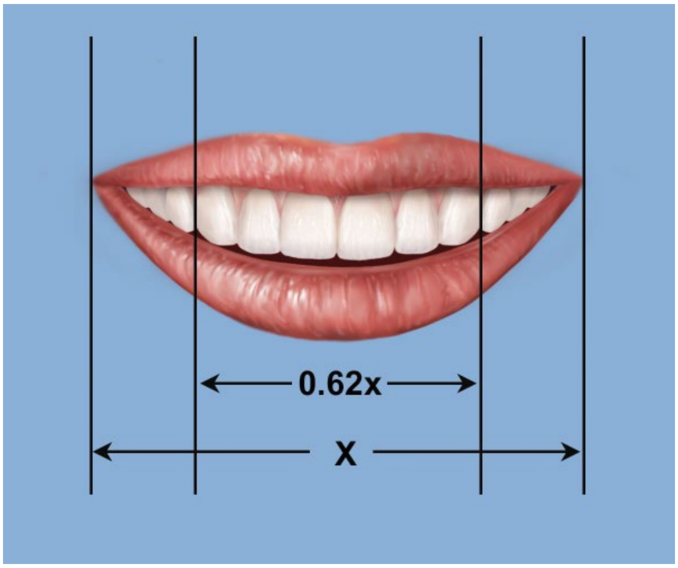

Figure 9.31 Intercanine width in golden proportion to intercommissural width.

width and 0.5 mm wider while a majority of females exhibited tooth measurements between the average width and 0.5 mm narrower (Figure 9.33). However; only 35% of patients showed all three average tooth widths concurrently.

Digital dental photography

The use of dental photography is essential for the evaluation of a smile. Facial images allow for the diagnostic analysis of the smile and are invaluable in treatment planning. Photos give the dentist and adjunct personnel an unlimited time to evaluate the smile. Photos allow the patient to more readily view their own smiles

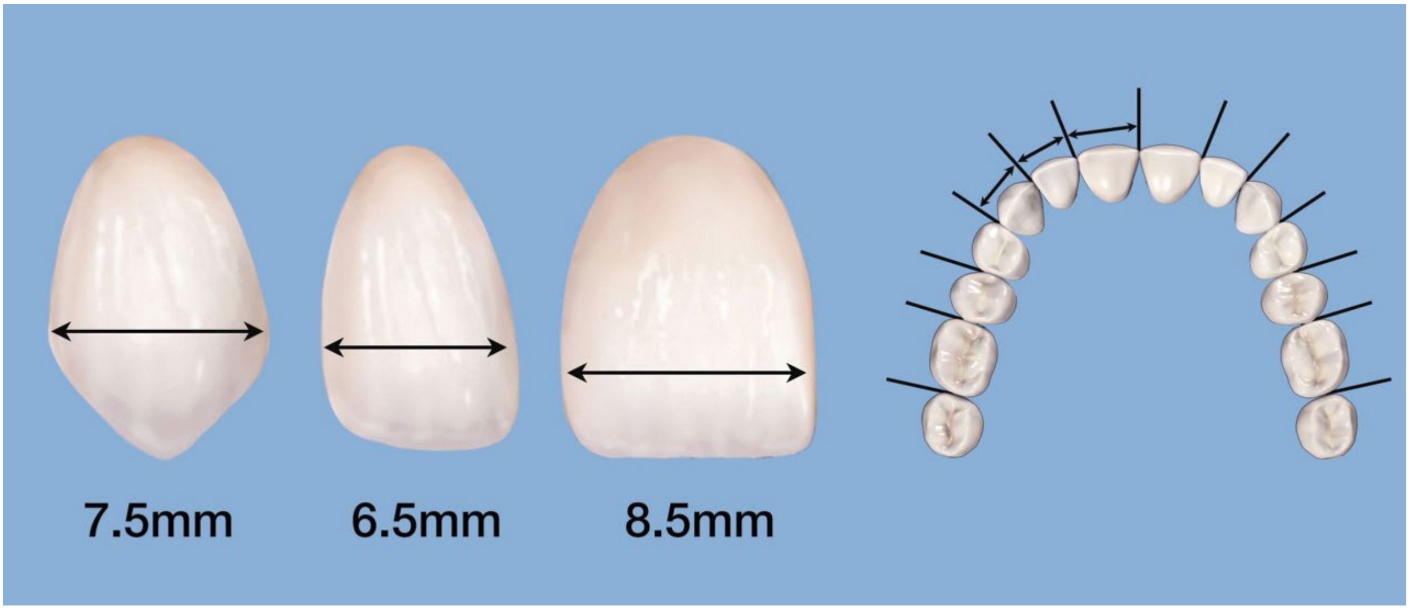

Figure 9.32 Average cast view widths of maxillary anterior teeth.

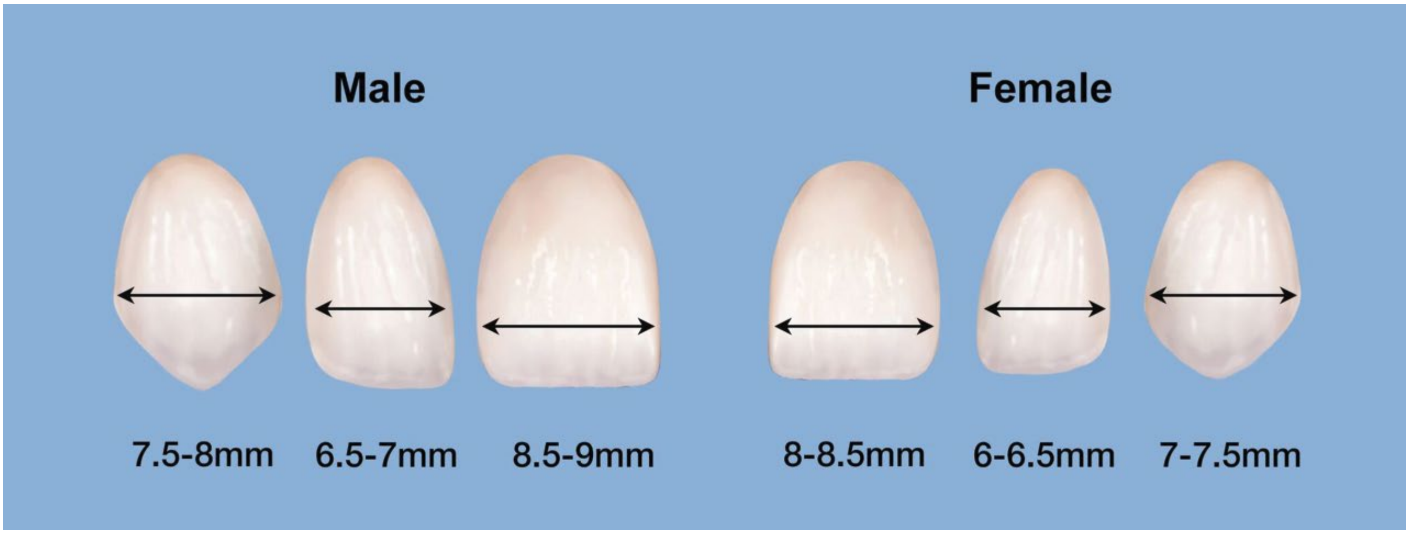

Figure 9.33 Average range of cast view widths of male and female maxillary anterior teeth.

and afford effective communication regarding treatment rationale and potential desired outcomes. Photos are useful when communicating with specialists and the dental laboratory and are easily emailed. Outward personality, appearance, and the role of the smile in the face, can be better understood by the ceramist. Archived pretreatment photos are important should questions arise after treatment begins or is completed.

Digital photography offers many advantages to print or slide film formats. Images can be instantly previewed to evaluate the exposure (Figure 9.34). Alignment and focusing can be viewed. Multiple views can be exposed since there is no additional expense incurred for external processing. A single-lens reflex (SLR) camera is recommended for better exposure control, precise focusing, and standardized image magnifications (see also Chapter 7). The SLR should be fitted with a telephoto/macro lens to allow the production of distortion-free images for accurate 2D

Figure 9.34 Digital single-lens reflex (SLR) instant image preview.

Figure 9.35 Digital SLR camera setup for dental photography.

proportional measurements (Figure 9.35). Standardized views at a consistent magnification produce useful before and after pictures and insure all cases can be analyzed in the same manner. The lens should be set on manual focus and the desired magnification selected. The photographer moves closer to or further away from the subject until the image is in focus. This results in all pictures of each magnification and view being exposed from the same distance away. The photographer should carefully preview the image in the viewfinder to properly center the view parallel to the incisal plane and properly align the angles and borders before taking the picture. Using a protocol of standardized views is important for review and documentation of all esthetic treatment (Figure 9.36).

Facial image view evaluation (FIVE)

The reference for any smile assessment is the view by an observer directly in front of the patient. This view gives a 2D representation of a 3D smile. The use of properly exposed photographic views to evaluate a smile is termed facial image view evaluation (FIVE). Aligned photographic views exposed parallel to the facial plane are essential to allow proper analysis of the smile and accurate relative tooth dimensions. It is important to understand the relative measurements of teeth when using FIVE may be significantly different than the sizes of teeth measured from varying angles (Figure 9.37). The teeth located further distal from the midline will be significantly smaller with FIVE than when measured parallel to each tooth's facial or buccal surface. Changes in tooth positions will change the FIVE. A maxillary canine extruded out buccally will have a larger FIVE width than one intruded palatally.

To use the FIVE method, a correlation must be established between the size of the teeth in the photo and the size of the teeth in the mouth. A common measurement should be made of a readily viewable dimension of a central incisor. Typically the length of the maxillary central incisor is used if the entire tooth can be viewed when the patient smiles. Otherwise the width can be used. The measurement in the mouth is divided by the size of the same measurement in the photograph, giving a fraction. The photograph is measured and the dimensions multiplied by this fraction to yield the FIVE widths and lengths. This produces the perceived sizes of the individual teeth in the smile by a viewer located directly in front of the patient (Figure 9.38).

Studies of Asian patients report the frontal view width of the maxillary anterior six teeth (intercanine width or ICW) is typically 5–6 mm less than the individual widths of the anterior teeth if the teeth were extracted and laid on a flat surface similar to the manner in which denture teeth are measured (Figure 9.39).[31] These same studies report the mesial/distal 2D angulations of the maxillary anterior teeth from parallel to the facial plane are 8° for the average maxillary central incisor, 26° for the average lateral incisor, and 56° for the average canine.

Proportional dental/facial analysis

Proportional and angular analysis is often employed by the dental specialties. Facial esthetic treatment planning must be directed toward balanced proportions and a harmonious arrangement of facial parts.[32] The measurement of frontonasal, nasal tip, nasolabial, interlabial, labiomental, and lip-chin-throat angles may be useful in evaluating the face as a whole.[33] Orthodontists routinely employ cephalometric analysis of facial bony components to predict clinical success (Figure 9.40).[34] Periodontists may measure papilla proportions to evaluate esthetic norms.[35] The measurement of proportions is equally important to the restorative dentist during treatment planning.

Width/length ratio of maxillary central incisor

One of the most important proportions for the esthetic success of a smile is the width/length ratio of the maxillary central incisor.[36] Studies have reported a wide range of naturally occurring width/length ratios. According to one often quoted study, the average width/length ratio of the North American central incisor is reported to be 85–86%.[37]

Another North American study cites the average as 90%.[38] A North American study of extracted teeth reveals that worn central incisors had an average width/length ratio of 87% but that unworn incisors had an average width/length ratio of 78%.[39] Several European studies reported an average width/length ratio of 81–84% for the central incisor.[40,41] However, several studies have recommended the use of maxillary central incisor width/length ratios in the range of 75–80%, which are smaller than those observed in nature (Figure 9.41).[42,43] Studies have revealed the width/length ratio to be a major determinant in smiles preferred by dentists with different tooth-to-tooth width ratios. In these studies, the majority of dentists chose the smiles with central incisors that were as close to the 75–78% width/length ratio as possible.[44] A useful plastic guide has been created which allows for easy reproduction of the 78% width/length ratio when held up in front of a maxillary central incisor in the mouth (Figure 9.42). The similarly colored vertical and horizontal lines are consistent with a 78% width/length ratio.

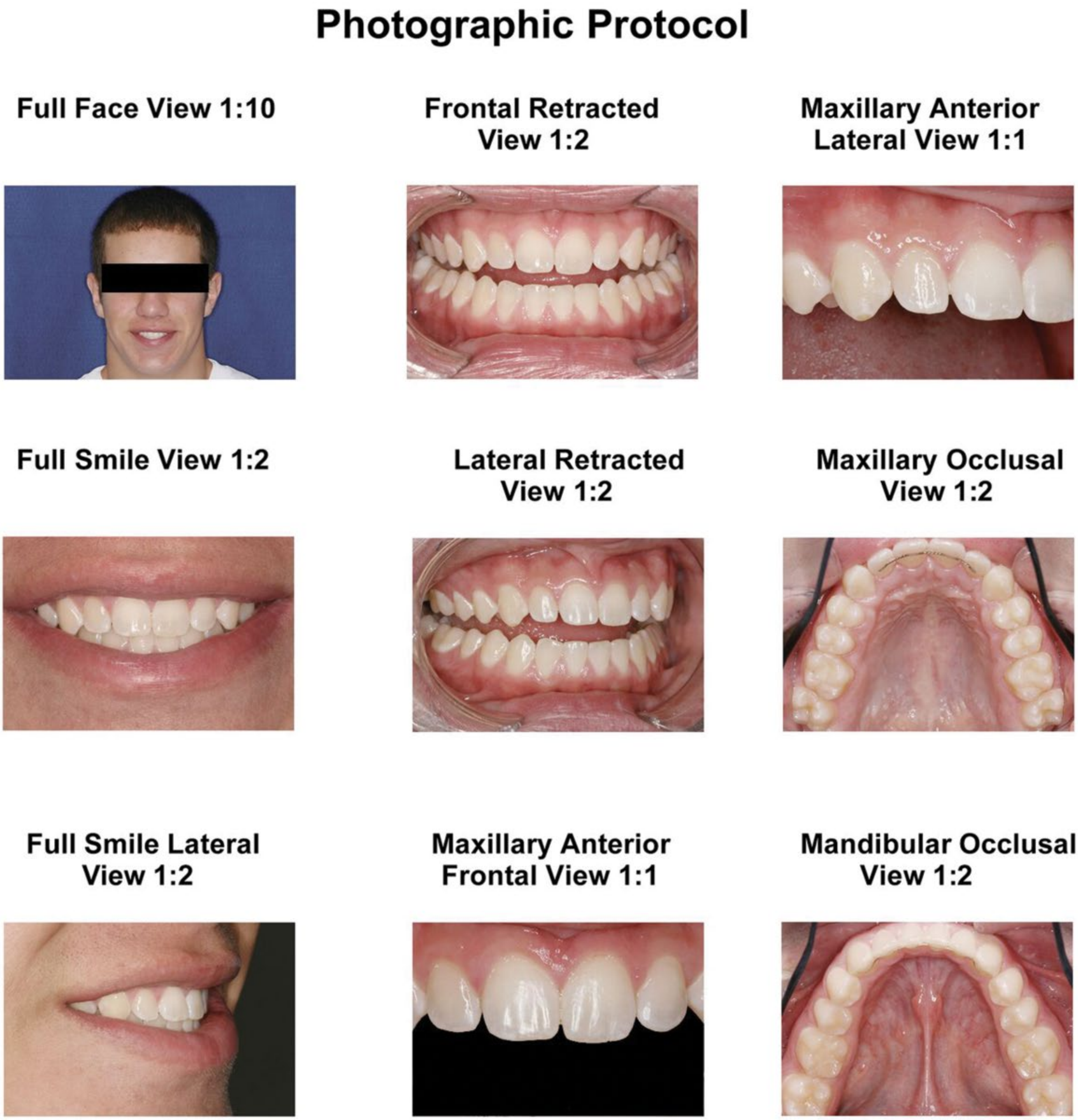

Figure 9.36 Standardized dental photographic series.

Tooth-to-tooth width proportion theories

One of the earliest to discuss the tooth-to-tooth width proportions of the maxillary anterior teeth was Lombardi.[45] He spoke of the need for a "repeated ratio" in which the facial view width proportion which existed between the maxillary lateral incisor and central incisor was repeated between the teeth progressing distally. He felt it gave the teeth unity and order. Beaudreau[46] proposed a "proportionate ratio" in which the actual width of each tooth was measured separately, parallel to the facial surface of each tooth. He suggested a ratio in which an 8 mm-wide maxillary central incisor should have a 6 mm-wide lateral incisor and 7 mm-wide canine. This would result in the cast view width of the lateral incisor being 75% the width of the maxillary central incisor and the canine being 87.5% the cast view width of the lateral incisor.[46] Levin used the concept of the repeated ratio but preset the ideal repeated ratio as the golden proportion or 62% (Figure 9.43).[47] Using the golden proportion, the facial view

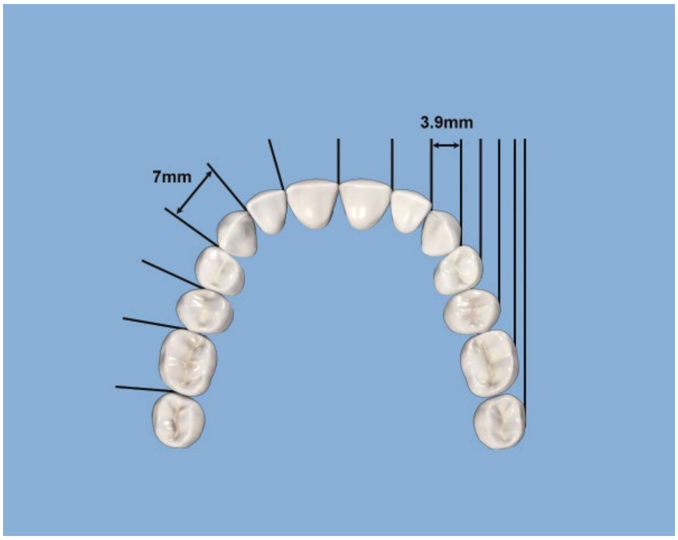

Figure 9.37 Angle of view changes measurements.

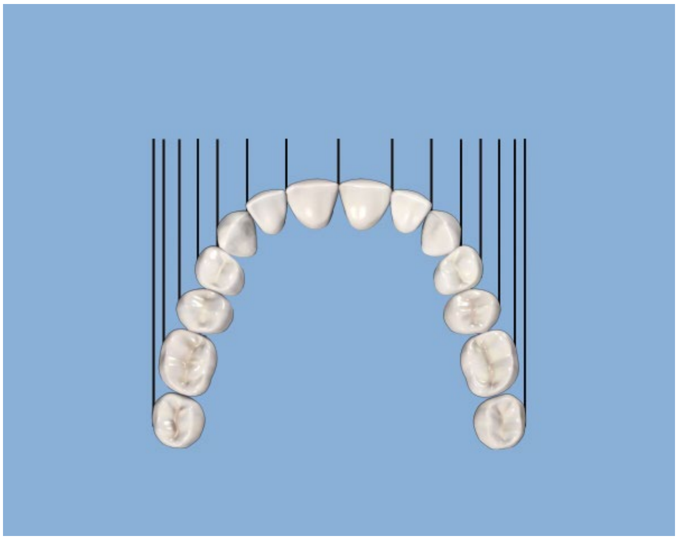

Figure 9.38 FIVE widths of maxillary teeth.

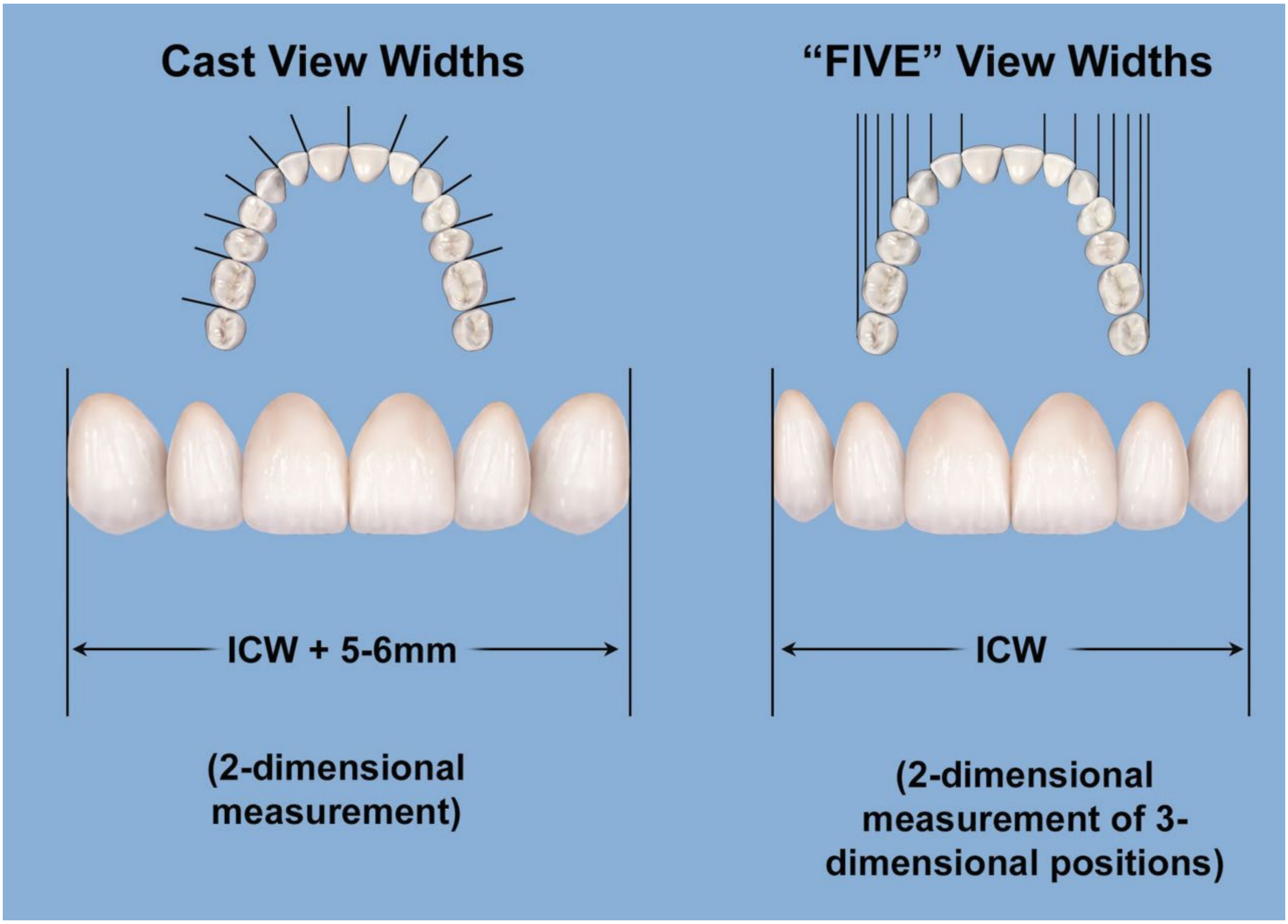

Figure 9.39 Cast view widths versus photographic (FIVE) view widths.

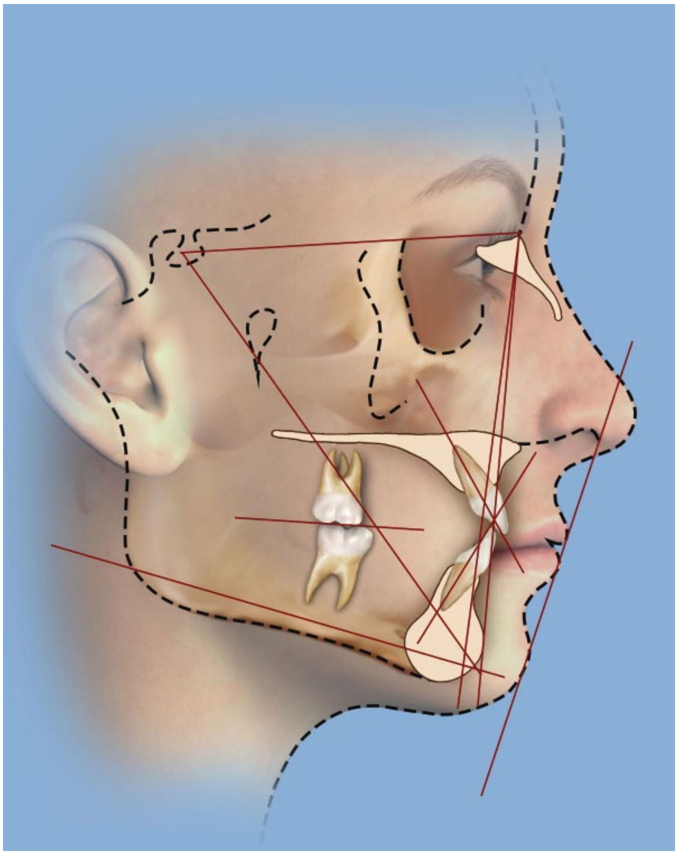

Figure 9.40 Cephalometric analysis.

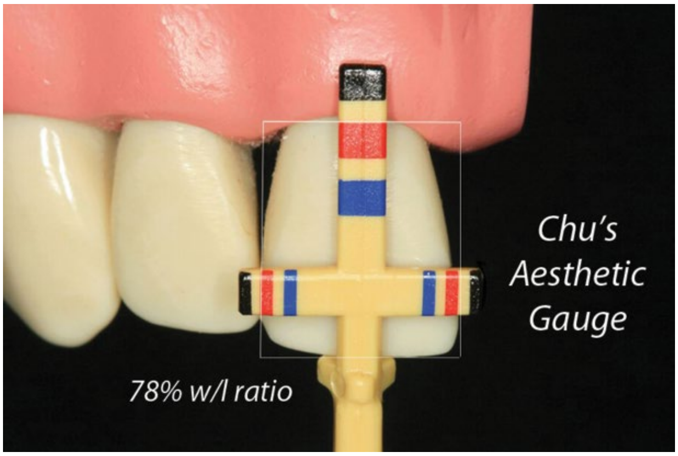

Figure 9.42 Chu aesthetic gauge.

Figure 9.43 Golden proportion.

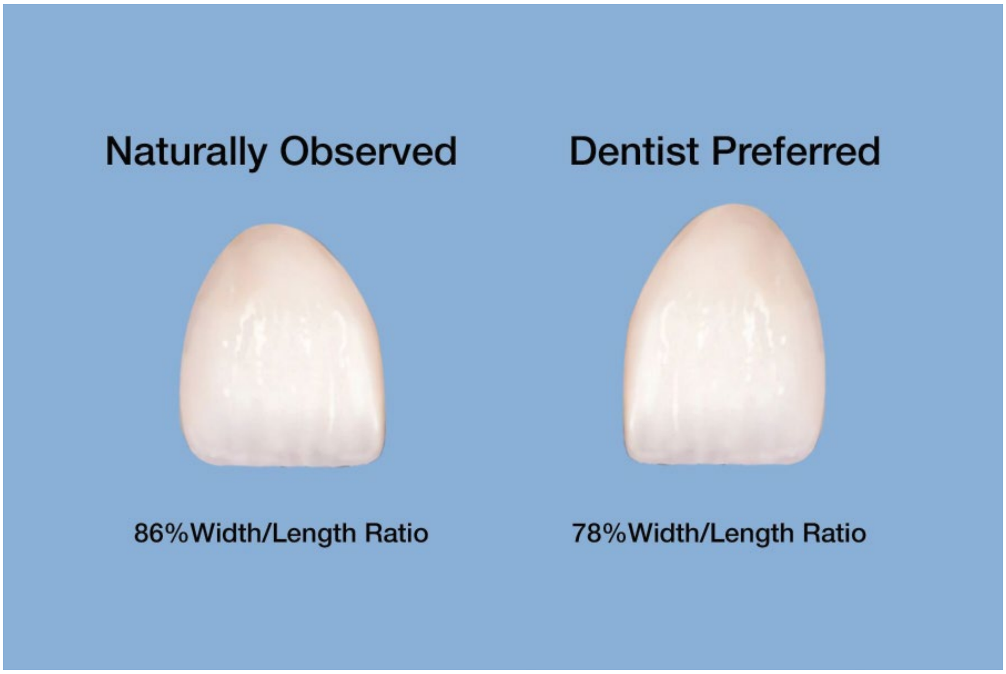

Figure 9.41 Dentist -preferred central incisor width/length ratio of 75–80% is smaller than that observed in nature.

FIVE width of the maxillary lateral incisor is 62% the FIVE width of the central incisor, and the FIVE width of the canine is 62% the width of the maxillary lateral incisor. Snow defined a "golden mean" in which each of the central incisors occupied 25% of the facial view width of the maxillary anterior six teeth (ICW), the laterals each 15% of ICW, and the canines 10% of ICW (Figure 9.44).[48] Albers discussed a number of fixed tooth-to-tooth width proportions including the 57% Plato beauty proportion, the 75% quarter 3:4 proportion, and the 80% human norm 5:6 proportion.[49]

Studies have evaluated tooth proportions observed in nature. Preston observed in a North American dental student population that the average maxillary lateral incisor was 66% the frontal view (FIVE) width of the central incisor and the average maxillary canine was 84% the FIVE width of the lateral incisor (Figure 9.45).[50] Gillen reported that the golden proportion (62%) was rarely observed in the casts evaluated.[38] Other studies have observed similar results, although the findings vary according to the ethnic population evaluated.[40,51]

Figure 9.44 Golden mean.

Figure 9.45 Preston proportion (naturally occurring).

Studies have attempted to correlate different factors to the size of the teeth.[52,53] In spite of many proposals for determining the ideal size of the teeth, they are not consistently found to exist in patients. The golden proportion was not routinely found in patients determined as possessing an esthetically pleasing smile.[54] Selecting one static tooth-to-tooth width proportion may not be suitable for universal use.

Recurring esthetic dental (RED) proportion

Fixed tooth-to-tooth width proportions or tooth sizes do not take into consideration the relationship between the teeth, the bony support, and the face. Considerations for the length of the teeth, the gingival architecture, and the facial view width of the anterior teeth should be factors for making decisions about the desired size of the teeth in a smile. The recurring esthetic dental (RED) proportion incorporates the existing or desired length of the maxillary central incisors with the ICW to calculate the sizes of the maxillary teeth. It allows the dentist to select the desired tooth-to-tooth width proportions, rather than accepting the existing width relationships, using the the repeated ratio or being confined to the 62% golden proportion or golden mean. The RED proportion states that the proportion between the successive frontal view widths of the teeth should remain constant as you move distally (Figure 9.46).[55] It allows for the selection of a successive width proportion which remains consistent throughout the designed smile. The proportion between the FIVE widths of the maxillary lateral incisor and the central incisor should be the same as the FIVE width proportion between the maxillary canine and the lateral incisor and continues as you proceed distally. RED proportions are in the range of 62–80% with 70% considered the standard for average or normal length teeth (Figure 9.47). The 70% RED proportion results in a maxillary central incisor identical in width to the central incisor identified by Preston's "naturally occurring" proportion.

Research has shown that dentists prefer using a RED proportion that will yield a width/length ratio of the maxillary central incisor between 75 and 78%.[44] Given a specific ICW, a number of RED proportions may be used dependent upon the relative length of the teeth, the size of the face, and the wishes of the patient. The ICW may be allocated to the anterior six teeth in a number of ways. The percentage of the ICW for each of the maxillary anterior teeth has been calculated according to the RED proportion selected (Figure 9.48). A patient with tall teeth requires wider maxillary central incisors in order to maintain the preferred 75–78% width/length ratio (Figure 9.49). Less space remains for the lateral incisors and canines, necessitating the use of a smaller RED proportion. A smaller RED proportion results in each successive distal tooth being a smaller percentage of the width of the preceding tooth. When using a smaller RED proportion the central incisor is wider or more dominant since the lateral incisor and canine diminish their widths at a greater rate. In fact, when using the 62% RED proportion (i.e. the golden proportion), 50% of the ICW is occupied by the two central incisors. It is understandable why fashion models who are usually tall look best when restored with tall teeth, dominant central incisors, and the golden proportion tooth-to-tooth width proportions.

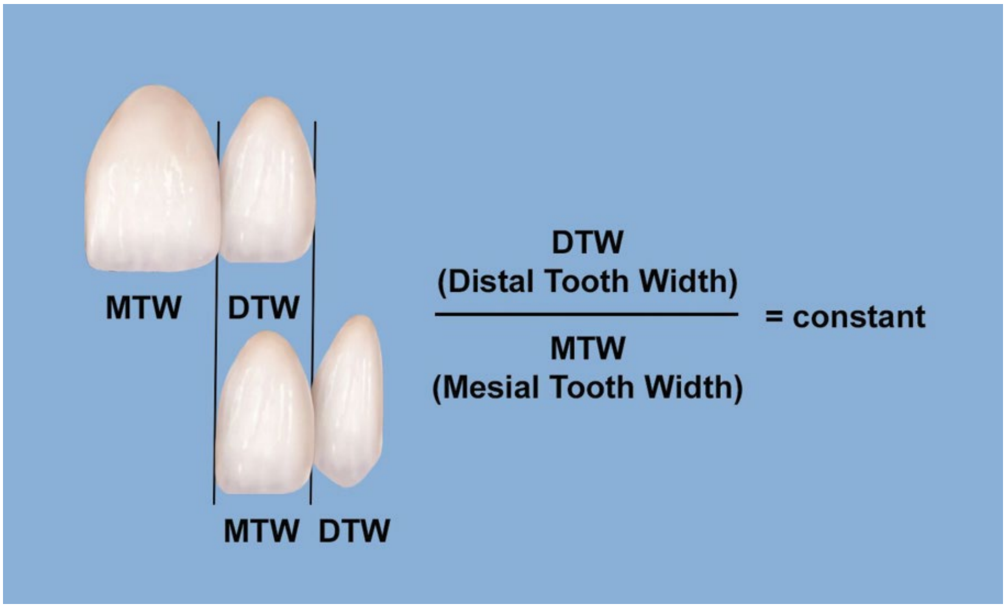

Figure 9.46 Recurring esthetic dental (RED) proportion.

Figure 9.47 70% RED proportion.

Dentist proportion preferences

Studies have been conducted to evaluate preferred successive tooth-to-tooth width ratios of teeth by dentists in conjunction with the relative tooth lengths.[44] The golden proportion was clearly not preferred for normal length teeth by dentists surveyed. With normal length teeth dentists preferred the size of the maxillary central incisor recommended by the 70% RED proportion (Figure 9.50). With very short teeth, dentists preferred the 80% RED proportion, which results in successive teeth more similar in width (Figure 9.51). With very tall teeth, the 62% RED proportion (golden proportion) was preferred (Figure 9.52).

In another study, dentists surveyed overwhelmingly preferred the 70% RED proportion and the Preston (naturally occurring) proportion to the golden proportion for normal-length teeth (Figure 9.53).[56] The golden proportion was preferred only in very tall teeth. They preferred the 70% RED proportion to the

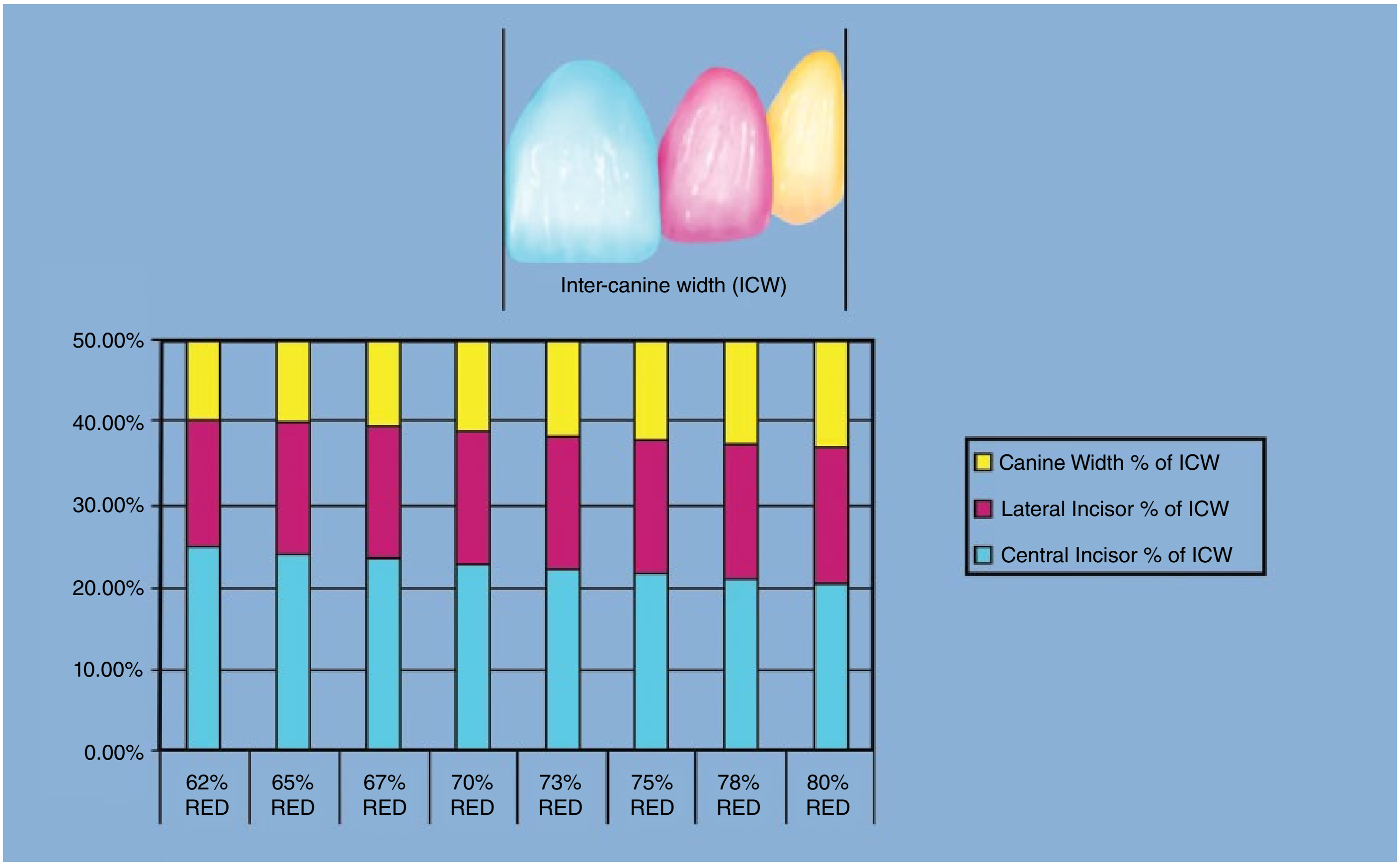

Figure 9.48 Individual tooth width percentage of ICW for different RED proportions.

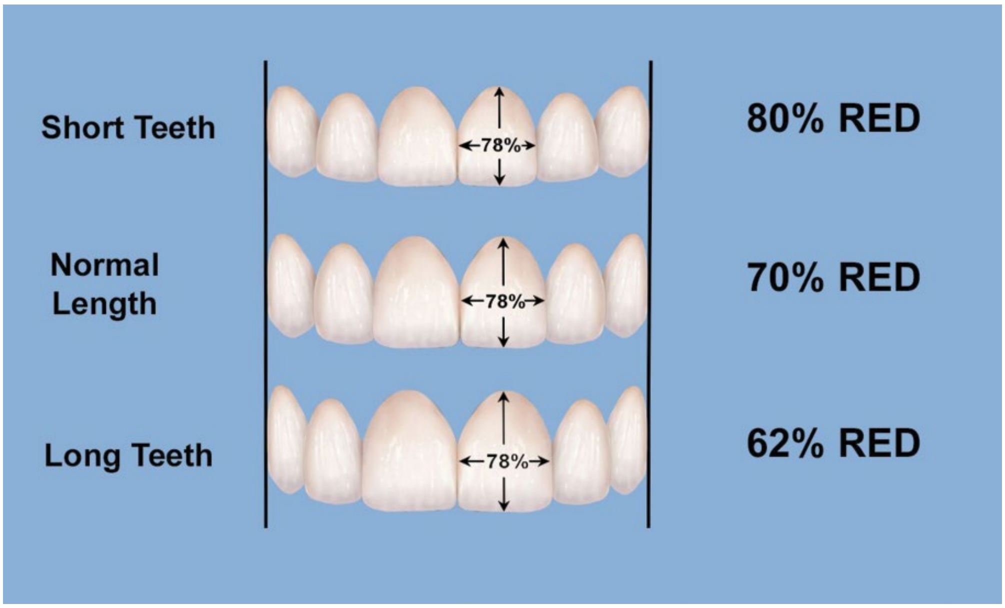

Figure 9.49 RED proportions incorporating tooth lengths which maintain 78% width/length ratio of central incisors.

Preston (naturally occurring) proportion (Figure 9.54). Both the 70% RED proportion and the Preston proportion have the same-size central incisor, the difference being that the lateral incisor is slightly larger and the canine slightly smaller in the 70% RED proportion.

Even though the RED proportion has not been readily observed in nature, dentists surveyed preferred it to natural proportions. Patients desiring a change in their smile likewise may not always find naturally occurring proportions to be the most desirable. In other areas of elective esthetic treatment, the final

Figure 9.50 Preferred 70% RED proportion for normal-length teeth. Reproduced from reference 56 with permission.

Figure 9.51 Preferred 80% RED proportion for very short teeth. Reproduced from reference 56 with permission.

Figure 9.52 Preferred 62% RED proportion for very tall teeth. Reproduced from reference 56 with permission.

results often do not mimic what is present in nature. Tooth whitening and orthodontic treatment are popular but often result in smiles different than the norms observed in nature. Likewise smile design concepts using proportions preferred by dentists but not readily observed in a patient population may be successfully employed.

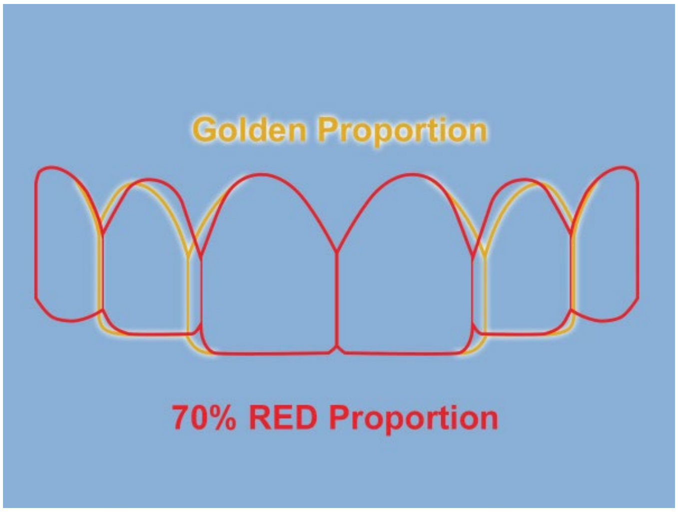

Figure 9.53 Comparing golden proportion to 70% RED proportion (normal-length teeth). Reproduced from reference 56 with permission.

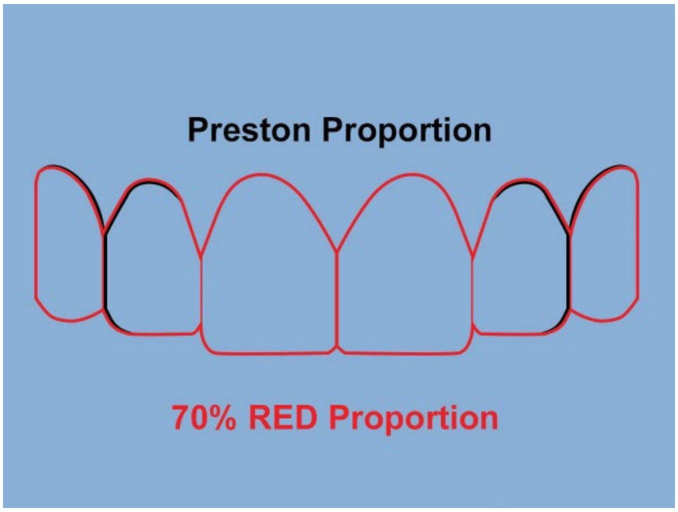

Figure 9.54 Comparing Preston (naturally occuring) to 70% RED proportion. Reproduced from reference 56 with permission.

Using the RED proportion to calculate ideal tooth widths

Understanding the relationships among the overall length of the teeth, the width/length ratio of the central incisor, and the recommended RED proportion allows the dentist to propose different tooth-to-tooth width proportions for different length teeth. For any given maxillary ICW, there are a number of different tooth lengths and tooth-to-tooth width proportions that may be utilized. It is dependent upon the desired length of the teeth (Figure 9.55). Patients who elect to have the clinical crowns of their teeth lengthened should have wider, more dominant central incisors fabricated (Figure 9.56). Longer clinical crowns can be achieved by placing the incisal edges more coronally, by crown lengthening, or a combination of the two (Figure 9.57).

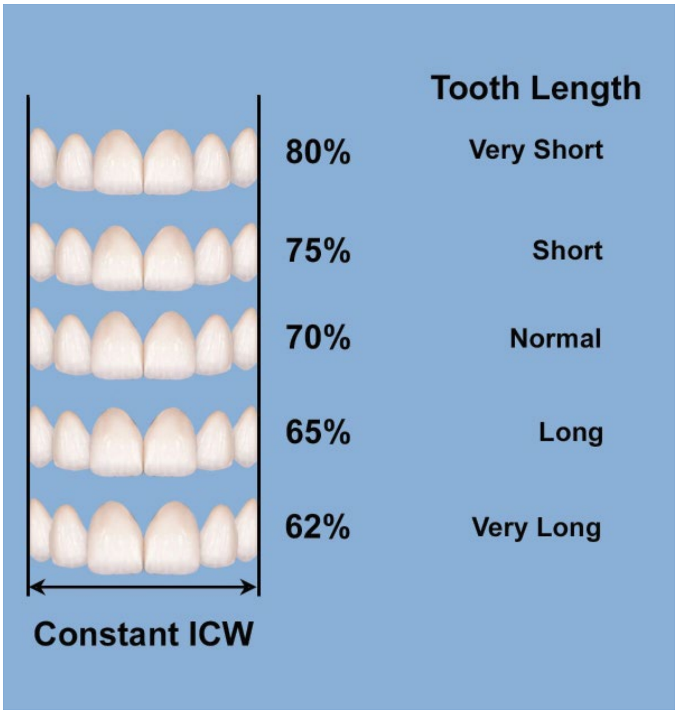

Figure 9.55 Different RED proportions (central incisor 78% width/length ratio) for the same ICW.

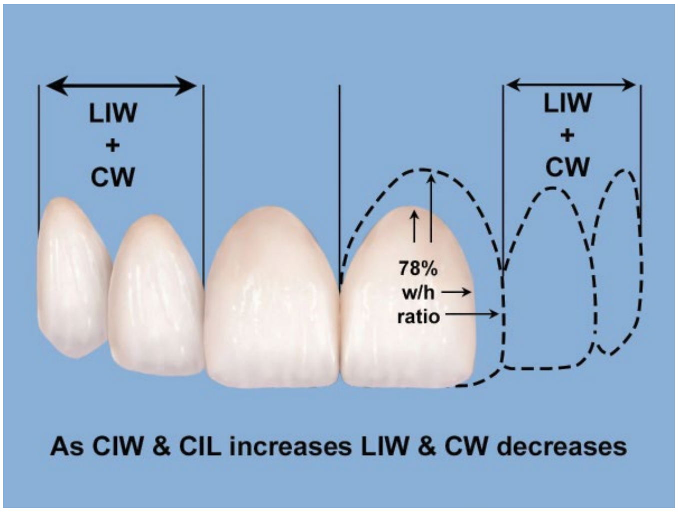

Figure 9.56 Taller tooth gives more dominant central incisor and narrower lateral incisor and canine. CIL, central incisor length; CIW, central incisor width; CW, canine width; LIW, lateral incisor width.

The incisal edge determinants, periodontal considerations, and desires of the patient will ultimately determine the final length of the clinical crowns.

Clinical use of the RED proportion

Correlating the preferred RED proportions of different length teeth with the preferred 78% width/length ratio of the central incisor provides a powerful tool for determining the ideal sizes

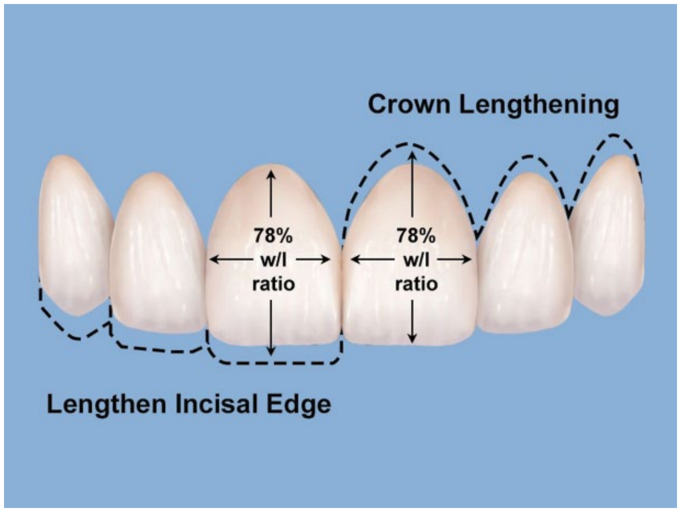

Figure 9.57 Methods to gain favorable width/length ratio in short teeth.

of the maxillary teeth. The central incisor width (CIW) relative to any RED proportion can be calculated by the equation:

$$\text{Central incisor width} = \frac{\text{FIVE ICW of anterior six teeth}}{2\left(1+\text{RED}+\text{RED}^2\right)}$$

If you substitute into the equation the values of RED for the very tall (62% or 0.62), tall (66% or 0.66), normal (70% or 0.7), short (75% or 0.75), and very short (80% or 0.8) teeth you can calculate the divisor for the intercanine width (ICW) appropriate to calculate the central incisor width (ICW). This equation was used to solve for the divisor of the 70% RED proportion:

$$\text{Central incisor width} = \frac{\text{FIVE ICW of anterior six teeth}}{2\left(1+(0.7)+(0.7)^2\right)} = \frac{(\text{ICW})}{4.38}$$

Table 9.1 shows the RED proportions associated with relative tooth lengths and how to calculate the maxillary anterior tooth widths. To use this table first determine if the general lengths of the teeth are very tall, tall, normal, short, or very short. Measure the same dimension (usually the length of a central incisor) on the cast and on the photograph and divide the cast dimension by the photographic dimension to calculate a conversion factor. This relates the actual size of the tooth to the size of the tooth on the photograph. Next, measure the width between the distal aspects of the maxillary canine teeth on the photograph and multiply by the conversion factor to determine the facial view (FIVE) ICW (Figure 9.58). Determine the RED proportion recommended width of the maxillary central incisor (CIW) by dividing the facial view ICW of the maxillary anterior six teeth (ICW) by the divisor listed in the table for the relative tooth

Table 9.1 Calculating Anterior Tooth Widths using Relative Tooth Lengths and the RED proportion

Relative Tooth Length	RED Proportion	Central Incisor Width (CIW) (rounded)	Lateral Incisor Width (LIW)	Canine Width (CW)
Very tall	62% RED	ICW/4.0	CIW*0.62	LIW*0.62
Tall	66% RED	ICW/4.2	CIW*0.66	LIW*0.66
Normal	70% RED	ICW/4.4	CIW*0.70	LIW*0.70
Short	75% RED	ICW/4.6	CIW*0.75	LIW*0.75
Very short	80% RED	ICW/4.8	CIW*0.8	LIW*0.80

Using a conversion Factor to determine
FIVE (Facial Image View) ICW (Inter-canine Width)

Step 1

$$\frac{\text{Cast length of Central Incisor}}{\text{Photographic length of Central Incisor}} = \textit{Conversion factor}$$

(Decimal less than 1)

Step 2

Photographic width between distal aspects of canines × *Conversion factor* = FIVE ICW *(Facial Image View inter-canine width)*

Figure 9.58 Using the conversion factor to calculate the facial image view ICW.

length. Multiply the resulting central incisor width (CIW) by the RED proportion decimal equivalent listed in the table for the determined relative tooth length to produce the lateral incisor width (LIW). Finally, multiply the calculated LIW by the same decimal listed in the table to calculate the facial view canine width (CW). To determine the central incisor length (CIL) divide the CIW by 0.78. Table 9.2 is a review of the steps to use the RED proportion to determine the anterior tooth widths for appropriate relative tooth lengths.

To determine the tooth widths for normal-length teeth using the RED proportion first determine the ICW. Look up in the chart the divisor for normal length teeth, which is 4.4. Divide the ICW by 4.4 to determine the width of the maxillary central incisor. Look up in the chart the RED proportion to be used for normal-length teeth which is 70%. Multiply the CIW by 0.7 (70% RED) to determine the LIW. Multiply the lateral incisor width by 0.7 (70% RED) to calculate the CW (Figure 9.59).

A patient being orthodontically treated with congenitally missing maxillary lateral incisors was referred for space evaluation (Figure 9.60). No alterations were planned to the width of the central incisor and the width/length ratio approximated 78%. The patient was determined to have very short teeth. The width of the central incisor was measured as 6.4 mm and the length was 8.3 mm (yielding a 77% width/length ratio). Looking at the chart and considering the very short 8.3 mm long maxillary central incisor, a RED proportion of 80% needed to be used. With an 80% RED proportion, the LIW should have been 80% of

Table 9.2 Using RED Proportions to Determine Anterior Tooth Widths and Central Incisor Length

Step 1. Determine relative tooth length	Select very tall, tall, normal, short, or very short relative tooth length
Step 2. Determine conversion factor	Measure same dimension on cast and photo, divide cast dimension/ photo dimension to calculate conversion factor
Step 3. Determine facial image view ICW	Measure distance between distal aspects of both maxillary canines on photo and multiply by conversion factor to determine ICW
Step 4. Determine central incisor width (CIW)	Divide ICW/divisor of desired relative tooth length (4.0, 4.2, 4.4, 4.6, 4.8) to determine CIW
Step 5. Determine lateral incisor width (LIW)	Multiply CIW × RED (0.62, 0.66, 0.7, 0.75, 0.8) of desired relative tooth length
Step 6. Determine canine width (CW)	Multiply LIW × RED (0.62, 0.66, 0.7, 0.75, 0.8) of desired relative tooth length
Step 7. Determine central incisor length (CIL)	Divide CIW/0.78

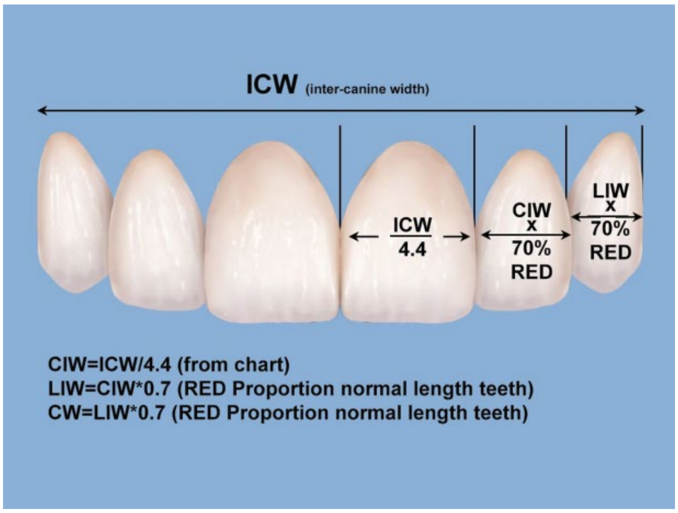

Figure 9.59 Using RED proportion to determine ICW for normal-length teeth. For definitions see text and Figure 9.56 legend.

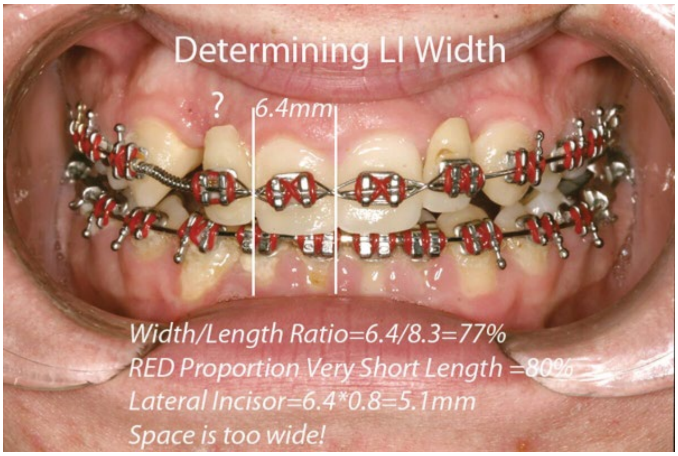

Figure 9.60 Figuring LIW using RED proportion.

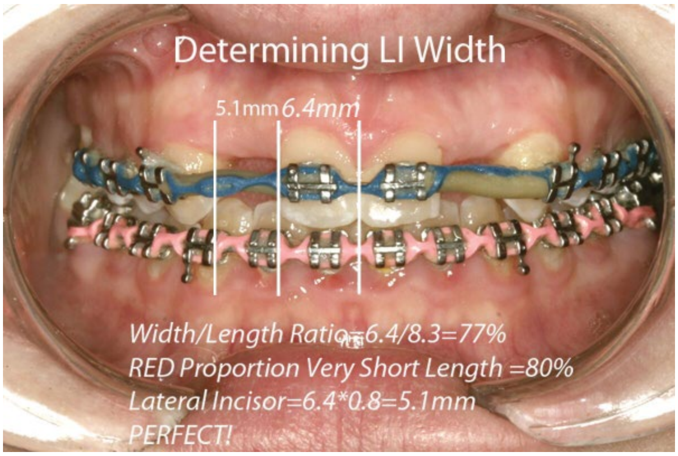

Figure 9.61 Verifying LIW width using RED proportion.

the width of the central incisor or 5.1 mm. The space was measured and deemed to be too wide. The patient arranged with the orthodontist to have their teeth moved to close the space to the desired 5.1 mm. The patient returned and the space was re-measured and determined to be correct (Figure 9.61).

Simplified use of the RED proportion

To further simplify the use of the RED proportion, a chart has been developed with the 78% width/length ratio substituted as a constant within the equation, the RED proportion tooth widths solved, and the quotient of the ICW divided by the CIL as the variable (Table 9.3). The facial view ICW is calculated and divided by the CIL (CIL) to produce a quotient (Figure 9.62). The quotient is looked up in the chart and the associated relative tooth lengths, RED proportion, and ICW divisors for each tooth are recorded. The ICW is divided by the divisors listed in the chart to determine the widths of the maxillary central incisor, lateral incisor, and canine. The length of a maxillary central incisor can be calculated by dividing the width of the maxillary central incisor by 0.78.

If the ICW/CIW quotient in the chart does not coincide with the desired relative tooth length, look up the quotient appropriate to the relative body height. Simple substitution gives:

$$\frac{\text{ICW}}{\text{Desired quotient}} = \text{CIL}$$

Divide the ICW by the quotient in the chart of the desired relative tooth length to calculate the CIL. Determine if the resulting length seems applicable. This is especially helpful when the incisal edges of the teeth are worn and can be lengthened and/or apical repositioning of the free gingival margin is possible. Using a longer central incisor often allows it to be proportioned to a 78% width/length ratio without making significant changes to the original widths of the teeth (Figure 9.63). Using the chart, repeat the calculations for the widths of the incisors and canines. Table 9.4 is a review of the above steps.

A patient presented requesting an improvement to her smile (Figure 9.64). Photos were taken and study models made. The left CIL measured 9 mm on the cast (Figure 9.65). The CIL on the photograph measured 25 mm (Figure 9.66). The measurements made on the photograph were multiplied by 9/25 or 0.36 to convert the photographic view measurements to the FIVE measurements (Figure 9.67). The width between the distal aspects of the two maxillary canine teeth measured on the photograph was 92.8 mm. Multiplying 92.8 mm by 0.36 gave a

Table 9.3 Chart using ICW/CIW Quotient to Determine Relative Tooth Lengths, RED Proportion, and Anterior Tooth Widths

ICW/CIL Quotient	RED Proportion	Relative Tooth Length	CIW	LIW	CW
3.1	62% RED	Very tall	ICW/4.00	ICW/6.47	ICW/10.43
3.2	65% RED	Tall	ICW/4.15	ICW/6.38	ICW/9.81
3.3	67% RED	Slightly tall	ICW/4.24	ICW/6.33	ICW/9.44
3.4	70% RED	Normal	ICW/4.38	ICW/6.26	ICW/8.94
3.5	73% RED	Slightly short	ICW/4.53	ICW/6.20	ICW/8.49
3.6	75% RED	Short	ICW/4.63	ICW/6.17	ICW/8.22
3.7	78% RED	Shorter	ICW/4.78	ICW/6.12	ICW/7.85
3.8	80% RED	Very short	ICW/4.88	ICW/6.10	ICW/7.63

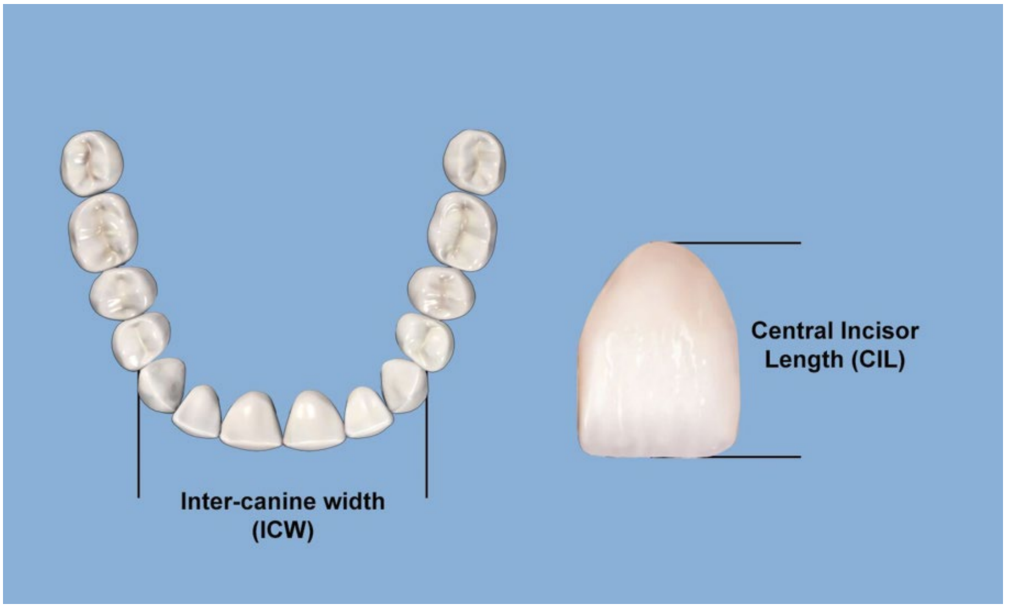

Figure 9.62 ICW is divided by the CIL to determine quotient.

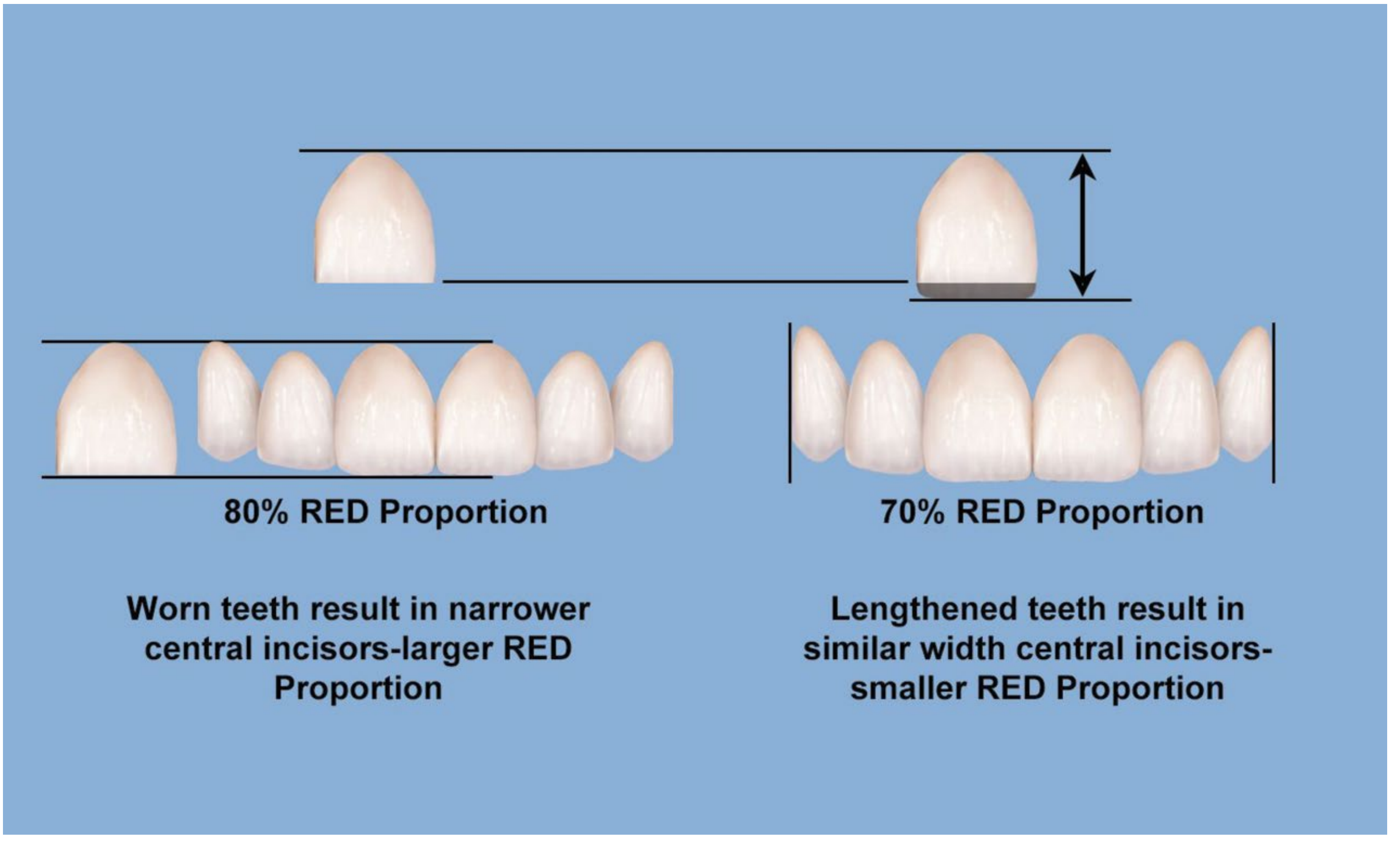

Figure 9.63 Adding length to central incisor allows smaller RED proportion.

FIVE ICW of 33.4 mm. Dividing 33.4 by the CIL of 9 gave a quotient of 3.7 (Figure 9.68). Looking at the chart shows that a quotient of 3.7 is appropriate for shorter teeth. The patient was a person of average height who preferred normal-length teeth. Looking at the chart, normal-length teeth have a quotient of 3.4 and RED proportion of 70%. Dividing 33.4 (FIVE ICW) by 4.38 (the divisor from Table 9.3 for the 70% RED central incisor) gave a 7.6 mm-wide central incisor. Dividing 33.4 by 6.26 (the divisor

Table 9.4 Simplified Method using ICW/CIL Quotient Chart to Determine Anterior Tooth Widths and Central Incisor Length

Step 1. Determine conversion factor	Measure same dimension on cast and photo and divide cast dimension/photo dimension to calculate conversion factor
Step 2. Determine facial image view ICW	Measure distance between distal aspects of maxillary canines on photo and multiply by conversion factor to determine ICW
Step 3. Measure central incisor length	Measure CIL on cast
Step 4. Determine ICW/CIL quotient	Divide ICW/CIL and look up quotient on chart
Step 5. Evaluate relative tooth length of quotient	If quotient matches desired relative tooth length proceed to step 7
Step 6. Select a different quotient	If quotient does not match, look up the quotient appropriate to the relative body height; divide the ICW by desired relative tooth length quotient in chart to calculate CIL; if appropriate proceed to step 7; if not choose a different quotient and retry
Step 7. Determine central incisor width (CIW)	Divide ICW/divisor of selected relative tooth length for CIW
Step 8. Determine lateral incisor width (LIW)	Divide ICW/divisor of selected relative tooth length for LIW
Step 9. Determine canine width (CW)	Divide ICW/divisor of selected relative tooth length for CW
Step 10. Determine central incisor length (CIL)	Divide CIW by 0.78 for CIL

Figure 9.64 Preoperative smile to be analyzed using simplified RED proportion method.

Figure 9.65 Measuring cast view length.

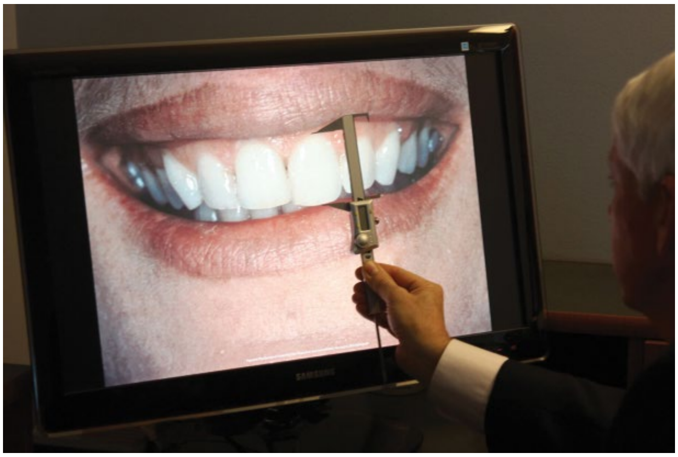

Figure 9.66 Measuring photographic view lengths and widths.

from Table 9.3 for the 70% RED lateral incisor) yielded a 5.3 mm-wide lateral incisor. Finally, dividing 33.4 by 8.94 (the divisor for the canine) gave a 3.7 mm-wide canine (Figure 9.69). The CIL was determined by dividing the CIW of 7.6 by 0.78 (desired width/length ratio) to yield a 9.8 mm-long central incisor. (Figure 9.70). The final dimensions of the maxillary anterior six teeth were calculated and inserted into a chart (Figure 9.71).

Use of computer simulation

Effective communication between the patient, dentist, and laboratory is important to satisfy the esthetic requirements of the patient. With the advent of the computer, smile analysis has become more objective. Tooth and smile proportions can be evaluated and the widths and lengths of the maxillary anterior teeth calculated according to RED proportion principles. A grid can be placed over the photograph with the appropriate RED proportion

Cast central incisor length	9mm	
Photo central incisor length	25 mm	
Cast/photo proportion	0.36	

Photographic Widths

	5	6	7	8	9	10	11	12	**Widths** #6-11
Width	2.7	12.4	13.8	20.6	20.6	13.8	11.6	4.7	92.8
Length	14.0	20.0	19.8	22.6	25.0	19.8	19.7	15.4	

Calculated Cast Widths (FIVE widths)
(Photo widths X Calculated Cast/Photo Proportion)

	5	6	7	8	9	10	11	12	**ICW**
Width	1.0	4.5	5.0	7.4	7.4	5.0	4.2	1.7	33.4 mm
Length	5.0	7.2	7.1	8.1	9.0	7.1	7.1	5.5	

Figure 9.67 Correlating cast lengths with photo lengths to calculate FIVE widths.

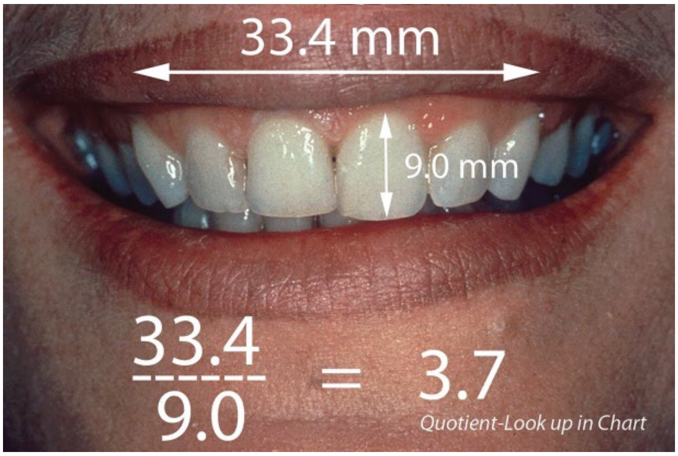

Figure 9.68 Calculating a quotient to look up in the chart.

Using CIW & W/L Ratio

CIW/0.78 = CIL
7.62/0.78 = 9.8mm *long central incisor*

Figure 9.70 Calculating central incisor tooth length.

Normal Length (ICW = 33.4 mm)

ICW/CIH quotient	RED Proportion	Relative tooth length	Central incisor width (CIW)	Lateral incisor width (LIW)	Canine width (CW)
3.4	70% RED	Normal	ICW/4.38	ICW/6.26	ICW/8.94

CIW = 33.4/4.38 = 7.6 mm (wide lateral incisor)
LIW = 33.4/6.26 = 5.3 mm (wide lateral incisor)
CW = 33.4/8.94 = 3.7 mm (wide canine)

Figure 9.69 Using ICW, calculating a CIL (shown as CIH, or central incisor height on the figure) quotient to calculate anterior tooth widths for patient.

(ICW = 33.4 mm)

RED Proportion Measurements (in mm)

	6	7	8	9	10	11
Width	3.7	5.3	7.6	7.6	5.3	3.7
Length	9.8	8.8	9.8	9.8	8.8	9.8

70% RED proportion 78% W/L Ratio

Figure 9.71 Completed chart using RED proportion.

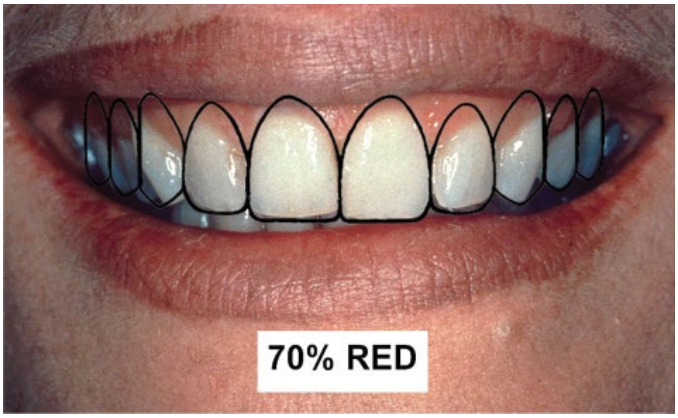

Figure 9.72 RED proportion template overlay.

Figure 9.73 Imaged nonperiodontal surgery smile.

Figure 9.74 Imaged periodontal surgery smile.

outlines of the desired teeth (Figure 9.72). Using computer imaging software, an image of the final desired sizes of the teeth can be produced. It is important to create simulations with the patient's own gingiva to show results that can knowingly be accomplished. The use of a smile library to insert other patients' teeth and gums within the lips of a patient may not accurately portray what is possible. A computer image of the final desired obtainable result allows open discussion before operative treatment begins.

The patient was originally interested in only six porcelain laminate veneers but wanted them to be lighter. After evaluating the display of her buccal corridor when smiling, it was determined there would be a sharp contrast between the veneers and the darker maxillary posterior teeth. A computer simulation of the probable final appearance without crown lengthening was prepared (Figure 9.73). Elective crown lengthening would allow for a more desirable width/length ratio of the central incisor. A RED proportion could be selected that coincided with the overall height of the patient. Using the calculations derived above, a simulation was produced for the likely outcome of crown lengthening and placement of eight porcelain laminate veneers. Extending treatment distally to the first premolar helps to visually fill the buccal corridor, give better unity to the anterior teeth, and allow for lighter final restorations. The RED proportion was used to determine the appropriate facial view width of the first bicuspids (Figure 9.74). The patient viewed both simulations and was able to make an informed decision. She elected to have crown lengthening performed and eight porcelain laminate veneers placed.

The patient was referred to the periodontist to have crown lengthening and gingival recontouring performed (Figure 9.75). It is important to inform the specialist the desired lengths of the final restorations, so that the free gingival margin can be placed in the proper position. The teeth that will be restored must be communicated as well. The tissue was allowed to heal and final

Figure 9.75 Postperiodontal surgery.

Figure 9.76 Postoperative smile designed using the 70% RED proportion.

gingival sculpting was performed. The anterior eight teeth were prepared for porcelain laminate veneers and the case completed (Figure 9.76).

Patient preferences and individuality

Studies have evaluated the smile preferences of patients. Their general likes and dislikes compared to dentists are similar but their acceptable variance is much broader. Patients accept greater deviance from defined norms.[57,58] Laypersons are not as discerning about likes and dislikes.[59,60] Patients often have a different order of criteria for what is considered esthetic.[61,62] In one study, patients were willing to accept variations of width/length ratio of the maxillary central incisor between 75 and 85% compared to dentists, who preferred 75–80%.[63] However, patients surveyed, like their professional counterparts, did not prefer the golden proportion to other suggested tooth-to-tooth width proportions with normal-length teeth.[64] Another aspect which has only briefly been investigated is variation in preference by gender. Members of each group may place different emphasis and regard for factors that comprise an esthetic smile. The bias of a dentist of one gender treating the other gender could result in minor differences of opinion.[56]

It is important to understand the characteristics which comprise an esthetic smile and then incorporate variations for the individual. A natural smile rarely exhibits all the ideal components of a smile. Learning how and when to break these rules allows for an expressive smile. As stated over 60 years ago by Frush and Fisher, our goal should be to create eminently suited, fully expressive smiles that convey the person's charm, character, dignity, and beauty.[6] By incorporating the design principles of an esthetic smile, we can provide our patients the ability to display on the outside their inner feelings via a pleasing smile.

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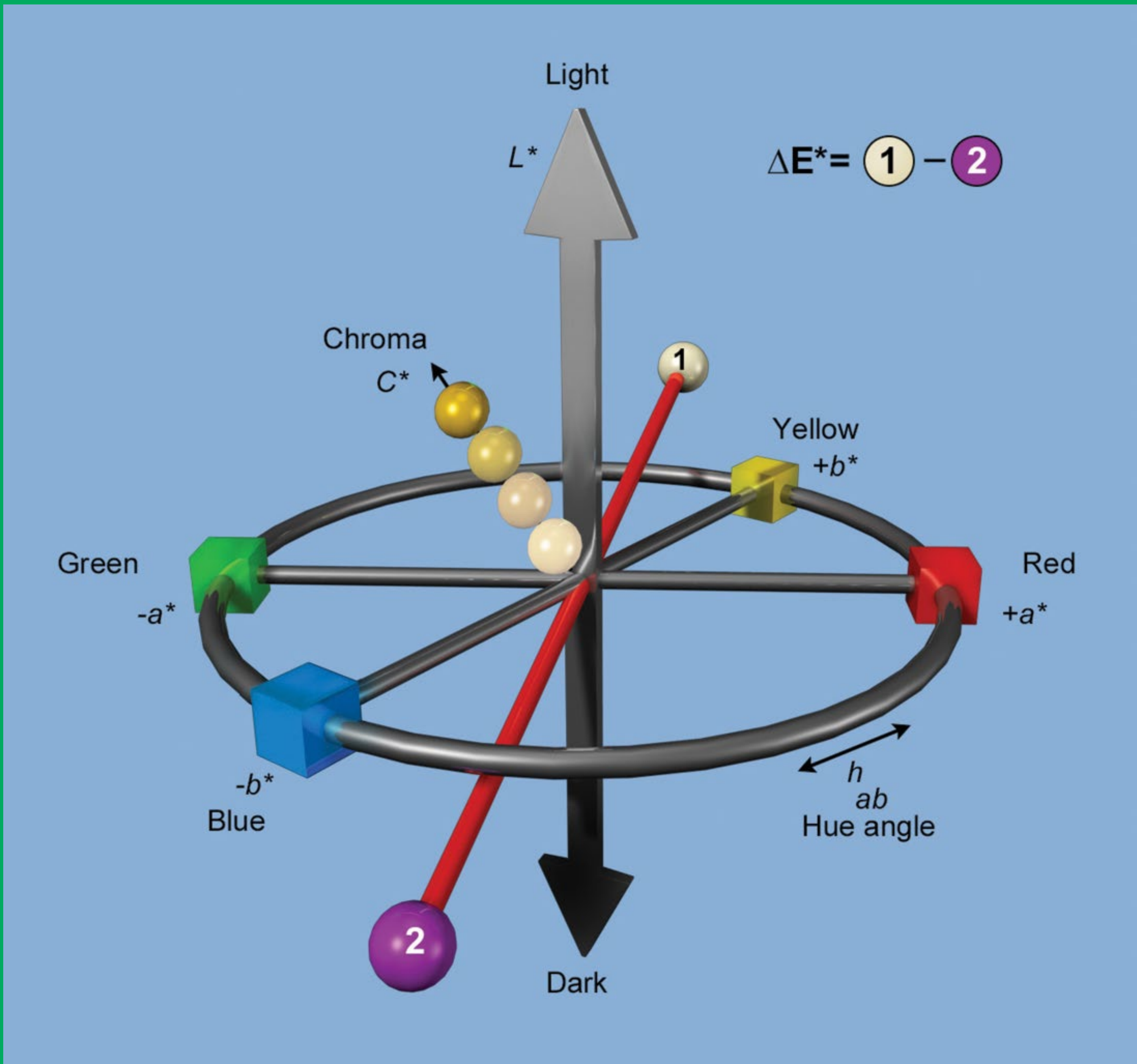

Light
L^*
$\Delta E^* =$ 1 – 2
Chroma
C^*
1
Yellow
$+b^*$
Green
$-a^*$
Red
$+a^*$
$-b^*$
Blue
h_{ab}
Hue angle
2
Dark

Chapter 10 Understanding Color

Rade D. Paravina, DDS, MS, PhD

Chapter Outline

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This book amply documents the many areas that must be coordinated to achieve the intangible result called "esthetic." Color must take its place as merely another building stone, a part of the total perceptual impression. However, just as the disharmony is created by a discordant note in a symphony, the wrong color can destroy a result so painstakingly sought.

To the untrained eye, all teeth are white. To the dentist, who must match the natural teeth using a restorative material, the wide and subtle gamut of color is a real, perceptual challenge. Although the need to know accepted color matching procedures is a basic requirement, it is often ignored in dental education. It is also usually poorly understood by the dentist, the technician, and manufacturers of dental materials. The science of color matching involves physics, psychophysics, psychology, and even philosophy. Knowledge of advanced algebra and calculus is helpful. The nature of light, color vision theories, spectrophotometric studies, color dimensions, color order systems, and other equally confusing matters are all part of the color scientist's world.[1,2] These advanced concepts are not required for perceiving and equating colors, but if one is to truly understand what is occurring in color perception and matching, they are essential.

This chapter is intended to provide practical guidelines for color matching. In a text that emphasizes the clinical approach to esthetics, the reader has the right to expect clinical guidelines on color matching instead of a technical discourse. Only that technical information essential to accomplish these goals is presented. Clinical color matching involves more than picking a tab from a shade guide and having a restoration of the same color processed. One often wishes it were that simple; unfortunately, that is the extent of understanding that usually accompanies the shade selection procedure. To develop an ability to select a shade that will ultimately result in a restoration matching the adjacent natural dentition, it is essential to have an appreciation of the role of the three-dimensional nature of color. There must also be a realization of the benefits and limitations of existing guides and materials.

Ronald E. Goldstein's Esthetics in Dentistry, Third Edition. Edited by Ronald E. Goldstein, Stephen J. Chu, Ernesto A. Lee, and Christian F.J. Stappert.

Basics of color

E. Bruce Clark, an early leader in color matching in dentistry, succinctly stated the need for learning the three-dimensional nature of color: "In the study of color not only is an intimate acquaintance with its three dimensions the first requisite that should be acquired, but it is, without exception, the most important."[3] Familiarity with the three-dimensional nature of color is the key to successful clinical color matching. A mental image of an object such as a box can be conveyed to another person by describing its length, width, and depth. It is easy to give instructions on modifying its dimensions, or to make comparisons of its size and shape with those of another box. This is possible because other people know what a "box" is, they understand the concept of three dimensions, and the scales, such as meters, centimeters, and millimeters, by which those dimensions can be expressed. The dimensions of color—hue, value, and chroma—enable similar type of communication regarding color. The mechanism of visual color perception—a light-object-observer triplet, color dimensions, and color notation systems—will be described in this section.

Color triplet: light, object and observer

Color is a psychophysical sensation produced in the eye by visible light reflected from an object and interpreted by the brain.[4–6] The color triplet consists of light source, object, and observer.

Light

There is no color without light. Visible light is merely one small portion (lies in a narrow band from 380 to 760 nm) of the electromagnetic spectrum (Figure 10.1). More detail about desirable light characteristics for work with color in dentistry will be provided in the section on color matching conditions.

Object

The light can be reflected, transmitted, and absorbed by the object (we seldom look at the light source). We see the reflected light, either from the surface (surface reflection), or from the body of the translucent material or tissue (volume reflection). Tooth color matching is closely related to volume reflection. Depending on the angle, reflection can be specular (mirror angle compared to incident light), diffuse (light reflected in any other angle), or total.

Observer

Light rays reflected from an object have the ability to stimulate the rods and cones, cells of the retina that enable color perception. Rods enable an achromatic component, while cones (red-, green-, and blue-sensitive) enable color perception. The information is then conveyed to the brain, which interprets it and allows the sense of sight.

Color dimensions

Colors differ in many ways: they may be red, orange, yellow, blue, and so on, or they may be light or dark, weak or strong. The description of these differences is the basis for the clinical approach to color matching in dentistry. The description of color dimension, similar to one provided by Munsell for his color notation system and later adapted in other systems, will be presented here.

Hue

The dimension of hue is most easily understood. It is "that quality by which we distinguish one color family from another, as red from yellow from blue or purple."[7] All hues are placed in a closed hue circle in Figure 10.2 (only green, red, blue, and yellow are shown). The order of hues in the visible spectrum is violet, blue, green, yellow, orange, and red. It is important to understand that these hue names are descriptive of a family of sensations and there is no clear distinction between where one hue terminates and another begins. The spectrum is a continuum of sensations to which we have given convenient (although sometimes meaningless) names.

Value

This is an achromatic dimension, ranging from black to white, with all the grays in between, as represented by a vertical value axis in Figure 10.2. Value relates to the quality (not quantity) of a color's grayness. A black and white image of a colored object would be a one-dimensional (value) rendition of a three-dimensional (colored) object.

Chroma

This color dimension enables discrimination between a strong color and a weak one. Chroma is represented by the distance of certain color from the point of the same value on an achromatic

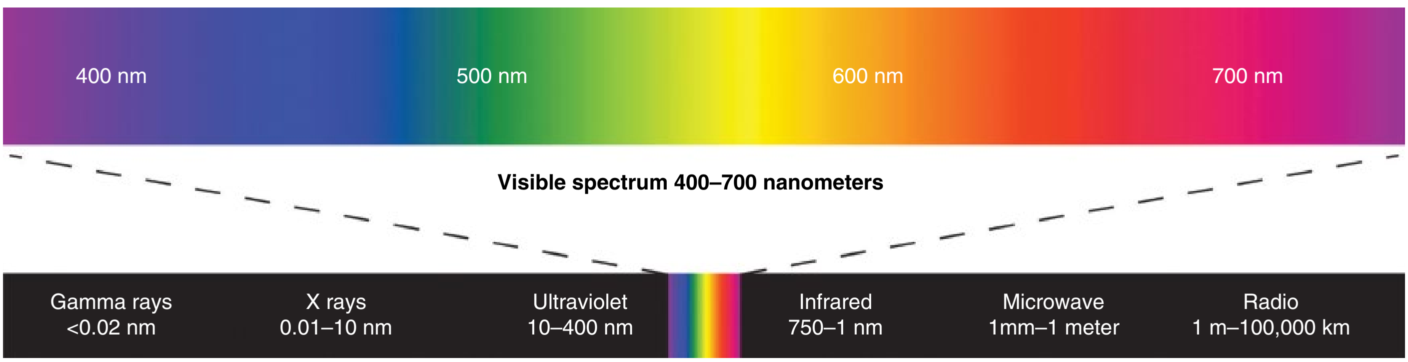

Figure 10.1 Electromagnetic spectrum with relative wavelengths and frequencies, and expanded visible light.

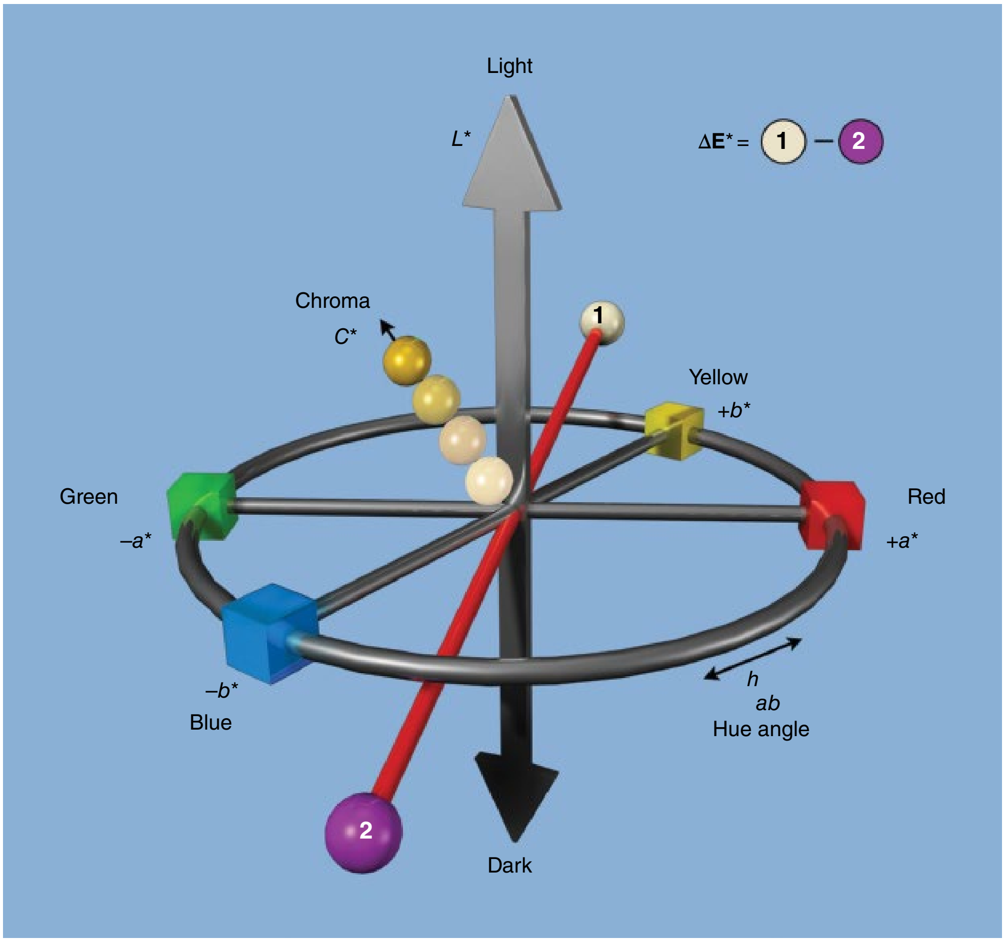

Figure 10.2 Color dimensions: hue, value, and chroma, and color difference, ΔE*, representing the interaction among color dimensions.

axis—it increases with the increase of this distance (Figure 10.2). Therefore, hue differences are associated with different colors, while chroma differences are related to different strength of the same color.

A large portion of this chapter has been devoted to understanding color dimensions because it is basic to comprehending a logical basis for color matching in dentistry. This will become more apparent when shade guides and their use are discussed. However, before familiarity with the three-dimensional nature of color can be a practical aid, one must know how to identify color differences and attribute them to hue, value, or chroma.

Color notation systems

Color dimensions—hue, value, and chroma—are used in different color notation systems and formulae. Familiarity with color dimensions can contribute to the traditional means of color matching, communication (for indirect restorations), reproduction, and verification. In addition, these systems are of the great benefit for color research in dentistry. The Munsell hue-value-chroma color notation system is probably mostly important historically, while different formulae of the Commission Internationale de l'Éclairage (CIE; International Commission on Illumination) system are presently most frequently used and will be more thoroughly described.

Commission Internationale de L'Éclairage (CIE) System

Similarly to the Munsell system, CIE system has achromatic (value) and chromatic component (hue and chroma). The CIELAB formula was developed in 1976 and it utilizes the following color coordinates: L* (lightness; synonym for Munsell Value), a* (–a* green, +a* red), b* (–b* blue, +b yellow), H* (hue), and C* (chroma), where H* and C* are calculated from a* and b* coordinates. Color difference in the CIELAB formula is denoted ΔE* (Figure 10.2); it represents the difference in sensation (the symbol delta, Δ, means the difference, while E is the first letter of the German word *Empfindung*, which means sensation), and represents the interaction of L*a*b* or L*C*H* differences.[1] A more recent and more advanced CIE formula, CIEDE2000,[8] has been subsequently introduced and it is increasingly used in dental color research.[9,10]

Color in dentistry

One of the best descriptions of the importance of color was offered by Bergen. He said "Color is unimportant to the physiologic success of a dental restoration, yet it could be the controlling factor in the overall acceptance by the patient."[11]

Dental professionals are routinely performing matching, replication, and/or creation of color of hard and soft oral tissues, while maxillofacial prosthodontists are dealing with color in the entire maxillofacial area. Therefore, this section is related to color of teeth, gingiva, and skin.

Familiarity with the basics of color is essential to the understanding of color-related clinical and dental technology applications, and the remainder of this chapter. What is the practical meaning of ΔE* values? What ΔE* corresponds to perfect match, *perceptibility*, and *acceptability thresholds* (wait, what is color threshold)? A ΔE* of 0 corresponds to perfect match—it is rarely seen and not really necessary. Visual thresholds are also known as industry tolerances, and these differ from one industry to another. A 50:50 perceptibility threshold is the difference in color that can be detected by 50% of observers. The other 50% of observers will notice no difference in color between the compared objects. A nearly perfect color match in dentistry is a color difference at or below the 50:50 perceptibility threshold. A 50:50 acceptability threshold is the difference in color that is considered acceptable by 50% of observers. The other 50% of observers would replace the restoration or correct its color. An acceptable color match in dentistry is a color difference at or below the 50:50 acceptability threshold.[12]

Tooth color

Color of human teeth differs by dentition: permanent teeth are darker and less chromatic than primary teeth. It differs by individual and by tooth type for the same person: incisors are in general the lightest while the canines are the darkest and most chromatic. It also differs for the same tooth, by the tooth area: from gingival to incisal, mesial to distal and buccal to lingual, and throughout the lifetime; "older" teeth are in general darker and more chromatic.[13,14]

The following color coordinate ranges of permanent teeth were reported: L* ranged from 56 to 90, a* ranged from −4 to 7, b* ranged from 4 to 39, C* ranged from −4 to 39, while H* ranged from 73 to 119.[15] When color of permanent teeth was compared by gender: female teeth were lighter, less red, and less chromatic, and the overall color difference (ΔE*) was 3.0. The same was found for comparisons between bleached and nonbleached teeth, and teeth of smokers and nonsmokers: bleached and nonsmoker teeth were lighter, less red, and less chromatic, with ΔE* = 4.6 and 3.4, compared to nonbleached and smoker teeth, respectively.[16] In general, lighter teeth are less chromatic and less red, regardless of all variables mentioned above. Based on the literature, the 50:50 perceptibility threshold for teeth ranges from ΔE* of 1 to 2,[17,18] while the 50:50 acceptability threshold ranges from ΔE* of 2.7 to 3.5.[5,18,19]

Gingival color

Color range of healthy human gingiva is far beyond the "ideal" light pink. A lightness range from 27 to 81, a* range from 4 to 38, and b* range from 5 to 27 were reported.[20] Wide ranges of color coordinates make restoring color of the gingiva more challenging whether dental materials (ceramics, acrylic, or composite resins) or human tissues are used.[21] Restorations that do not primarily involve gingiva can also affect its color: partial dentures, implants, crowns, and veneers. Inflammation and tooth whitening can also cause reversible color changes of gingival tissue.

Skin color

There are numerous reports of dissatisfaction with the longevity, function, esthetics, or color stability of facial prostheses.[22–24] When perceptibility and acceptability thresholds for human skin replications were evaluated, significant differences were found by primary specimen color and type of threshold. CIELAB perceptibility thresholds for light and dark skin replications were 1.1 and 1.6, respectively. Corresponding values for acceptability thresholds were 3.0 and 4.4, respectively.[25]

Visual color matching

Tooth color is most frequently matched through visual comparison with dental shade guides. Visual comparison is subjective and to a certain extent inconsistent, and also includes variables such as color matching conditions, tools, and method. Several traditional myths persist: (a) dental professionals are gifted for shade matching; (b) females are better in shade matching than males; and (c) experienced practitioners are better than novices.

The truth is that ability to see and differentiate color for dental professionals varies from individual to individual, comparable to the general population. According to the results of the Farnsworth–Munsell 100 Hue Test, humans have 16% superior, 68% average, and 16% low color-discrimination abilities.[26] There is no professional vision research or dental research that supports female "supremacy" in color matching ability for color-normal individuals.[27,28] However, color deficiency is far more frequent in males (1 in 12, or 8%) than females (1 in 200, or 0.5%).

There is no sufficient evidence to show that those with more years of experience have superior skills. If experience has been with inadequate color matching conditions, inappropriate shade guides and color matching methods, this could hardly be considered good color training experience. Experience is important, but so is the status and age of the eyes. Typically a healthy 25 year old has better vision than a 50 year old. It would be beneficial to test color vision of all dental students and professionals using both conventional (nondental) and customized (dental) tests. Testing *color discrimination competency* (CDC) in dentistry has been described in the technical report by the International Organization for Standardization (ISO TR 28642).[12] The dental test includes matching pairs of tabs from two shade guides under controlled conditions and method. Superior, average, and low CDCs correspond to a score of 85, 75, and 60%, respectively.

Color matching conditions

Appropriate lighting and environment are of critical importance for work with color in dentistry. Poor color matching conditions can reduce chances for successful color matching before one even starts.

Lighting

When a wavelength of light is lacking in the light source, it cannot be reflected from the object being viewed. Full-spectrum color-corrected lighting is needed to elicit all the color a tooth is capable of reflecting. For example, teeth fluoresce a blue color when seen in a light source that includes ultraviolet energy (such as daylight). This blue fluorescence acts as a whitening agent, through the principles of additive color. Without getting into the technicalities, the blue light emitted by fluorescence neutralizes some of the yellow light and makes the tooth appear whiter. Therefore, the light source should have a near-ultraviolet component.

Daylight varies from morning to evening, with the cloud cover, the air pollution, and from any colored object from which it is reflected. Therefore, it is not recommended to use natural daylight for dental color matching; furthermore, the solution is just a "click away"—there is a huge selection of appropriate ceiling, portable (floor and table lamps), and hand-held lights (Figures 10.3 and 10.4).

There are several parameters that describe an ideal light for shade matching in dentistry. The first one is called *correlated color temperature* (CCT). Color-corrected lights resembling standard daylight at 5500 and 6500 K (D55 and D65) are recommended. Another key factor is termed the *color rendering index* (CRI)—a light source that has CRI of 90 or greater is appropriate. Lighting of these characteristics would have a *spectral power distribution* (SPD) that is similar to standard daylight. Finally, the light needs to be of adequate intensity, which is termed the *illuminance*, and measured in lux (abbreviated to lx). The level of illuminance at the color matching area should be 1000 lx.[1] More intense light, up to 1500 lx, might be used to overcome other ambient lighting. The importance of proper light intensity cannot be overemphasized: low intensity reduces our color matching ability, while the outcome of very intense light is similar: it can "wash out" color differences between the tooth and shade tab or restorative material. Light meters (lux meters, flash meters, exposure meters), like the ones used by photographers, should be used to control the illuminance.

Figure 10.3 Hand-held lights. **(A)** Demetron Shade Light (KerrHawe); **(B)** Shade Wand (Authentic Dental Lab); **(C)** Ritelite (AdDent); **(D)** Optilume Trueshade (Optident); **(E)** Esthelite Shade Matching Light (EFOS).

Figure 10.4 Color matching with a Ritelite hand-held light.

High-quality lights are widely available in specialized stores and online. Sales people or customer support can provide invaluable help—one just needs to ask for color-corrected light of appropriate CCT, CRI, and light intensity.

Metamerism

Teeth, shade tabs, and restorative materials are composed of different materials, and have different spectral curves. When the color of a pair of specimens having different spectral reflectance functions matches under one set of illuminant and observer conditions, but mismatches under another set of conditions, this phenomenon is called metamerism, conditional match, or nonspectral match, while these specimens are called metamers.[5] Inversely, specimens with identical spectral reflectance functions (spectral or unconditional match) are called isomers. There are several types of metamerism: *illuminant* (different lighting conditions), *observer* (different persons), *geometric* (different viewing angles), and *field size* (different viewing distances) *metamerism*. Ideally, dental restorations would match color of natural teeth under any of mentioned conditions. Because of the different nature and composition of hard dental tissues and dental materials this is not always achievable.

Environment

Shade matching environment encompasses the *background* and the *surround*. These two terms are closely related to *visual angle of subtense*, which is calculated from the size of the observed object and viewing distance. The background is defined as the surface upon which specimens are placed; the environment of the stimulus extending for about 10° from the edge of the stimulus in all, or most, directions. For tooth color matching, this would correspond to up to a 100 mm circular area around the tooth, and include adjacent teeth, soft oral tissues, lips, and skin. The surround is defined as the field outside the background.[12] In practical situations, the surround can be considered to be the entire environment in which the stimulus is viewed.[2] The surround should be matte and neutral light gray. Hand-held lights are very useful for overcoming the influence of the surround on color matching, especially when overhead lights are turned off.

Color matching tools—shade guides

Shade matching tools for visual shade matching are called dental color standards or shade guides.[5] Depending on their purpose, basic division encompasses shade guides for teeth (ceramic and resin-made shade guides), oral soft tissues, and facial skin. The latter two types are not routinely used in dentistry.

Tooth shade guides

Shade guides designed by Clark and Hayashi are among the most important shade guides historically. Clark created the Tooth Colour Indicator, a ceramic shade guide consisting of 60 ceramic tabs (Figure 10.5),[11] while the Hayashi shade guide consisted of all the combinations of five lightness, five chroma, and five hue levels, for a total of 125 printed chips. The Spectratone shade guide, consisting of 256 three-dimensionally arranged ceramic tabs, was also a noteworthy attempt to create a systematic dental color standard.[5] Logical order and adequate color distribution have been emphasized as two primary requirements for dental shade guides for a long time.[29–31] Current shade guides fulfill these criteria to different extents and they are divided into three main groups as follows:

1. VITA classical A1–D4
2. VITA System 3D-Master
3. others: proprietary or classical-proprietary shade guides.

The VITA classical A1–D4 (VITA classical, VITA Zahnfabrik, Bad Säckingen, Germany) was a gold standard for shade matching in dentistry for decades and to a large extent it still is. The vast majority of resin composites, dental ceramics, and denture teeth are keyed to this shade guide. VITA classical contains 16 shade tabs. The original tab division is known as the "A to D" arrangement (Figure 10.6a). The four groups are created based on hue: A is reddish-brown (A1, A2, A3, A3.5, A4), B is reddish-yellow (B1, B2, B3, B4), C is gray (C1, C2, C3, C4), and D is reddish-gray (D2, D3, D4). Within the groups, tab arrangement is based on increasing chroma and decreasing value—the higher the number, the higher chroma and the lower the value.[5]

An alternative tab arrangement, known as the "value scale," has been established according to the "degree of brightness," with no group division (Figure 10.6b). The value scale tab order

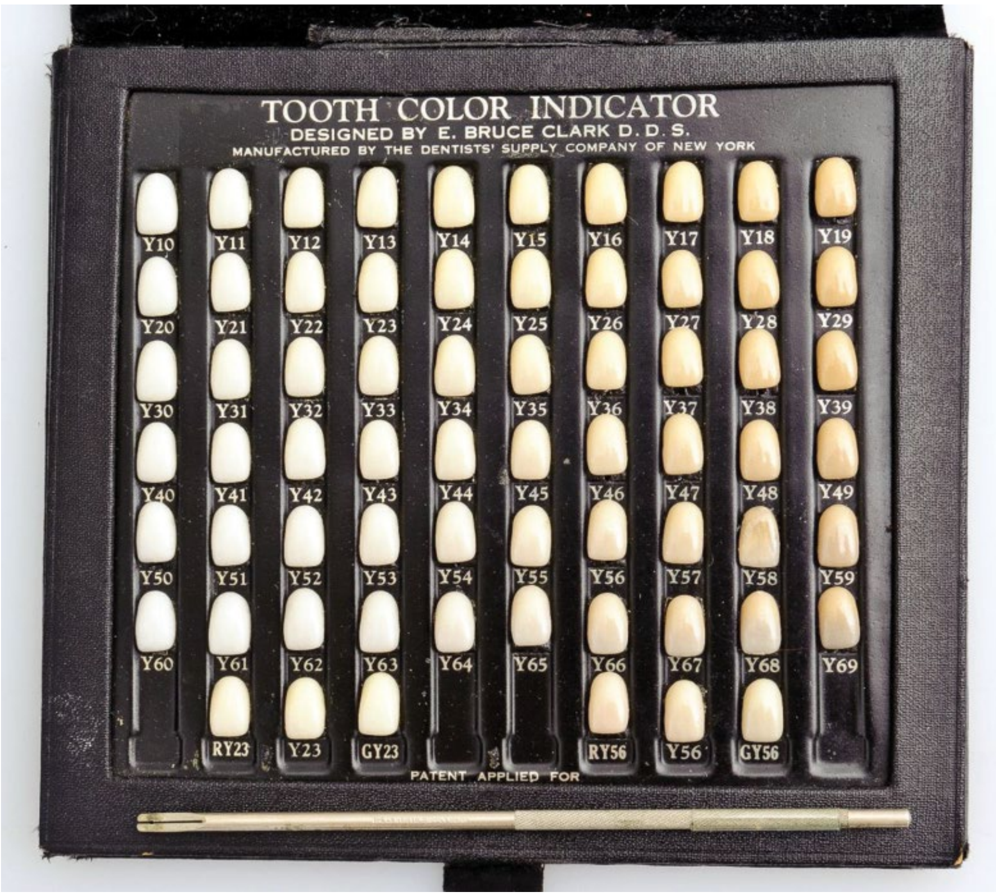

Figure 10.5 Tooth Color Indicator, a shade guide designed by E.B. Clark in 1931.

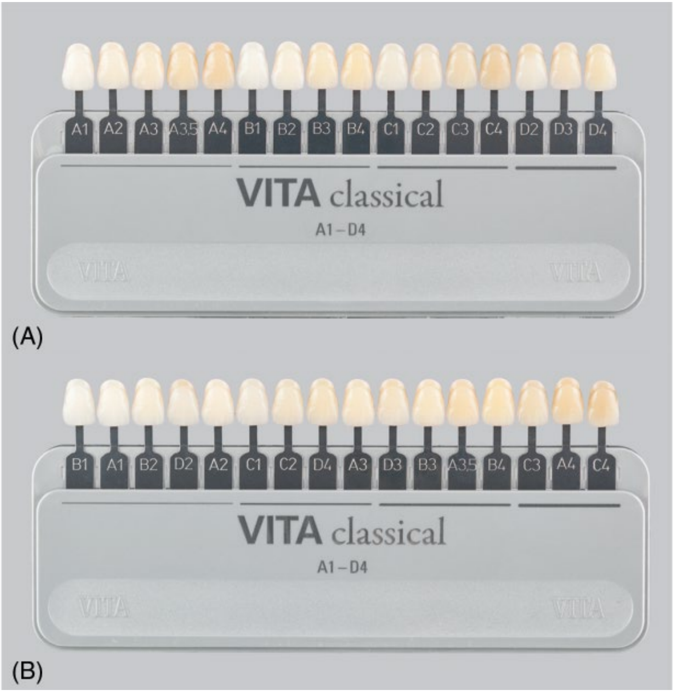

Figure 10.6 VITA classical A1–D4 shade guide: **(A)** A-to-D tab arrangement; **(B)** value scale.

is B1, A1, B2, D2, A2, C1, C2, D4, A3, D3, B3, A3.5, B4, C3, A4, and C4. The value scale is a gold standard for monitoring tooth whitening, expressed in *shade guide units* (sgu)—tab number (from B1, tab 1 to C4, tab 16) before bleaching minus the tab number after bleaching. Visual and instrumental change of 3, 4, and 5 *color change units* (ccu) of the value scale are the American Dental Association thresholds of clinical success for over-the-counter home-use tooth whitening products, dentist-dispensed home-use products, and professional in-office bleaching products, respectively.[32–34] The value scale is more logical and preferred by many over the A-to-D arrangement when it comes to color matching for dental restorations. However, several significant shortcomings of the value scale have been emphasized when it comes to monitoring whitening: (a) it does not correspond to visual light-to-dark order; (b) it has narrow range and inconsistent color distribution; (c) it is poorly correlated with the increase in chroma; and (d) it lacks very light tabs, which dictates exclusion of huge percentage of the population from whitening studies.[35,36] These concerns compromise findings on tooth whitening efficacy to a certain extent. Given its empiric nature and concept, and the fact that the classical was not originally designed for monitoring tooth whitening, the above-mentioned shortcomings are not surprising.

VITA System 3D-Master Shade Guides have been developed based on research on color of natural teeth. There are three 3D-Master shade guides: Toothguide, Linearguide, and Bleachedguide. 3D-Master tabs are marked using a number-letter-number combination. The first number designates the group and represents value, from 0 (the lightest) to 5 (the darkest). The letters L, M, and R represent hue: L corresponds to yellowish (or less red), M to medium, and R to reddish.

Figure 10.7 VITA Toothguide 3D-Master.

The number after the letter represents chroma, which increases from 1 to 3, with designations 1.5, 2, and 2.5 in between.

The VITA Toothguide 3D-Master (Figure 10.7) consists of 29 tabs divided into six groups according to lightness. Within the groups, tabs are arranged according to chroma (vertically) and hue (horizontally). Groups 0 and 5 have three tabs each; group 1 has two tabs, while groups 2, 3, and 4 have seven tabs each.[5] Shade matching with the Toothguide is basically a three-step procedure. In the first step, the value (group 0–5) is determined using the entire shade guide, thus reducing the number of possible shades. The second step is to determine chroma, while hue is determined in step three. Given that hue variations are present only in groups 2, 3, and 4, there are only two steps for groups 0, 1, and 5. This method can be challenging for those with little experience in tooth shade matching. The same is true for users with little knowledge about the physical background of the system.[6]

The VITA Linearguide 3D-Master (Figure 10.8) has the same shade tabs as the Toothguide. The differences are in its design and shade-matching method. Similarly to the Toothguide, the group selection occurs in step one, but using only a single linear scale that contains the middle tabs from each group (0 M2 to 5 M2, dark gray tab holder; Figure 10.9). The initial selection is simplified by a small number of tabs with huge color differences and the familiar linear tab arrangement. The second step is "fine tuning" by selecting the best match within the group selected in step one. The tabs from groups 0–1, 2, 3, 4, or 5 are placed into five separate light gray holders (Figure 10.10). The Linearguide 3D-Master was viewed as superior compared to the Toothguide and many users described the shade-matching method with Linearguide as self-explanatory and user-friendly.[37]

The VITA Bleachedguide 3D-Master (Figure 10.11) has been developed specifically for visual monitoring of tooth whitening. It has 15 shade tabs, marked in the same letter-number-letter style as the Toothguide and Linearguide tabs. The Bleachedguide tabs are also marked with odd numbers 1 to 29 sgu, representing 29 original 3D-Master tabs, from 0 M1 to 5 M3. Even numbers have been added as interpolated sgus, to comply with the American Dental Association recommendation that 1 ccu = 1 sgu = 1 ΔE^*, and to increase its precision (when a tooth shade is in between two shade tabs) and sensitivity. Tooth whitening causes a decrease in chroma and hue, and an increase in lightness

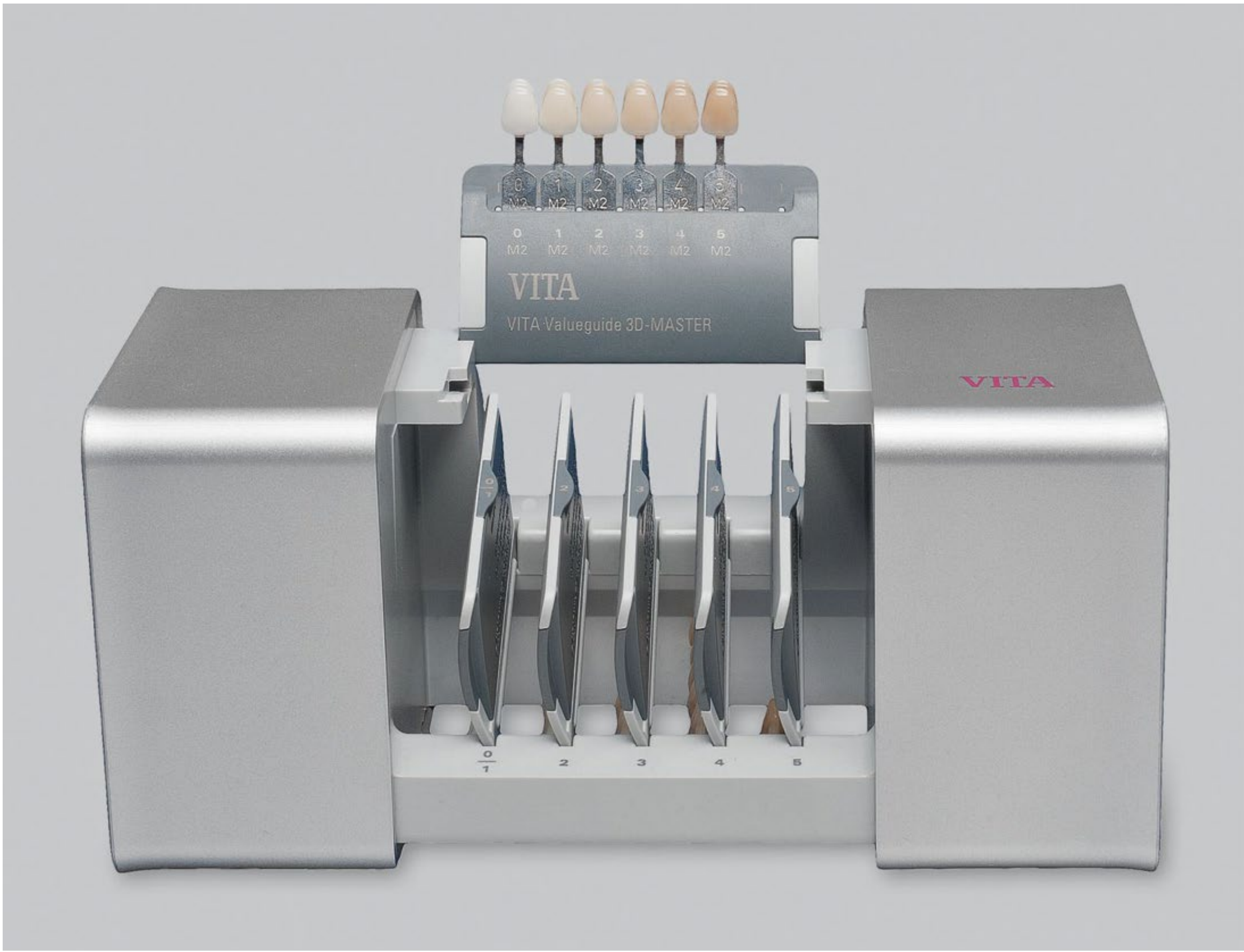

Figure 10.8 VITA Linearguide 3D-Master.

Figure 10.9 VITA Linearguide 3D-Master: dark gray holder for initial shade matching (step 1, select the group).

of natural teeth: changes in chroma are the most pronounced, followed by changes in lightness and hue. Chroma over lightness is called saturation, and it decreases upon bleaching (teeth are becoming less saturated). The Bleachedguide is a color scale (not a value, chroma, or hue scale), with lighter tabs being less chromatic and less red than the darker tabs.

Given the number of people who bleach their teeth and mentioned shortcomings of the classical value scale when it comes to monitoring whitening, the development of an advanced shade guide for this purpose was greatly needed. The Bleachedguide exhibits a wider color range and a more consistent color distribution than the classical value scale and some other products. Inclusion of very light shades and interpolated shade guide units further complement contemporary esthetic dentistry, starting from the fact that no patient inclusion/exclusion needs to be done based on their tooth shade before bleaching. Even a patient with the classical B1 shade before whitening can be included—this would correspond to number 6 on the Bleachedguide. This is a huge advantage compared to the classical value scale. In order

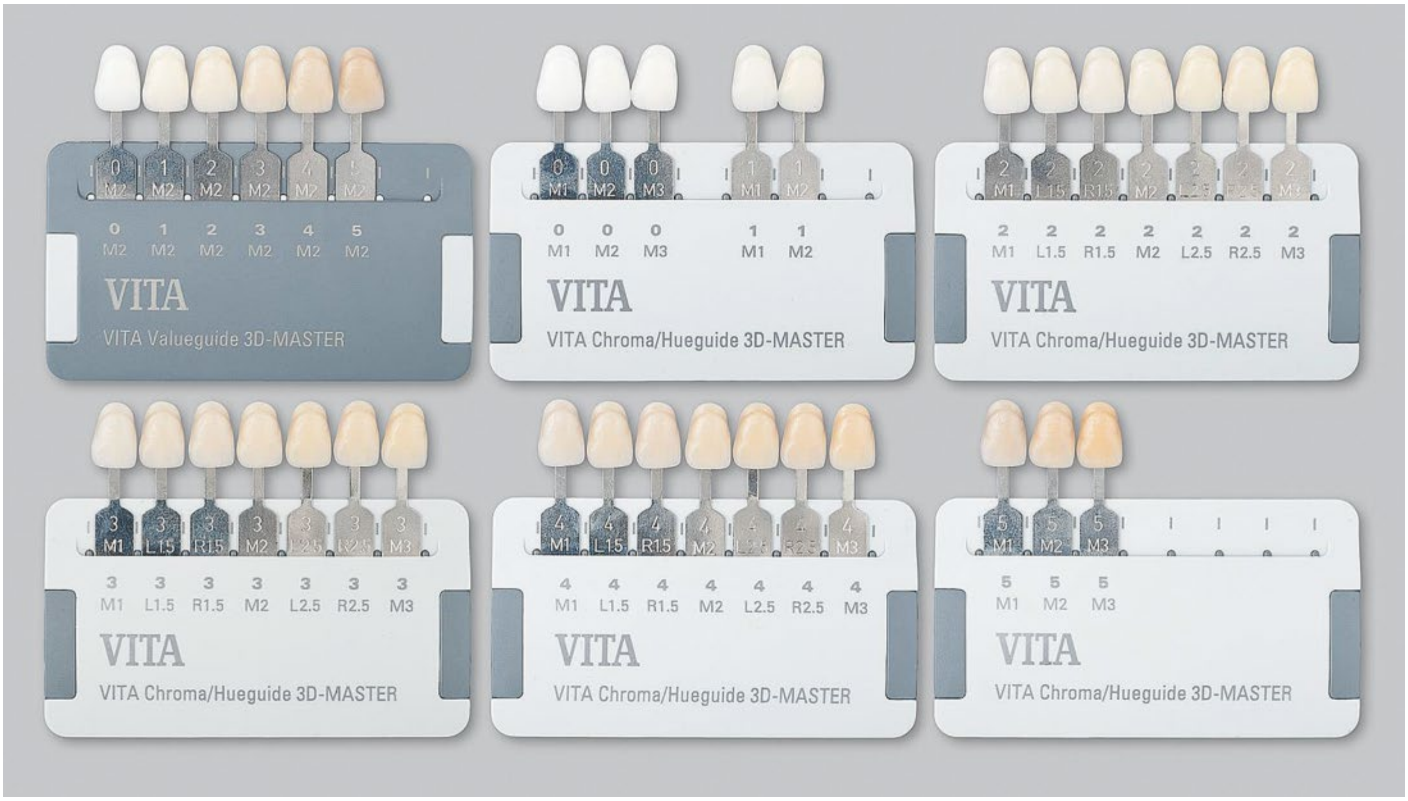

Figure 10.10 VITA Linearguide 3D-Master: upon selecting the group using the dark gray holder (upper left), fine tuning should be performed using the corresponding light gray holder (step 2, select within the group).

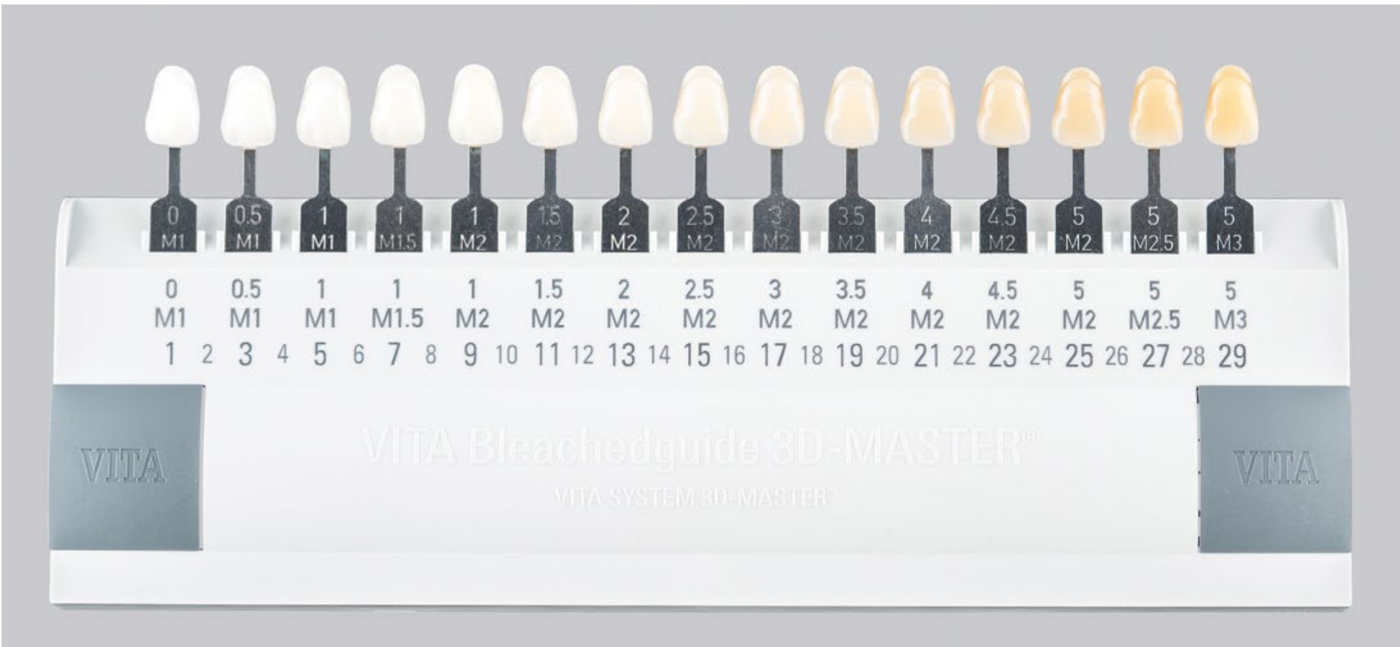

Figure 10.11 VITA Bleachedguide 3D-Master.

to compensate for a lack of lighter shades (lighter than B1), many studies included only patients whose teeth were A3 or darker before bleaching, thus excluding more than 52% of population.[13]

Proprietary or classical-proprietary shade guides: there are many shade guides made of dental ceramics, or single-layer or multilayer resins, with proprietary shades, or partly keyed to VITA classical (Figures 10.12–10.15).

The Ivoclar Chromascop (Ivoclar Vivadent, Schaan, Liechtenstein; Figure 10.12, top) is a proprietary shade guide with the same group division principle as VITA classical. It is

Figure 10.12 Proprietary or classical-proprietary shade guides: (top) Ivoclar Chromascop; (bottom) Trubyte Bioform.

divided into five groups according to the hue: group 1, white; group 2, yellow; group 3, light-brown; group 4, gray; and group 5, dark-brown. Each group consists of four tabs, marked by adding the numbers 10, 20, 30, or 40 after the group number (e.g., 310, 320, 30, and 340 for group 3). As in VITA classical, the tabs with higher number within each of the group are darker and more chromatic. A group 0, consisting of four extra light shades (010, 020, 030, 040), was later added to the original shade guide. In addition to the three-digit number marking, each Chromascop tab is additionally marked with a number-letter combination, without explanation on the meaning of these markings.

Trubyte Bioform (Dentsply International; Figure 10.12, bottom) is a classical/proprietary ceramics/resin shade guide arranged according to hue and as the VITA classical value scale. The former includes A-to-D classical arrangement and eight proprietary shades, while the latter represents a light-to-dark order of 24 tabs marked with two-digit numbers (order: 59, 51, 91, 62, 66, 52, 53, 92, 63, 54, 65, 93, 55, 69, 94, 95, 67, 56, 77, 81, 96, 83, 84, 85). As in many other shade guides, the additional bleached tabs are also available.

Pros and cons of tooth shade guides

Dental color standards are the only tools available for visual shade matching and should be used to their best advantage. Familiarity with these products, including the awareness of their good and bad sides, is probably the most logical starting point.

As mentioned previously, dental shade guides have different characteristics and indications. A single shade guide should not be used for all purposes. For example, VITA classical is the most frequently used shade guide in the dental profession, and it is appropriate for color matching for composites and ceramics, but much less appropriate for monitoring whitening. VITA 3D-Master shade guides enable the best color match to human teeth (see next paragraph) and have the most uniform color distribution. However, the Linearguide was found to be more user-friendly than its "peer," the Toothguide, and the biggest concern about this shade guide appears to be the absence of resin composites keyed to it. The Bleachedguide has been designed specifically for visual monitoring of tooth whitening.

Coverage error (CE) is a very convenient and simple method for evaluation of how well dental shade guides match the color of human teeth: the lower the CE, the better the shade guide and the better the chances of selecting an appropriate match. The CE actually quantifies the mean color difference between each evaluated natural tooth and the best matching tab from a particular shade guide. As shade guides are schematic representation of tooth color space, they have to have some CE. Although the reported CE values vary due to differences among color measurement instruments and techniques, it is evident that VITA classical and Trubyte Bioform have the highest CE, while VITA 3D-Master has the smallest CE. Other shade guides are in between these boundaries: Chromascop

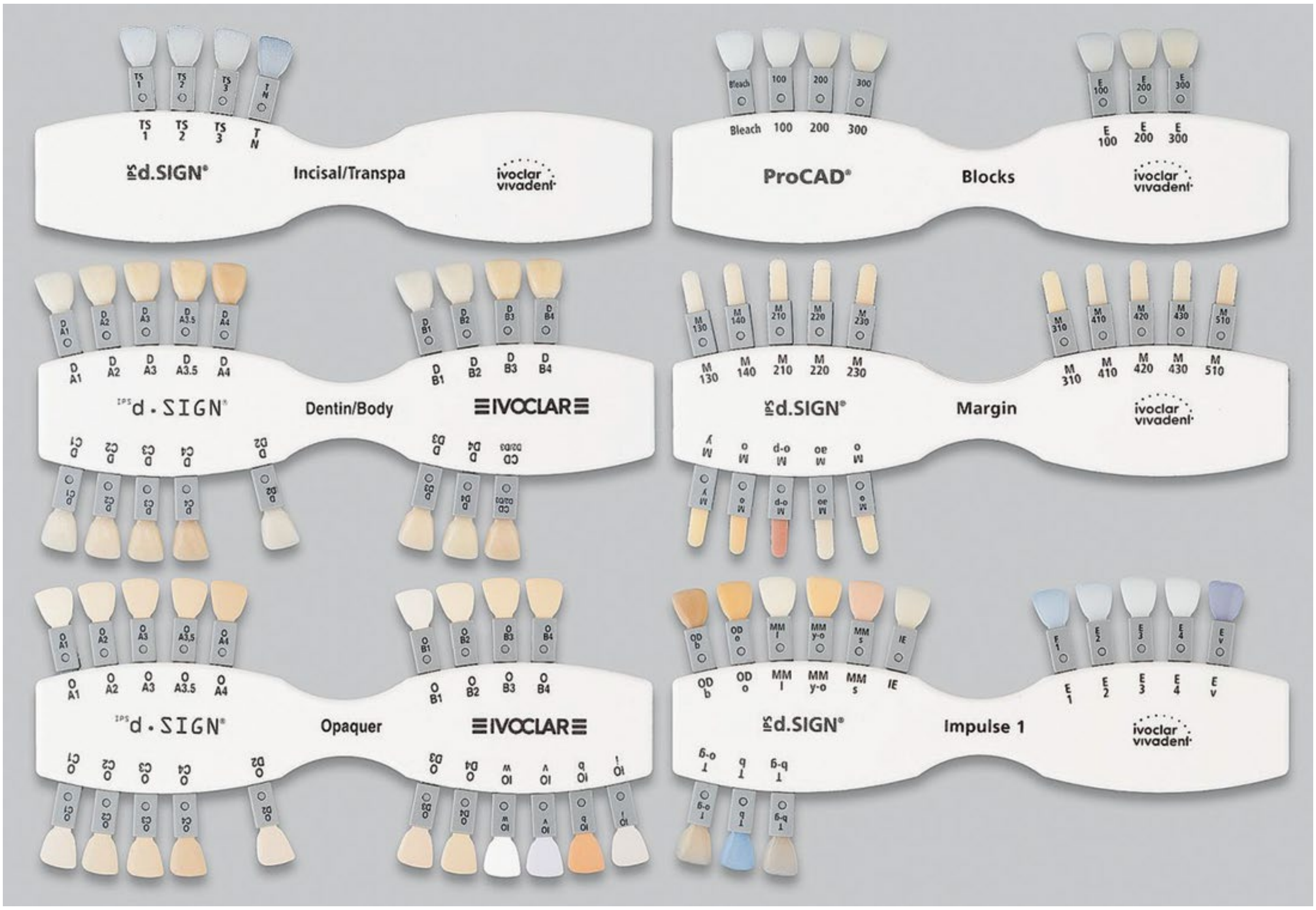

Figure 10.13 Proprietary or classical-proprietary shade guides for different layers and different materials, and color characterization (Ivoclar Vivadent).

and Vintage Halo are closer to classical, whereas Vintage Halo NCC is closer to the 3D-Master.[38]

Inadequacies of various dental shade guides have been reported many times in the literature and throughout this section. These concerns, summarized in Table 10.1, apply to some shade guides more than to others.

Shade Guides for Oral Soft Tissues

Color reproduction of the wide variety of shades of human gingiva and the other oral soft tissues requires the full attention of the dental profession. An esthetically pleasing result can be achieved by using adequate basic shades (custom or commercially made), by custom intrinsic and extrinsic characterization, or both. Ethnic differences and shade tab size, shape, and thickness should be taken into consideration when designing respective shade guides.

The Lucitone 199 shade guide (Dentsply Trubyte) consists of four glossy shade tabs of the same shape: original, light, light reddish pink, and dark. The IPS Gingiva (Ivoclar Vivadent) is a shade guide available in 10 shades: five "regular shades" (G1, G2, G3, G4, G5), four gingival modifier shades (GM1, GM2, GM3, GM4), and one gingival opaquer shade (GO). The Gummy gingival indicator (Shofu Dental) is available in three gingival shades (light, medium, and dark) and enables color matching combined with tooth shade tabs.[5]

Shade guides for facial prostheses

There is no gold standard for color matching of maxillofacial prosthetics—color matching and reproduction of a wide range of human skin are commonly performed using the trial-and-error method. Esthetic, social, and cultural demands suggest development of shade guides for facial prostheses for growing numbers of patients. Physical specimens that represent color of available maxillofacial materials and pigments cannot be considered skin shade guides. In addition, they are frequently limited to white skin shades, which is not adequate to serve the full ethnical diversity of our patients.[5]

Development of facial skin shade guides and color formulations for facial prosthetic materials can help clinicians achieve better and more predictable shade-matching results, thereby saving time and money. Furthermore, improving the quality of facial prostheses through the development of reliable facial skin shade guides will enhance quality of life for prosthetic patients. Another significant concern is poor color stability of some maxillofacial elastomers, and this issue has to be addressed simultaneously with the development of facial shade guides.

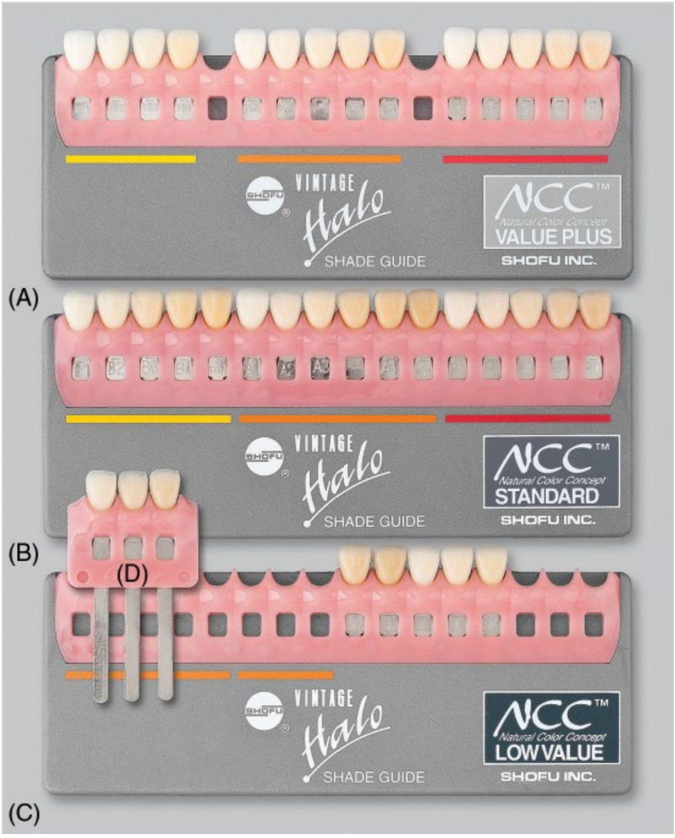

Figure 10.14 Proprietary or classical-proprietary shade guides, Vintage Halo NCC (Shofu): **(A)** Value Plus; **(B)** Standard; and **(C)** Low Value.

Color matching method

An adequate color matching method should complement the appropriate color matching conditions and the selection of the appropriate shade guide. This phase is of critical importance and "from the patient's point of view, the selection of a shade for the conservative anterior esthetic restoration that will match the

Table 10.1 Top 10 Concerns Regarding Some Dental Shade Guides

	Concerns Regarding Dental Shade Guides
1	Narrow color range compared to natural teeth; lack of darker and redder shades[7,31,39]
2	Uneven color distribution[30,40,41]
3	Different reflection curves compared to natural teeth[42]
4	Color differences among shade guides of the same manufacturer[43,44]
5	Shade guides keyed to VITA classical match color of original classical tabs with various success[5]
6	Lack of color stability of some resin-made shade guides due to factors such as disinfecting solutions, heat, and age[5]
7	Anatomy and optical characteristics of upper central incisors are not ideal for color matching of all teeth, especially posteriors[45]
8	Tab arrangement is sometimes confusing[46]
9	Shade tabs are frequently considerably thicker than the final restoration[40]
10	Other appearance attributes of shade tabs do not fully match natural and denture teeth, and restorative materials[5]

Adapted from reference 5.

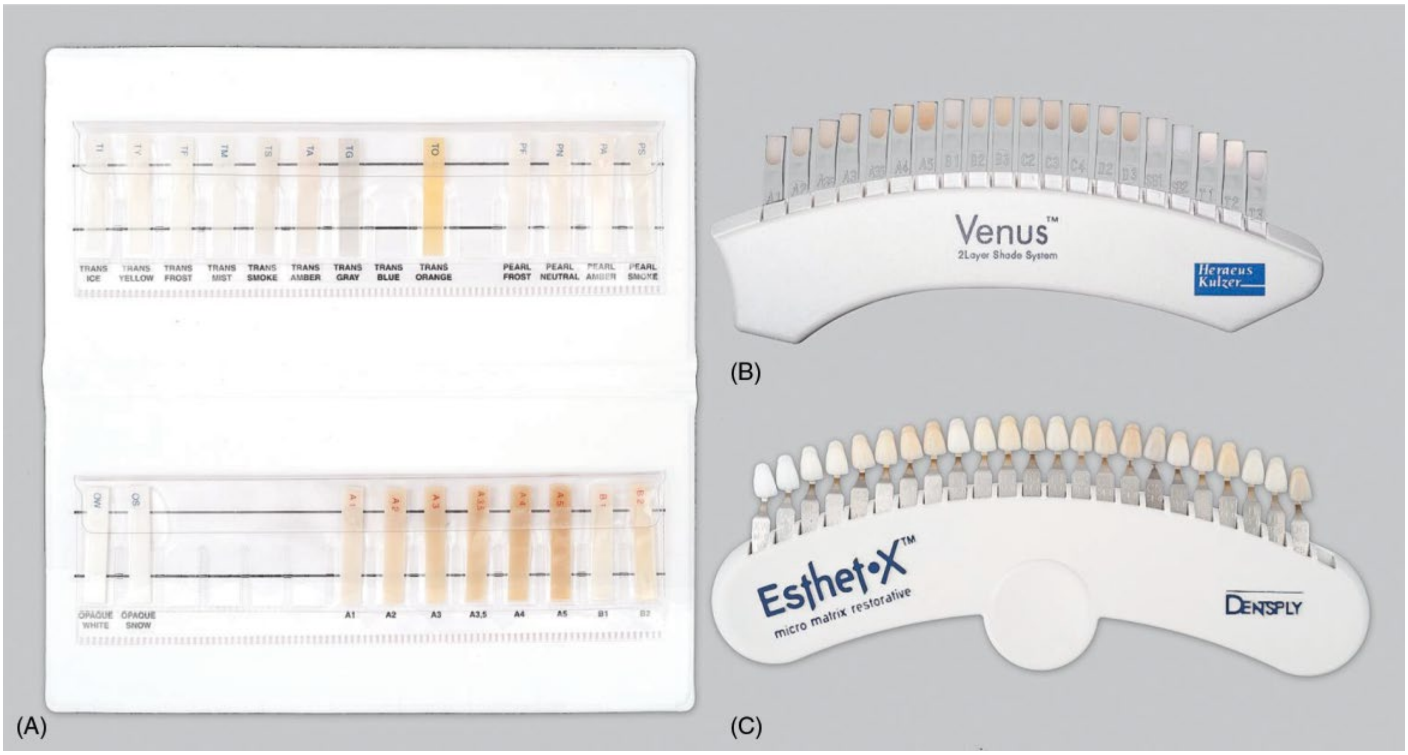

Figure 10.15 Proprietary or classical-proprietary shade guides: **(A)** Vit-l-ecsence (Ultradent Products); **(B)** Venus (Heraeus Kulzer); and **(C)** Esthet-X (Densply Caulk).

color and translucency of the tooth to be restored is probably the most important part of the appointment period."[47] Before the shade matching, patients need be asked to remove any lipstick and anything that could distract our attention or influence our judgment (large jewelry, eyeglasses, and similar). Teeth need to be cleaned and traces of prophy paste should be removed.[48]

Dental professional should not wear tinted eyeglasses or contact lenses while working with color as they can affect color perception. Shade matching should be performed at the beginning of the appointment as dentist eye fatigue and tooth dehydration could occur during the appointment—when teeth are allowed to dry out, they appear whiter and more opaque. The traditional belief that shade matching should be performed at arms' length is incorrect since that distance would create too small a *visual angle of subtense* (which, depending on the object size and viewing distance, should not be smaller than 2°).[1] Therefore, the arms' length distance would cause a decrease of visual precision. Color matching distance should be 25–35 cm.

The *optical geometry* is defined by the angle of illumination and the angle of viewing relative to the surface of the object. Several types of optical geometries are recommended for visual shade matching in dentistry. A 45°/0° optical geometry (45° illumination geometry/0° viewing geometry; Figure 10.16a) or a diffuse/0° optical geometry are more frequently seen in clinical shade matching. A 0° illumination geometry and 45° viewing geometry (Figure 10.16b) or 0°/diffuse geometry are more frequently seen in the dental laboratory setting. It is recommended to perform color matching using different lights because of the potential existence of illuminant metamerism. The dentist's eyes should be on the patient's tooth level. Whenever possible, shade tabs should be placed in the same plane and with the same relative edge position as the tooth. When the adjacent tooth is present, tabs can be placed horizontally or vertically in between the upper and lower teeth (Figure 10.4). The tab carrier should be along the tab's normal axis.[6]

The first impression of tooth color is frequently the most accurate. Since the vision pigment is used up quickly and to prevent the eye fatigue, an individual shade-matching trial should last 5–7 seconds, and the number of potentially adequate tabs should be reduced as quickly as possible. The traditional belief that it is good to gaze at a blue card between two shade-matching trials because this will increase the eye sensitivity to yellow is questionable. Staring at blue card will increase sensitivity to yellow, but it also provokes the chromatic induction effect, where a neutral field may appear slightly yellow. Therefore, one should observe a gray card between trials.

There is a huge difference between color dimensions and physical dimensions of an object (height, width, and length)—individual color dimensions cannot be distinguished when a single object is observed. What we see is the interaction of all three color dimensions. When we compare two objects, like in dental color matching, the eye cannot distinguish individual color dimensions of either tooth or shade tab, but can pretty accurately detect subtle color differences between them. However, our ability to detect the magnitude and direction of this difference (hue, value, and/or chroma) is much lower. Hue differences are, perhaps, the only dimensional differences that most individuals have been accustomed to judging with any degree of accuracy. Differences of value and chroma are often vaguely lumped together and used interchangeably. The danger in confusing a value difference (rod function) with chroma difference (cone function) is clear. It is evident that even with a correct level of one color dimension, differences in the other two may still prevent a color match.

It appears that "select the best match" is the best and most appropriate color matching method in dentistry (and in the best accordance with physiology of color vision). There is no standard combination or rule for the origin of color differences between tooth and shade tab or restoration.[5] The "dimension by dimension" method can be a subsequent, fine-tuning supplement once color matching using the former method is completed. This includes squinting for orientation about the value. Indeed, color vision can be excluded at scotopic (very low) levels of light, which is hard to achieve without sacrificing other useful visual information. However, a digital image converted to grayscale is a good alternative and can be beneficial for color communication and reproduction. The use of several shade

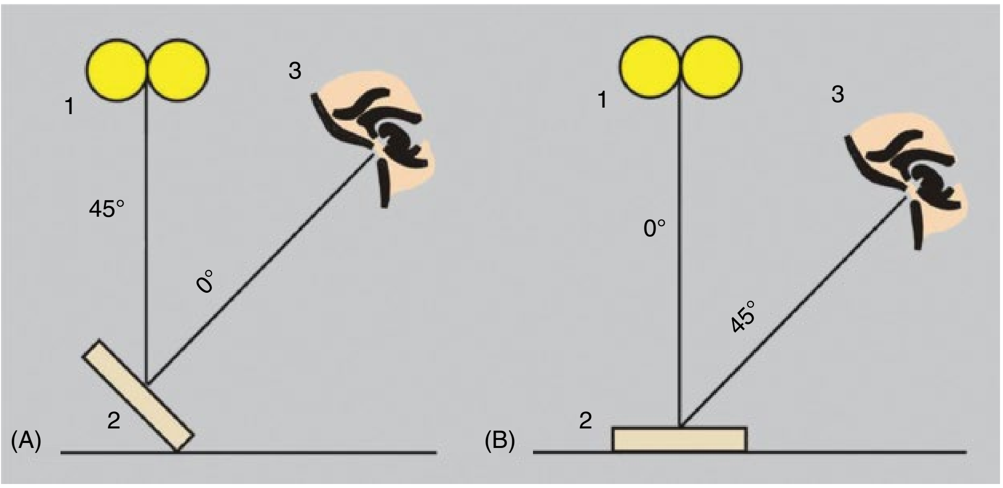

Figure 10.16 Illumination/viewing geometries for work with color in clinical and laboratory: **(A)** 45°/0°, more frequently utilized in clinical shade matching; **(B)** 0°/45°, more frequently utilized in dental laboratory (in both cases 1 = illuminant, 2 = tooth/specimen, and 3 = observer).

guides (and corresponding materials) would expand the choice of shades thereby increasing the likelihood of identifying a good match. The same is true for the use of extended shade guides, with the tabs representing different layers of the restoration.

Color transitions and local color characteristics of a single tooth sometimes dictate selection of more than one shade tab. The success of shade selection can also be enhanced by noting the color of dentin after enamel is removed. Color differences among different teeth of the same patient dictate selection of more than one shade tab for restorations of multiple teeth. Magnification is helpful to discern nuances of shading as well as the presence of any local color characteristics. Such custom color matching and reproduction requires more time, is more demanding of both the ceramist and the dentist, and yields greater satisfaction for everyone.

Other appearance attributes should also be visualized and matched. Translucency, denoting the state between total opacity and transparency, is probably the most important one. Translucency is the opposite of opacity—the higher the former, the lower the latter, and vice versa. Surface roughness and gloss are also of importance and could influence the tooth's appearance. The tab and the tooth should be wet with water in order to neutralize the influence of surface texture differences during color matching. Patients must also be made to understand that although a restoration, a single central incisor in particular, may look good in one lighting environment, it may not in another (metamerism). For this reason, the dentist may wish to select a shade in a specific critical environment.

Myths and facts about visual color matching

The myths related to visual color matching in dentistry and corresponding facts have already been elaborated throughout this section. In order to emphasize them, a summary is given in Table 10.2.

Table 10.2 Top 10 Myths and Facts About Visual Color Matching

	Myth	Fact
1	Dentists are gifted for shade matching because of their ability to differentiate color.	There is no sufficient evidence that dental professionals can differentiate color better than others, but there is evidence that education and training can improve one's color matching skills.
2	Gender and experience influence shade-matching quality.	There is no sufficient evidence of this as far as color-normal individuals are concerned.
3	Northern daylight and huge windows are ideal for color matching.	Daylight is highly variable in color temperature and intensity, while tinted windows further limit this option. A plethora of excellent office/lab lighting is available.
4	One shade guide fits all (our needs).	No. Shade guide should be selected based on the purpose, restoration type, and selection of restorative material.
5	VITA classical value scale should be used for monitoring whitening.	VITA classical is an inferior product for monitoring whitening compared to a new VITA Bleachedguide 3D-Master (highly recommended).
6	"Tooth whitening" accurately describes the effects of bleaching.	Not really. All three color dimensions change upon bleaching: teeth become less chromatic (most pronounced), lighter, and less red (least pronounced). Overall, teeth are becoming less saturated (chroma over lightness ratio).
7	Arms' length is the best shade-matching distance.	Color matching distance should be 25–35 cm.
8	Observe a blue card in between shade-matching trials.	A gray card should be observed in between two color matching trials.
9	Matching one color dimension at a time is the best color matching strategy.	We cannot see color dimensions separately—we see only their interaction. Therefore, we should start by identifying the best color match and then potentially detect and describe differences in individual color dimension.
10	Squint to match value.	Very low levels of light can hardly be achieved without sacrificing other useful visual information. A digital image converted to grayscale may be a good alternative.

Color matching instruments

Dental color matching instruments and systems have potential advantage over visual shade matching due to their objectivity and ability to quantify differences in color and its dimensions compared to the closest match from different shade guides. Although hand-held color matching instruments are accurate and user-friendly, the role of dental professionals is still a decisive one—the more we know about instrument's features and limitations, the more useful they are for color matching, communication, reproduction, and verification. Instrumental and visual color matching methods complement each other and their combined use can lead toward predictable esthetic outcome.[49,50]

Spectrophotometers measure reflectance throughout the visible spectrum.[51] Two such devices will be described here: SpectroShade Micro (MHT Optic Research; Figure 10.17a) and VITA Easyshade V (VITA; Figure 10.17b). Both instruments consist of a cordless handpiece and a base unit.

The SpectroShade Micro is an imaging spectrophotometer that measures the complete tooth surface providing a tooth "color map." It uses a digital camera connected to an LED spectrophotometer, and an internal computer with storage capacity. Its software matches and calculates color differences between the tooth and selected shade tab, providing laboratory

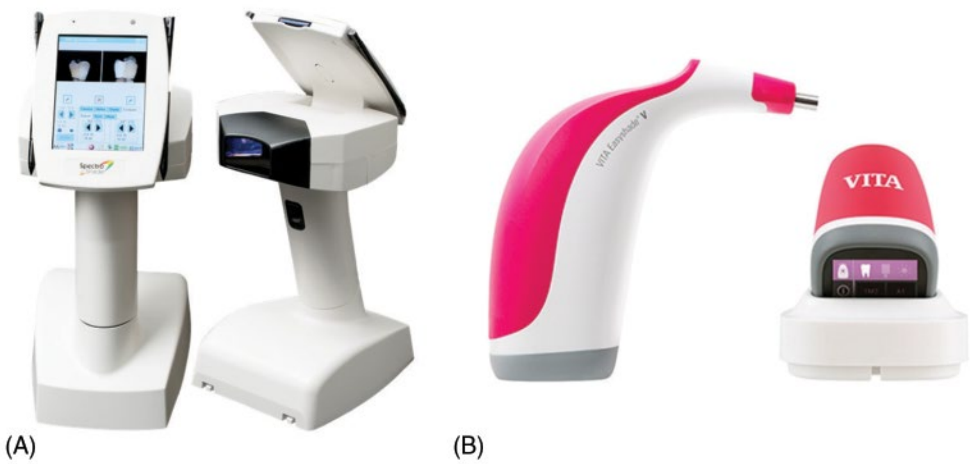

Figure 10.17 Dental color measuring instruments: **(A)** SpectroShade Micro; and **(B)** VITA Easyshade V. Figure courtesy of VITA Zahnfabrik.

information about lightness, chroma, and hue. Tooth positioning guidance system, shown on the LCD screen, enables controlled measurements.[52]

The VITA Easyshade V is the newest-generation spectrophotometer for tooth color matching, communication, reproduction, and verification. The device enables quality measurement through different mechanisms including neural network. Basic tooth shade or color by area, from cervical to incisal/occlusal third, is displayed in VITA classical A1–D4 and VITA System 3D-Master shades. The instrument also indicates adequate shades for computer-aided design/ computer-aided manufacture (CAD/CAM) materials, layered crowns, denture teeth, materials for direct fillings, and veneers. Calculation of bleach shades is an additional unique feature of this device. The Windows-based software VITA Assist and the smartphone application VITA mobileAssist enable Bluetooth communication between office and dental lab and communication with patients. According to some calculations, the savings in color matching costs using the Easyshade exceed $9000 per year compared to visual color matching, which is more than four times the price of the instrument.

Color matching instruments and systems have also generated significant interest from dental researchers. The topics investigated include evaluation of color of natural teeth, gingiva, skin, and various dental materials,[13,53] tooth whitening,[54,55] comparison with visual findings,[56,57] and performance assessment.[58–60] In addition to dental spectrophotometers, colorimeters, digital cameras, and scanners can be used to record color information and provide a detailed image of the tooth surface and useful color mapping.

Communicating color

Color matching and reproduction are complex procedures that can only be simplified by an understanding of the factors involved, and better controls at each step. The dentist and technician need to work together on effective communication, and invoke the controls needed to optimize results. The rewards outweigh the efforts, and the patient benefits as a result. Verbal and written instructions and sketches, modified and custom-made shade guides, and digital images as tools for communication on color and appearance will be described in this section. Traditional photography and slide films have been valuable methods to communicate color and appearance in dentistry in the past. They have been progressively replaced with digital imaging, and presently have only historical importance.

Verbal and written instructions and sketches

Verbal and written communication are the basic methods to communicate information on color and appearance. A detailed diagram or chart of the tooth is a valuable addition to verbal and written instructions and so are sketches of the color zones and variations in translucency. Such sketches do not have to be artistic renderings but should adequately define areas of transition between shades, relative translucency and transparency, and characterizing colors. They should include not only the facial view, but a labiolingual cross-section to indicate the relative thickness of each layer. Such sketches require a narrative describing the meaning of each part of the drawing. Often just making oneself look closely enough at tooth color to attempt to minutely describe it in sketches improves perception of the actual color components.

Modified and custom-made shade guides

When a tooth closely approximates a specific shade tab, but has characterizations or deviations, those variations may be defined and communicated using a shade guide with the glaze removed and a set of dental surface colorants ("stains"). Airborne particle abrasion using aluminum oxide is recommended to remove the glaze although this may also be done using emery discs. The colorant may be applied, and removed or modified until the proper effect is achieved. Once the shade tab closely resembles the tooth to be matched, it should be placed in a vial to avoid smearing, and sent to the laboratory along with a description of the colorants used and the effects desired.

Custom shade guides made of the actual restorative material, especially the ones having an expanded shade range, are another advanced communication tool. Although fabrication of such a guide is time consuming, it provides a more realistic representation of what is achievable. Fabrication of a custom guide for metal ceramic restorations should include a metal backing. In all cases, custom shade guides should be of realistic thickness, achievable with clinical restorations. Guides having varying textures and gloss may also be helpful.

Digital images

Digital imaging is a rapidly evolving field and permits the easy transfer of images from the clinician to the technician through electronic and storage media. Accordingly, the reference digital photography is highly recommended for communication on tooth color.[49] The photos should be taken with selected shade tabs in proper orientation in reference to the tooth. For consistent color communication, camera and light settings and image format must be kept constant. It is beneficial to have photo of the three basic shade tabs representing the respective color in gingival, middle, and incisal third, next to the tooth in question. Photos of two additional reference shade tabs should be included to graduate and calibrate shifts in hue, chroma, and value between physical tabs visually in the laboratory. One of these tabs should be lighter in shade and one darker in shade in respect to the selected basic shades.

The digital image gives a vivid description of the relative translucency, opacity, color zones, and incisal variation. Although the technique requires photographic equipment, the cost of improved shade selection is rapidly offset by avoiding remakes and disappointment. Accurate information on color and appearance obtained through visual and instrumental shade matching combined with standardized reference shade communication photography can ensure a predictable esthetic outcome.[49]

Color modification

Color modifications may be either intrinsic (at the time of fabrication) or extrinsic (surface coloration). Without unnecessarily complicating this explanation, suffice it to say that the principles of modifying a restoration, either intrinsically or extrinsically, involves subtractive color mixing (as one adds color, the resulting color gets darker), and the use of complementary colors (colors of the "opposite" hue). For example, when modifying a completed restoration using surface colorants, the surface color blocks some bands of the spectrum (hues) and the resulting appearance is usually lower in value (less bright).

If the ceramist fabricating the restoration is familiar with the dimensions of color, some of the modifications may be accomplished during fabrication. If not, choosing a shade that is higher in value and lower in chroma will keep the restoration in the proper volume of color space that permits successful modification at the chair side. Of course, the dentist must have the proper materials and equipment to make such modifications, as well as the time and desire to do so. A few simple and relatively inexpensive supplies and pieces of equipment are needed including a selection of colorants for porcelain (usually termed "stains"), high-quality sable brushes, a ceramic or glass mixing surface, and a glazing oven in which to fire the restorations. Any porcelain furnace will suffice. Vacuum or sophisticated circuitry is not needed for glazing, but the unit should have automatic (and accurate) temperature control that will signal to the operator when the desired temperature has been reached.

Porcelain fusing is a result of time and temperature, so a restoration can be taken more rapidly to a higher temperature, or to a lower temperature and held at that temperature longer. Since porcelain is also a product of its thermal history, the type of porcelain and the number of times it has been fired as well as the temperatures used in fabrication will determine the temperature at which the desired maturation will occur. The smoothness and surface gloss must be visually inspected to evaluate the proper glazing temperature.

The choice of materials is optional, but it should evolve through a cooperative effort of the technician and dentist. "Stains" are metallic oxides in a modified porcelain base. Even though most stain kits use the same color names, the actual colors vary widely. Colorants from a number of kits may be used to supply the desired colors. The most useful colors are orange, yellow, violet, gray, and browns of different hues and concentrations, and whites of different translucencies. Violet is useful for neutralizing the basic hue, reducing chroma, and giving the appearance of a more gray (lower value) and translucent appearance of the incisal one-third. Brown plus the dominant hue will lower value, and increase chroma in the cervical portion. Yellow and orange are helpful in hue changes. White, gray, orange, and brown may all be used in characterizing.

There is no question that intrinsically building color in a tooth produces a superior restoration and is the preferred technique. Surface modifications should be reserved for minor changes to improve the initial results. This section is not intended as an extensive treatise on the technique of surface coloring but rather to point out the principles involved.

Color-related properties of dental materials

Esthetic dental materials have undergone amazing improvements related to optical properties during the last decade. Materials are now available that exhibit satisfactory color compatibility, good color stability, and color interactions that could reduce color mismatch, such as blending and layering (Table 10.3).[6]

Table 10.3 Color-Related Properties of Dental Materials

Property	Subdivision
Color compatibility	With natural teeth;[13] among restorative materials[61,62]
Color stability	During fabrication/at placement: firing/polymerization/other types of setting[63,64]; after placement: aging, staining[65]
Color interactions	Layering[66–68]; blending (chameleon effect)[69,70]

The material selection is an important component for the esthetic outcome. The "same hand, different outcome" results based solely on material selection is common in dentistry. Frequent updates from professional publications and other sources listed in the following section on color education and training can reduce this problem.

Color education and training

A clear conclusion on the importance of color education and training in dentistry can be drawn based on the statement of Sproull: "The technology of color is not a simple matter that can be learned without study neither is it a complicated matter beyond the comprehension of dentists."[7] Research on this topics and current publications and programs will be presented in this section.

Surveys

The first survey on education on color in dentistry was performed in 1967. Only three out of 115 institutions that responded had a color science course, with an average of 2.3 classes.[7] The results of the second survey were published in 1990. A total of 69 dental schools responded: courses on color were taught at 26% schools in core curriculum and at 17% as an elective course.[48] A survey from 1992 reported on 138 responses with an average of 6.6 hours on color-related topics.[71] Finally, the most recent survey, published in 2010, reported on teaching of color at 130 institutions. A course on "color" or "color in dentistry" was included in 80% of predoctoral and 82% of postdoctoral programs, with an average of 4.0 and 5.5 hours, respectively.[15]

The substantial increase of interest in color in dentistry is followed by the increase in number and variety of publications and programs. A Medline search using the keywords "color" and "dentistry" and limited to the time of the first survey (1967) returned fewer than 50 papers. On the other hand, more than 6500 papers were listed when the search was performed without the time limitation (at the time this chapter was prepared).

Current publications and programs

It has already been noted that many changes have occurred since the times of the first survey on color in dentistry. This includes the changes in color research, education, and training resources compared to the times and pioneer work of Sproull, Bergen, Preston, and Miller.[7,11,19,29–31,40,72] Currently available specialized resources are listed in Table 10.4.

Table 10.4 Currently Available Specialized Resources for Color Education and Training

Resource (Publisher)	Format and Features
Color in Dentistry – A Clinical Guide to Predictable Esthetics (Quintessence Publishing)[73]	Clinically oriented textbook, appropriate for students, general practitioners, and specialists. Content: basics of color theory, followed by chapters on conventional and technology-based shade matching, digital photography, material selection, predictable color reproduction, and clinical cases
Esthetic Color Training in Dentistry (Elsevier)[5]	Research-oriented textbook with color training program on CD-ROM
Society for Color and Appearance in Dentistry, SCAD (www.scadent.org)	Professional group that promotes interdisciplinary collaboration and discovery among researchers, clinicians, and laboratory technicians, and relevant educational and training programs for dental professionals and students
Special Issues on Color and Appearance in Dentistry (Wiley Blackwell)	Peer reviewed journal, a permanent semi-annual issue of *Journal of Esthetic and Restorative Dentistry*
Dental Color Matcher, DCM (SCAD; VITA Zahnfabrik)[6]	Free online educational and training program for esthetic dentistry, www.scadent.org
Dentistry – Guidance on Color Measurement (ISO/TR 28642)[12]	Terms and definitions, visual and instrumental color assessment, qualification of observers, testing and interpretation of acceptability and perceptibility thresholds, reporting of color and color difference measurements
Color and Shade Selection for Prosthodontics (American College of Prosthodontists)[4]	Educational DVD; figures and instructional videos complement the text
Toothguide Trainer, TT and Toothguide Training Box, TTB (VITA Zahnfabrik)[74]	Color training program, software (TT), and physical shade tabs (TTB)

Adapted from reference 73.

The specialized publications and programs should be combined with nonspecialized resources such as Medline, clinical and research journals, meeting proceedings, and independent evaluation sources (US Air Force Dental Evaluation & Consultation Service, Dental Advisor, Clinicians Report, Reality Publishing, and similar).

Dental Color Matcher (DCM) is a free online color education and training program for esthetic dentistry, hosted through the SCAD website (www.scadent.org). This program is also available as a CD (Figure 10.18). The DCM is in essence a computer game and it consists of several different interactive color matching exercises: there are closest match (there in no exact match), exact match, and match the pairs exercises (Figures 10.19 and 10.20). VITA Linearguide 3D-Master is used in all exercises in the fashion described in the section on tooth shade guides (step 1: select the group from the dark gray holder; step 2: select the best match using corresponding light gray holder/s). Six different achromatic backgrounds are available for shade matching. In the exact and best match exercises, tabs are placed over the image of the upper edentulous jaw. Users can place up to two tabs next to the target tab (one on each side), and hide everything except

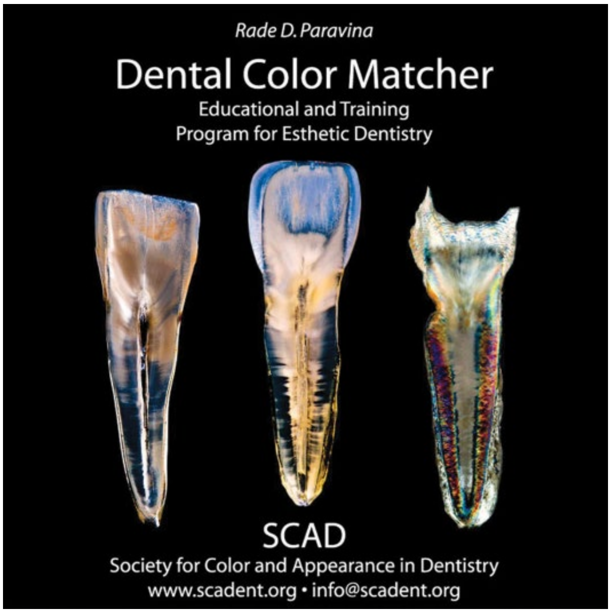

Figure 10.18 Dental Color Matcher, a color education and training program for esthetic dentistry: CD cover (also available online at www.scadent.org).

the immediate working area if distracted. In the "matching pairs" exercises, users are asked to separately match 15 lighter pairs and 14 darker pairs of Linearguide tabs. Breaks (light gray screen) are available during and in between all color matching exercises. A 20-minute didactic video addresses color matching conditions, tools, and techniques, while a 12-question quiz brings additional competitiveness. A diploma and two continuing education hours are available upon the program completion. DCM has had thousands of registered users from more than 100 countries since its September 2010 release.

Bottom line: education and training

Perceiving and analyzing color is a skill that can be taught, and one that can be improved with practice. Significant advances have occurred in color education and training resources in dentistry. Regardless of the differences, all mentioned resources have the same intention—to educate dental students and professionals on color and appearance in dentistry. Resources are available, now it is up to us to implement the philosophy of Thomas Jefferson, third president of the United States: "I'm a great believer in luck, and I find the harder I work the more I have of it". Indeed, we can't afford to have an undeveloped potential.

Figure 10.19 Dental Color Matcher, select the best match exercise: after selecting the Linearguide group in step 1 (group 2 tab is circled in red in a dark gray holder, upper right corner), optional matches have been selected in step 2 (select within the corresponding group); the first choice (2 L2.5) is on the left (circled in red in a light gray holder underneath the dark gray holder), the target tab is in the middle, while the second choice (2R2.5) is on the right; a variety of achromatic backgrounds is shown.

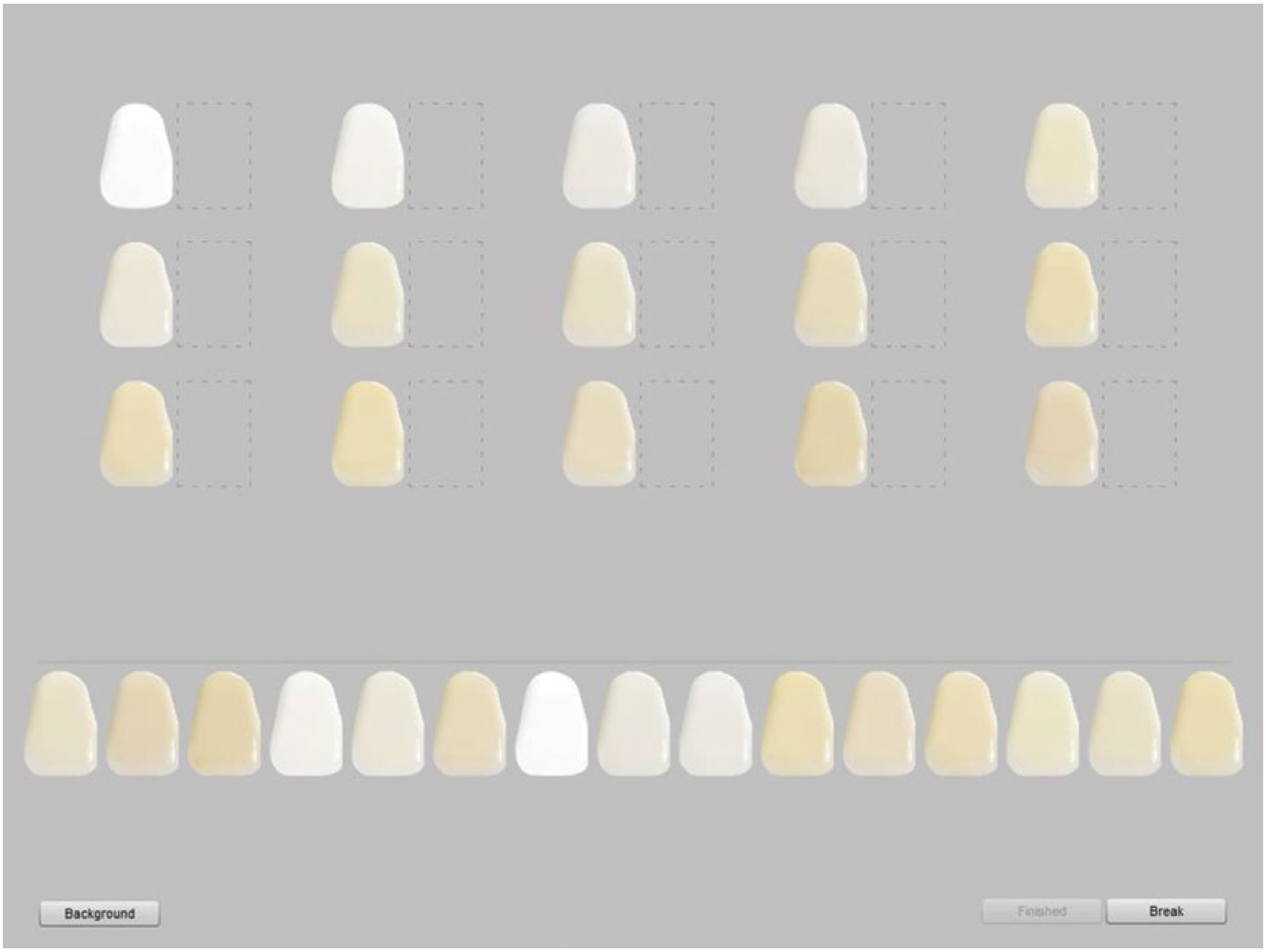

Figure 10.20 Dental Color Matcher, match the pairs exercise (light pairs): each of 15 tabs from the bottom row need to be arranged (using the drag-and-drop technique) next to the corresponding tab in the upper three rows.

Case study: Class IV restoration by Newton Fahl, Jr, DDS

This book details various aspects of esthetics dentistry and elaborates the most advanced materials and techniques for achieving the predictable success. The following case study demonstrates the ultimate synergy between art and science in reproduction of color and appearance. The technique used and thinking outside the box added an additional flavor and resulted in a superb esthetics.

Figure 10.A1 A defective Class IV restoration is present on the left central incisor and needs replacement.

Figure 10.A2 Shades are selected for the composite resins to be used and are layered to form a color mock‐up tab according to the precise thickness and contour of each layer.

Figure 10.A3 The associated shades are compared to the natural tooth used as a color reference and aspects such as opacity, chroma, hue, value, and opalescence are ascertained. At this stage, the operator decides on changes in material selection and thickness of each layer to be implemented during the final restorative steps.

Figure 10.A4 Tooth preparation is carried out by placement of a 2.5 mm long bevel on the facial aspect and a small chamfer on the palatal aspect. The long, thick, and infinity-line bevel provides for generating a smooth optical gradient from tooth to synthetic materials after completion of the restoration.

Figure 10.A5 From a wax-up model or an intra-oral mock-up, a silicone matrix is made to be used as a three-dimensional reference for the establishment of palatal contours and, most importantly, the incisal edge position.

Figure 10.A6 A milky-white semi-translucent layer of composite is applied to the silicone matrix and sculpted to conform to the shape of a "lingual shelf." This layer should be approximately 0.3 mm in thickness but the incisal halo can be made slightly thicker to impart a more marked opalescent amberish-white appearance. Light curing is carried out and the silicone matrix is removed. For the application of the subsequent layers, there is no need for the use of the matrix because the three-dimensional landmarks are already established with this layer.

Figure 10.A7 A dentin composite resin of a chroma one tone higher than the intended final chroma is applied and contoured to mimic the histological boundaries of a natural tooth. The exception to this is present at the bevel area, where the artificial dentin should cover the beveled enamel about half of its width. The key element at this stage is to be able to fully conceal the fracture line with the dentin composite, which aids in determining a seamless transition between tooth and composite. At this stage, dentin mamelons are sculpted with a fine-tipped instrument to replicate the morphology of those of the contralateral tooth. This layer is light cured.

Figure 10.A8 An effect translucent enamel bearing opalescent properties is applied in between and around the mamelons, slightly covering them. By virtue of its chemical composition, the composite resin selected for this layer should reflect bluish wavelengths and transmit amber wavelengths of light. The amount of inner opalescent effect achieved is directly related to the thickness of this layer, which should be used sparingly so as not to overemphasize the bluishness nuance.

Figure 10.A10 A final layer of a non-VITA classical-based (achromatic) enamel is applied over the incisal one-third and thinly feathered over the VITA classical-based enamel. This enamel is also called value enamel, as it can corroborate or modulate the tooth value to the higher or to the lower, depending on the effect that is intended. A more translucent enamel of lower value allows more light transmission and thus a more obvious halo, opalescent, and dentin mamelon effect is perceived. If it is more opacious and, therefore, higher in value, a whitish appearance is achieved over the incisal one-third and less of the underlying effects are observed. As with any layer of composite, the modulating properties of this layer are directly dependent on thickness and opacity.

Figure 10.A9 A VITA classical-based (chromatic) enamel composite resin of the final intended hue, chroma, and value is applied beyond the bevel finish line and brought to almost final facial contour. A cut-back is realized along the incisal one-third to permit a greater degree of light transmission and to capture the details of the underlying dentin and enamel layers. This chromatic enamel layer brings both tooth and restoration into perfect color harmony. As the thickness of this enamel layer is thin and varies according to the areas over which it is applied based on the amount of chroma that is desired, a correct assessment of its blending properties is mandatory to ensure an ideal optical and color integration.

Figure 10.A11 The restoration is finished to primary anatomy, followed by sequential steps leading to secondary and tertiary anatomy placement. After final polishing with rotary instruments and polishing pastes, the surface gloss mimics that of the natural enamel.

Figure 10.A12 Following complete rehydration, a few days later, the restoration depicts a harmonious form and color integration with the natural tooth tissues.

Figure 10.A13 Transmitted light shows the inner histological morphology and optical differences between artificial dentin and enamel. Composite resins with optical properties similar to the natural enamel show identical properties when compared to the natural dentition.

Figure 10.A14 The greatest challenge of the direct restorative dentist is to achieve seamless restorations. When selected according to a strict protocol, composite resins can emulate the natural dentition in all of its morphological, physical, color, and optical properties.

A look to the future

It is always risky to predict the future. However, chances are good that progress will occur in undergraduate and graduate education and training of dental students and professionals on color and appearance. This will likely be complemented by new technologies including the affordable, high-quality color matching instruments. Further improvements are expected from dental materials: new, improved shade guides and color-stable materials that correspond to the color of human teeth and exhibit pronounced blending will be a step in the same direction.

Cooperation between educators, practitioners, technicians, and manufacturers can lead to solutions to the color problem in dentistry. The combination of science, education, and training will allow objective color matching, communication, reproduction, and verification to become a routine part of dental education and practice. The acquired knowledge and skills should facilitate not only improved results but the enjoyment of accomplishing the difficult task of replicating natural beauty, with patients being the ultimate benefactors.

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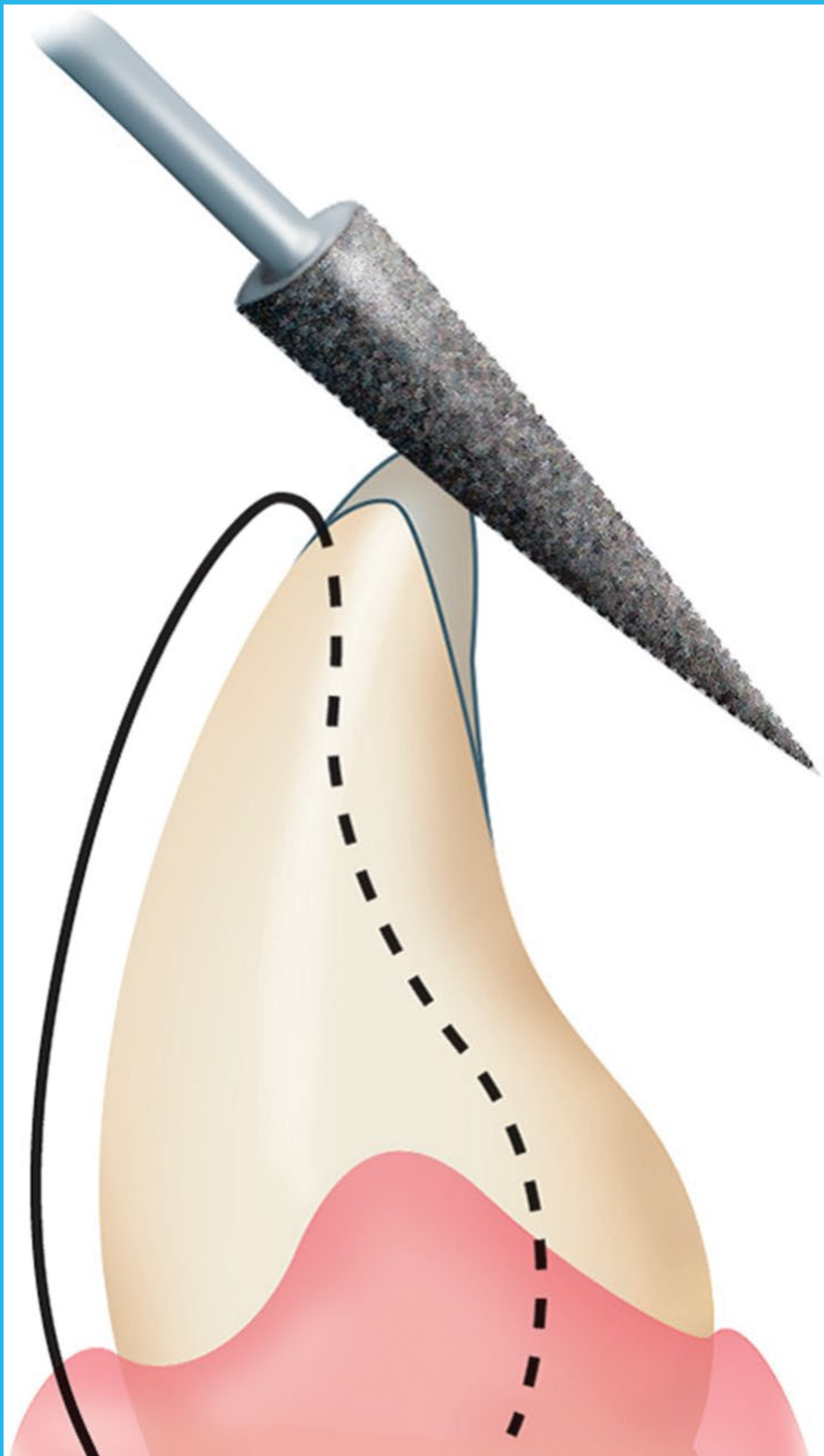
PART 2
ESTHETIC TREATMENTS



Chapter 11 Cosmetic Contouring

Ronald E. Goldstein, DDS

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Cosmetic contouring is the reshaping of the natural teeth to create an illusion of straightness for esthetic purposes. Such reshaping does not merely consist of filing and leveling the incisal edges—it involves shaping the mesial, distal, labial, and lingual surfaces as well. It is necessary to have a good concept of the original tooth anatomy and how that structure can be recarved into the teeth—only improved.

Early techniques

Cosmetic contouring is one of the oldest of all the esthetic procedures known, because as long as humans have had teeth, we have had tooth fractures. Since the file was an instrument known to early humans, it is easy to understand that the sharp edges on fractured teeth would be filed to a smoother surface

Ronald E. Goldstein's Esthetics in Dentistry, Third Edition. Edited by Ronald E. Goldstein, Stephen J. Chu, Ernesto A. Lee, and Christian F.J. Stappert.

Figure 11.1 **(A)** This 2000-year-old Mayan skull bears evidence of how early civilizations used cosmetic contouring for cosmetic and possibly functional purposes.

Figure 11.1 **(B)** In Bali, it is the custom for young women to undergo filing of their labioincisal enamel at puberty to make the edges appear even.

and that people in some cultures filed teeth merely to beautify them. A 2000-year-old Mayan skull shows teeth contoured into points for cosmetic purposes (Figure 11.1A). In fact, the ornamental use of jadeite inlays in anterior teeth and other decorative treatments is further evidence of ancient cosmetic tooth contouring. In Bali, it has been a custom for young women to undergo filing of the labioincisal enamel at puberty to make the edges of the teeth appear even (Figure 11.1B). This shortening of the anterior teeth is said to be necessary for eventual cremation and was thought to be a factor in assuring the normal growth and development of the child. Central African Wawira men point their teeth for esthetic reasons only. A man who does not do so may be unable to find a woman in the tribe who would want to marry him.

In our society, cosmetic contouring has become one of the major esthetic treatments and happens to be one of the most economical as well. Nevertheless, the public at large still is not aware of just how much the technique can help improve almost everyone's smile. For instance, in a landmark 2-year study performed on 60 beauty contestants, cosmetic contouring was strongly indicated in 40% of cases and almost all the rest of the contestants could have been helped through contouring as a compromise to more extensive treatment.[1] Cosmetic reshaping provides an excellent compromise in many situations when other procedures are prohibitively expensive. It is always better to offer a suggested treatment for less-than-ideal esthetic improvement than to tell the patient nothing can be done except veneers, crowning, or treatment that is considered ideal. If crowning is the ultimate answer but cosmetic reshaping could improve the appearance somewhat, there is no reason why crowning cannot be done later if the patient so decides. Finally, cosmetic contouring is one of the most valuable of all esthetic procedures because, in addition to esthetic benefits, function frequently is improved. Reshaping and polishing malposed teeth can make them more self-cleansing and even reduce the likelihood of chipping or fracture, especially in lower incisors.

Perhaps most importantly, cosmetic contouring is one of the dental treatments most appreciated by patients. As Pincus declared, "One must always keep in mind that one is dealing with organs which can change an individual's entire visual personality. Few things will cause a patient to enthuse as much as the results which may be obtained by a little rounding of very long sharp cusps, creating a 'softer' more rounded effect instead of the harsh angular appearance."[2] And as Shelby said, "In every restoration, contouring the teeth may lend that esthetic extra that creates life and character."[3]

Indications

Cosmetic contouring has a number of other advantages over other more involved esthetic procedures. Other than bleaching, it is perhaps the most inexpensive cosmetic treatment. It is a rapid procedure that gives immediate and long-lasting results. It is painless and therefore requires no anesthetic. Cosmetic contouring is indicated for the following purposes.

Alterations of tooth structure

The most frequent use of cosmetic contouring is in the reshaping of fractured, chipped, extruded (Figure 11.2A), or overlapped teeth to give them a more pleasing appearance. Reshaping and repolishing chipped incisal edges also decreases the chance of additional fracturing (Figure 11.2B).

Correction of developmental abnormalities

Often teeth that are malformed can be reshaped to correct unattractive areas at the incisal edges, such as nonfused mamelons (Figure 11.3A–C).

Substitute for crowning

Cosmetic contouring can sometimes be a substitute for bonding, veneering, or crowning anterior teeth. Too often the dentist,

Figure 11.2 (A) This 35-year-old night club manager wanted a better-looking smile.

Figure 11.2 (B) It only required one cosmetic contouring procedure to produce a more pleasing smile.

Figure 11.3 (A) This 33-year-old female had complained about the jagged appearance of her front teeth. Clinical examination revealed maxillary central incisors with nonfused mamelons. The mandibular incisors were slightly overlapped and distolingually inclined.

Figure 11.3 (B) The maxillary central incisors were cosmetically contoured to eliminate the spaces caused by the prominent mamelons and to reduce the amount of distolabial overlap of the mandibular central incisors.

Figure 11.3 (C) The post-treatment smile reveals more symmetrically balanced maxillary and mandibular incisal edges. Note the right central incisor could be made to look more esthetic by bonding the distoincisal corner. However, the patient was completely satisfied with the esthetic result of contouring.

in an attempt to improve the patient's appearance, will think only of more invasive procedures, sacrificing tooth structure that might have been merely recontoured.

Minor orthodontic problems

Cosmetic contouring is a recommended treatment in patients with slightly crowded anterior teeth that are not sufficiently maloccluded to warrant orthodontic intervention. These teeth usually can be reshaped to create an illusion of straightness. Extruded teeth in Class II cases can be reshaped to appear more esthetic. Cosmetic contouring may be used after orthodontic treatment to obtain an even better esthetic result.

Removal of stains and other discolorations

Reshaping can cause light to be deflected at different angles and effectively "remove" a superficial hypocalcified area or make a stain appear lighter in certain cases (Figure 11.4A–C). If contouring and polishing are not successful, microabrasion may remove the stain, or a bonded restoration can effectively mask the stain.

Periodontal problems

Coronal recontouring is definitely indicated in cases where destructive occlusal forces have injured the periodontium. If significant evidence of injury such as tooth mobility, migration, or bone loss exists, the specific interferences should be found and eliminated. The usual specific problems that can be addressed by contouring include uneven incisal levels, overlapping, rotation, supraeruption, and insufficient horizontal overlap.

Bruxism

Bruxism can make the anterior teeth wear evenly across the front, producing sharp angular edges, which may be considered masculine. The teeth can be reshaped by rounding the corners to make the lateral and central incisors look more feminine, especially where the incisal embrasures have been obliterated by wear. Excessive grinding can also wear the incisal edges of the central incisors creating interincisal distance but wearing central and laterals. This wear can age the smile especially when the cuspid tips are worn flat as well. The following case illustrates how cosmetic contouring can improve the appearance of a patient with excessively uniform teeth caused by bruxism.

Figure 11.4 **(A)** This 13-year-old girl avoided smiling due to the hypocalcified areas on her teeth.

Figure 11.4 **(B)** A 6 mm 30-blade carbide bur (ET6UF Brasseler USA) was used to gently but effectively remove most of the hypocalcified areas.

Figure 11.4 **(C)** A much improved smile was achieved through cosmetic contouring, which helped greatly to improve not only this young lady's smile but also her self-image and confidence.

Clinical case: Excessive uniformity of the maxillary incisors caused by bruxism

There are few habits that can cause so much tooth damage as unconscious grinding of the teeth. Bruxism is a major culprit that can ruin a beautiful smile. The shapes of both cuspid tips and incisal embrasures contribute to nature of the smile. It is unfortunate that more hygienists and dentists who constantly examine the same patient multiple times during each year fail to diagnose the obvious signs of grinding before severe wear occurs. Hygienists need to be trained to alert the dentist and patient about cuspal and incisal wear, so appropriate action can be taken to prevent further tooth loss. However, cosmetic contouring can many times help to restore tooth shapes and improve the smile.

A female model presented with excessive uniformity of the maxillary incisors and extrusion and crowding of the left lower anterior, which caused the lip to be shifted slightly to the right (Figure 11.5A). Cosmetic contouring of the maxillary and mandibular incisors was performed by reopening the incisal embrasures and varying the length of the incisal edges. The importance of feminine or masculine reshaping of the anterior teeth should be remembered when contouring in these cases. The result was a more attractive smile created with minimal effort (Figure 11.5B). To prevent additional, future damage, it is often necessary to correct the underlying problem of bruxism, and a night guard may well be indicated.

Figure 11.5 **(A)** This 23-year-old female presented with anterior edges worn flat due to bruxism which gave her a more masculine smile.

Figure 11.5 **(B)** A younger, more feminine, and attractive smile was accomplished with cosmetic contouring of the maxillary and mandibular incisors.

Contraindications

Cosmetic contouring cannot change the position of the teeth, and the position of the teeth may limit the amount of tooth structure that can be removed. Furthermore, the patient's occlusion may limit the amount of cosmetic treatment achievable. The following sections include the contraindications to cosmetic contouring.

Hypersensitive teeth

If a patient, usually a child or adolescent, complains that the tooth is sensitive, it is better to defer cosmetic contouring until the tooth becomes or can be made less sensitive. The patient should be encouraged to have orthodontic treatment to correct even minor crowding since there is a chance the tooth may remain sensitive for most of the patient's life. If you must contour a sensitive incisal edge, use a coarse diamond (AC2, Brasseler USA), which tends to create less heat as it cuts.

Large pulp canals

Young people with extremely large pulp chambers and pulp canals may be poor candidates for cosmetic contouring (Figure 11.6) because of possible discomfort during the procedure and sensitivity afterward. If contouring is absolutely necessary, the teeth can be desensitized but it is advisable to do as little contouring as possible in such cases. It may even be necessary to administer a local anesthetic. If crowding is the problem, orthodontic treatment may be the best option.

Figure 11.6 Due to the large pulp canals, sensitivity could be a problem for this 24-year-old student if extensive cosmetic contouring were performed.

Thin enamel

Cosmetic contouring should be avoided in patients with overlapping incisors where proximal reduction might create translucency or expose dentin. Excessive removal of enamel from the labial surface of the incisors may result in the darker yellow dentin beneath showing through, creating an unesthetic problem. Excessive thinning at the mesio- and distoincisal corners of teeth that already have thin enamel may lead to future fracture. Teeth with thin enamel on the mesiolabial, distolabial, or incisolabial surfaces as the result of erosion, attrition, or abrasion should not usually be considered for cosmetic contouring. If, however, these teeth are in bucco- or linguoversion, it is sometimes possible to contour the linguoincisal or labioincisal to make them blend in and look straighter. It is important to preserve all possible enamel on the labioincisal and linguoincisal so that the tooth can resist further wear. In the final analysis, it is a value judgment based on experience of the dentist and the patient's goals for the esthetic treatment. A combination of conservative cosmetic contouring and bonding or veneering may be indicated.

Deeply pigmented stains

Hypocalcifications or stains that would require extensive reduction to eliminate or lighten should be treated by restorative procedures. Otherwise, the enamel may be too thin and the dentin may become more visible. In this situation, minor cosmetic contouring may be tried and, if it is unsatisfactory, microabrasion, bonding, or veneering should be considered. If there are doubts as to the thickness of the stain, be sure to let your patient know in advance that additional treatment may be necessary to completely eliminate the stain.

Occlusal interferences

Centric occlusion and lateral and protrusive excursions should always be checked before the treatment. Cosmetic contouring is contraindicated if it might create an occlusal disharmony, for example eliminating a cuspid rise, thus changing the occlusal relationships.

Periodontal involvement

In many cases the teeth may need to be orthodontically repositioned to make them easier to clean. There should never be any doubt that orthodontics would be the ideal treatment to achieve the best functional and esthetic result. In fact, by reshaping the incisal edges, cosmetic contouring might only postpone ideal treatment. For the most part, cosmetic contouring is usually a compromise treatment and should be explained as such to the patient and documented in the chart. Nevertheless, for the patient who will not consider orthodontic treatment, there may be considerable benefit to a compromise treatment of cosmetic contouring. Certainly, by making the teeth easier to clean and eliminating some food traps, the teeth will look better and the patient will feel better about his or her appearance. Thus, the patient will be more apt to take better care of the teeth and gums (Figure 11.7A–D).

Susceptibility to caries

As the enamel is made thinner a tooth could be more susceptible to caries. In situations of crowded teeth, however, this is partially offset because the now less-crowded teeth are easier to clean. In all cases the tooth must be repolished and treated with fluoride postoperatively.

Negative psychological reactions

Certain patients may be subconsciously afraid to look better. Cosmetic contouring can alter a person's smile, so the patient should be forewarned of the change in appearance. Occasionally, the spouse may be the concerned individual. Therefore, show the patient and spouse, if necessary, how the appearance will change by first doing esthetic imaging, or use a black alcohol marker to show your patient exactly where and how much reshaping you are intending to do. This step will help to create an illusion of how the final result will appear. When you give your patients a full-face mirror to visualize the result, make sure the mirror is held at arm's length. Also consider taking a full-face digital smile photo to compare the before smile with the intended treatment smile.

Figure 11.7 **(A and B)** This executive assistant was unhappy with her crooked, worn, and chipped teeth.

Figure 11.7 **(C and D)** Although orthodontic treatment would have been an ideal option, she chose cosmetic contouring.

Large anterior restorations

Large composite or other anterior restorations may limit the amount of contouring that can be done. When too much enamel is reduced, the remaining tooth structure may be weakened and eventually fracture.

Extensive anterior crowding or occlusal disharmony

Although cosmetic contouring can usually help improve the appearance of crowded anterior teeth, if there is severe crowding it may accomplish so little that it should not be attempted. In these situations, the patient should be strongly advised to undergo corrective orthodontic treatment. This also applies to those instances when there is extreme functional impairment in the dentition. Cosmetic contouring is never a substitute for definitive or complete occlusal adjustment or functional repositioning of misaligned teeth.

Principles of cosmetic contouring

Proportion

Dentists who perform cosmetic contouring must give foremost attention to the tooth proportion (see Chapter 9). Whether or not a tooth or other structure conforms to the golden proportion is best evaluated by visualizing the silhouette form of a tooth or an arch. The silhouette form is the shape of a tooth as defined by the outline of the tooth, and this, even more than color, governs what most people perceive as either attractive or unattractive. The outline of the tooth is usually determined by the portion of the tooth within the mesiolabial and distolabial line angles. This area defines the perception of how big, long, or short a tooth is. Total perception is gained not only by looking at the tooth but also by looking at the smile and at the entire face. It involves first focusing on the tooth and how the teeth relate to each other and then stepping back and visualizing the smile and its relation to the face and seeing what, if anything, can be done to improve the overall appearance. Opening or closing an incisal embrasure may make a difference. The silhouette form of a tooth that is out of proportion can be altered by adjusting the location and curvature of the mesiolabial or distolabial line angles. But a distoincisal line angle that is needed to preserve the proportion should not be curved. Care must be taken to also understand the effect on the illusion created by light reflection (see Chapter 8).

Gender differences

The assumption of gender differences in tooth form was introduced in the 1950s by Frush and Fisher in their series on full denture esthetics.[4–9] They said that the feminine tooth has more curves whereas the masculine tooth is more angular and boldly textured. However, according to Abrams there is no anthropologic basis for this claim. In 1981, Abrams conducted a survey at the American Academy of Esthetic Dentistry's annual meeting. He showed images of teeth from 60 patients from right, left, and center views with the lips blocked out so that the audience could not see whether the person was male or female. The 150 dentists who participated in the test were given 5 s to determine whether each person was a male or female and their degree of certainty. Only one participant guessed correctly more than 50% of the time. This study showed that dentists have prejudices about what is masculine and feminine, but according to Abrams these prejudices are not substantiated by the facts. In your clinical practice, however, you should be aware that rounding teeth can soften the appearance and making the mesioincisal and distoincisal line angles more angular can give a harder, more aggressive look. You should consider these appearances as descriptive rather than gender-specific.

Occlusion

Cosmetic contouring must always be done with the principles of proper occlusion in mind. Nothing should be added or eliminated that will produce occlusal disharmonies. Occasionally, the factors that produce poor esthetics are also responsible for the malocclusion, and an esthetic improvement may correct both. Simring et al. reviewed a series of occlusal considerations for anterior teeth.[10,11] Ideally, in mandibular anterior teeth a series of thin, symmetrical incisal edge contacts exist that produce vertical forces that are contained within the area of periodontal support.

When establishing a new incisal level for mandibular anterior teeth through contouring, consideration should be given to the following.

- Establish an incisal level that permits optimum contact without producing occlusal trauma. An uneven incisal level and a labiolingual curve produced by crowded teeth not only create problems in esthetics but also create occlusal trauma.
- Establish symmetrical incisal edge contacts, and when that is not possible, labial contacts should be created that are positioned as far incisally as possible.

In maxillary anterior teeth, the objectives for centric and protrusive positions and excursions are as follows.

- To reduce destructive forces occurring in these positions.
- To produce optimum contact and to eliminate deflecting contacts. Optimum contact is contact of the greatest possible number of teeth without poor esthetics or undesirable occlusion. Since the optimum mandibular incisal level should be established first, all additional grinding to obtain these objectives should be done on the maxillary teeth. Sometimes there will be a conflict between the amount of reduction that gives optimal function and the amount that gives optimal esthetics. The decision will have to be based on the degree of occlusal dysfunction that will remain, the esthetic importance, and the ultimate health of the dental organ.

Treatment planning

Cosmetic contouring is one treatment that should be considered in almost every patient's overall treatment plan. When deciding whether to bond, veneer, or crown, ask yourself the question: "Can cosmetic contouring help me to achieve a more successful esthetic result?" Four methods are useful in answering this question:

1. esthetic imaging
2. diagnostic study casts
3. intraoral marking
4. radiographs.

Esthetic imaging

One of the best ways to show your patient how cosmetic contouring can improve his or her smile is with esthetic imaging (Figure 11.8). The technique accomplishes two purposes: first, it serves as a good method for patient communication and, second, it can be invaluable in letting you know exactly how much tooth alteration is necessary to achieve the best result. Even if patients can appreciate basic principles of tooth alteration, it is almost impossible for the average patient to visualize the tooth changes you plan through cosmetic contouring, or how the new tooth shapes will affect the smile and the face. This can also be the quickest method of determining if cosmetic contouring will suffice or if an alternative treatment should be chosen (Figure 11.9A–C).

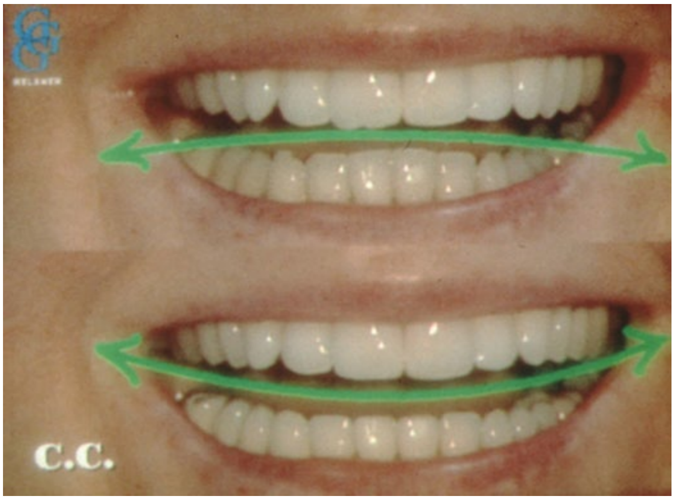

Figure 11.8 Computer imaging is the best method to show your patients how cosmetic contouring can improve their smiles. It can also show you just how much tooth alteration you will need to do to achieve the best result.

Diagnostic study casts

Take impressions of both arches and pour a duplicate set of models. Analyze where and how tooth structure will have to be altered and perform the proposed treatment on the patient's duplicate study models (Figure 11.10). By practicing this way, the end result will be more predictable. In addition, the patient also can more easily visualize what the final result will be, and it gives you an exact record of what the teeth were like before they were reshaped. Finally, it will give you a good idea of where and just how much tooth structure you will have to contour to achieve the result you envision.

Intraoral marking

A third method of predetermining the effect of cosmetic contouring, which was previously mentioned, is to block out the tooth surfaces that will be contoured with a black alcohol marker. Dry the teeth with your air syringe and mark the visible overlapping tooth surfaces. Have your patient hold a mirror at arm's length or have the patient stand before a large mirror to see the effect of the new silhouette form. If the patient wears glasses, ask him or her to remove them for a more realistic view of the proposed silhouette form.

Radiographs

Radiographs, particularly of the anterior teeth, should be examined for thickness of the enamel as well as for the size and shape of the pulp. This is the best way to predict potential sensitivity and to give an indication of how much enamel you will safely be able to remove.

Figure 11.9 **(A)** This 30-year-old woman wanted straighter teeth without orthodontic treatment. Note the uneven appearance of the mandibular incisors.

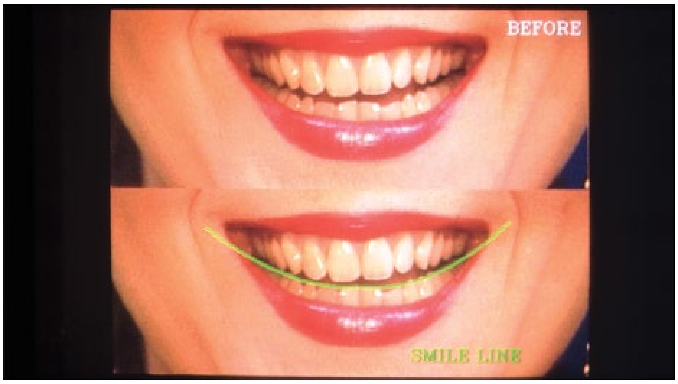

Figure 11.9 **(B)** By selecting an imaginary lower arc which mimics the lower lipline, it is possible to create an illusion of straightness, especially in the lower anterior area.

Figure 11.9 **(C)** Cosmetic contouring provides the illusion of straightness the patient desires.

Techniques of cosmetic contouring

Achievement of illusions

The purpose of planning is to determine how to achieve an illusion of straightness. This process must include different views and perspectives (Figure 11.11A–C). An optical illusion should work most effectively in the position from which most people will be viewing the patient, and you need to view the illusion from that standpoint first (see Figure 11.11C). The easiest way to determine if cosmetic contouring can obtain the result you want is to use computer imaging to record the way more people will view your patient. Draw an imaginary line to simulate the arc you wish to create by contouring (see Figure 11.11C). Most contour planning should be done by marking the teeth with a black marker when the patient is sitting. However, the patient should also stand with you sitting, and then both the patient and you should stand. Each time, the areas to be contoured should be dried and marked with a black alcohol marker. Areas to avoid cutting, such as a holding cusp in the cuspid areas, may be distinguished with a red alcohol marker. The patient should have an opportunity to visualize the planned reshaping or contouring with a mirror. Many times the patient will see something that you may not have observed.

Angle of correction

A lower incisor that actually or apparently extends above the lower incisal plane can be quite noticeable. The angle of view is important, especially in shaping a lower tooth. Owing to the relative positions of the eyes and mouth, most people look down at the lower arch. This is why, because of the angle of view, an anterior tooth that is in linguoversion appears to be much more prominent than the one in labioversion. To contour the tooth in linguoversion, its incisal edge should be beveled lingually (Figure 11.11D). Figure 11.11E shows the position of the

Figure 11.10 Before and after study models aid in treatment planning of cosmetic contouring. This helps both the dentist and the patient to better visualize the anticipated result.

Figure 11.11 **(A)** This patient desired straighter-looking lower teeth. Although the teeth appeared to be even from a horizontal aspect, a more normal speaking position revealed lingually locked right central and left lateral incisors.

diamond stone used to reduce the unsightly tooth. Correction must be done with this lingual aspect in mind. Using these principles helped create a much more attractive smile with straighter-looking teeth when this patient smiled or spoke (Figure 11.11 F).

Reduction

Before doing even preliminary contouring, you need to be aware of the fact that reshaping of the natural dentition must always be in relationship to the lip positions in both speaking and smiling. Failure to do this may lead to over-reduction in areas not actually needed for esthetics. In addition, the lips should be retracted as little as possible during the recontouring procedure so that their influence and natural relationship toward the dentition will always be apparent.

The entire process of contouring should usually be scheduled in two appointments instead of a single appointment simply because, after prolonged observation, the teeth tend to be seen as you want them to be, rather than as they actually are. In rare cases it may be necessary to desensitize the teeth. The teeth can be desensitized using one of the topical agents you routinely prescribe. These patients should also be advised to use a desensitizing toothpaste as necessary after treatment.

It is important during all cutting operations to use a water spray as a coolant. Furthermore, with the use of water, it is often possible to see a slight color shift before the enamel is completely penetrated. The last few layers of enamel are more translucent, so that the yellow dentin becomes more visible. Enamel removal should be stopped as soon as a color shift is observed and hopefully before. When such a tooth is dried and polished, it should look fine. As the teeth are contoured, it is important to move from one tooth to another frequently. Not only will this minimize frictional heat buildup but it helps maintain a proper perspective toward the overall goal.

If a tooth is being shortened, it will need to be reduced labiolingually as well. If this is not done, the patient may be able to feel the difference in the widths of the incisal edges and the difference may also be visible.

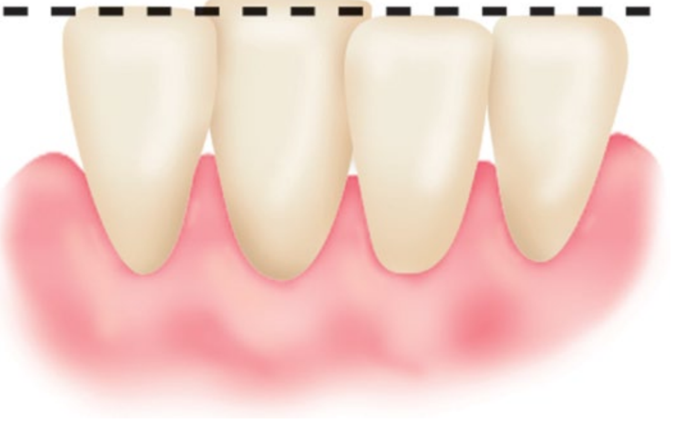

Figure 11.11 **(B)** This is the view of the lower arch as seen by a person at eye level.

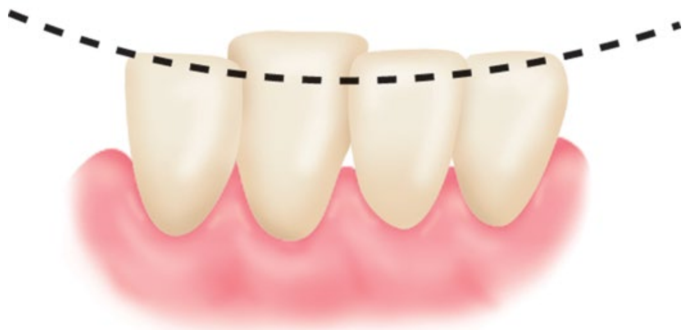

Figure 11.11 **(C)** Shows the same individual as viewed when speaking. A line is drawn to simulate the desired arc.

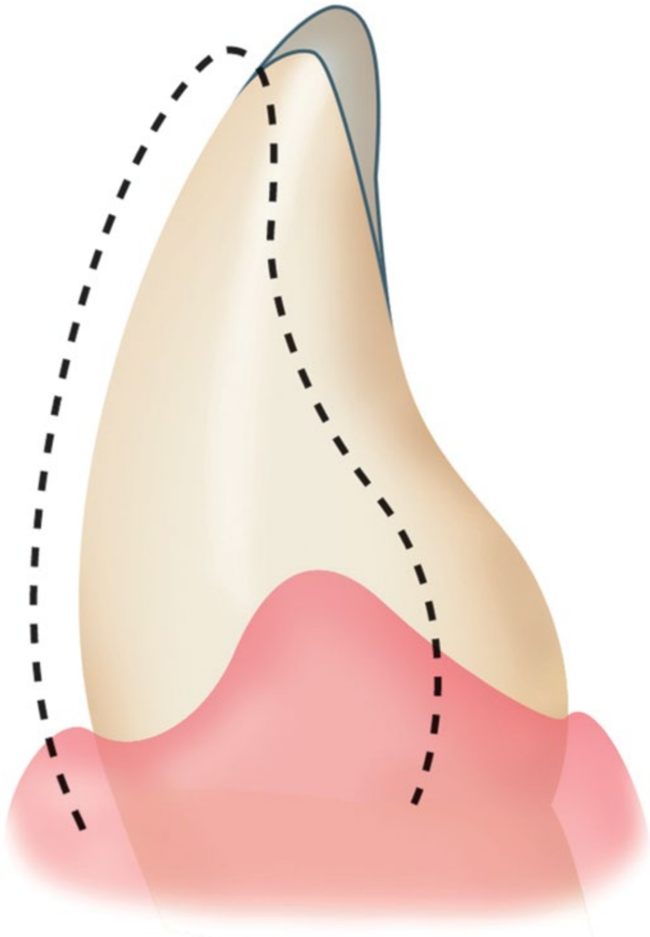

Figure 11.11 **(D)** Shows the relative amount of linguoincisal enamel necessary to alter to achieve a straighter look.

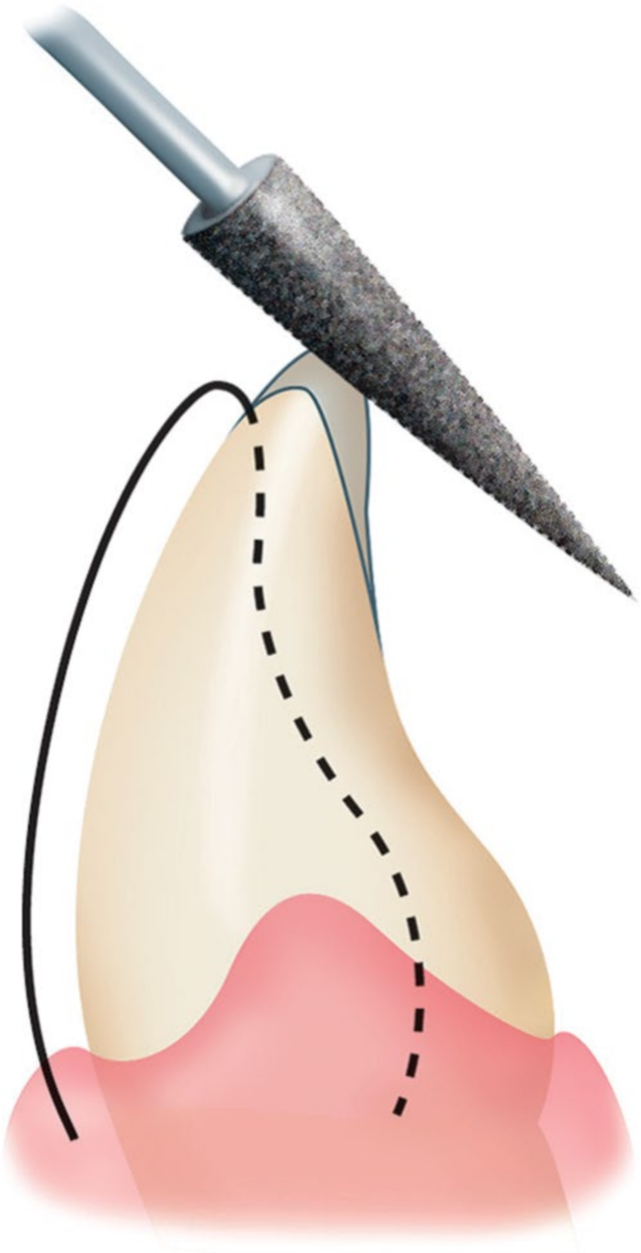

Figure 11.11 **(E)** Notice the correct angle to hold the bur.

Figure 11.11 **(F)** The final photo shows how much straighter the lower teeth appear following cosmetic contouring. Both mesial and distal aspects of the adjacent labial surfaces were also contoured.

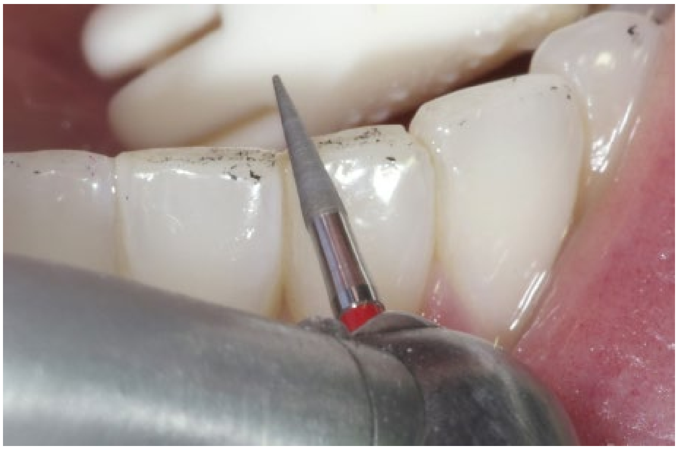

Figure 11.12 The 6 mm 30 μm diamond (DET-6, Brasseler USA) is the perfect shape and grit size to perform cosmetic contouring.

Anterior teeth in the lower arch should be shortened only to the level where they still occlude in protrusive movements. Simring et al. state, "Lower anterior teeth that are ground out of occlusal contact in the intercuspal position will not overerupt if they have occlusal contact in protrusive excursion."[11] Wear facets can detract from the esthetic shape of the teeth. These teeth can be esthetically contoured by rounding away from the flat planes of wear, thereby distributing the occlusal forces more evenly and creating a more pleasing appearance. There are times when initial shaping of the teeth is performed with fine and ultrafine diamonds on a high-speed handpiece with water spray. Excellent diamond shapes are the needle-shaped DET-6 (F and UF) and the DET-4 (F and UF) (Brasseler USA). Reduction is accomplished by carefully shaping the marked areas with a bulk reduction diamond, AC-2 (Brasseler USA), except for the lower anterior teeth. Bulk-reduction in these teeth should be done first with a fine (a 30 μm diamond DET-6) finishing diamond at high speed rather than with the bulk-reduction diamond (Figure 11.12). Because of the thinness of the enamel on these small teeth, if enamel is cut with a fine grit, little will be lost at one time. Therefore, there is less danger of cutting away too much tooth structure. After the initial reduction, the patient should be viewed again in all relevant positions and the teeth remarked.

Final shaping on the mesial, distal, incisal, and embrasure is done with the thin and extra-thin diamond points, because their shapes allow for better access to these areas. After facial shaping is complete, finishing is begun by using an extra-coarse sandpaper disc (Sof Flex, 3 M or EP200, Brasseler USA). Finishing is continued by using the impregnated polishing wheels of varying grits in the following order: plain shank, single yellow band, and double yellow band. This will restore the enamel to its original luster; this procedure can also be used to refinish porcelain.

The following figures are a good step-by-step example of a patient who chose cosmetic contouring as an esthetic treatment. A female graphic illustrator, aged 40, presented with malposed, supererupted, and chipped anterior teeth for cosmetic analysis (Figure 11.13A). Orthodontics was ruled out because the patient wanted an immediate esthetic result. She also was reluctant to have her teeth reduced for crowning or veneering.

Treatment

Cosmetic contouring was the treatment of choice for an economical and quick esthetic solution. The first step in the procedure is to analyze the occlusion. The patient is asked to chew on articulating paper in various directions to determine existing centric holding cusps and lateral inclined planes (Figure 11.13B and C). It is necessary to determine how much the tooth structure can be altered without sacrificing functional occlusion. The angle from which most people see the patient determines the angle of view for which an illusion of straightness will be created. The areas where the initial reduction will be done are drawn on the teeth with a black alcohol marker, which creates marks that are removed by cutting with the diamonds and carbides (Figure 11.13D and E). Looking in a mirror, the patient can get some idea of how the teeth will look. The vertical correction was made first by reducing the incisal edges slightly to achieve an esthetic balance (Figure 11.13 F). The distal edges of the overlapping laterals (Figure 11.13G) were then recontoured. The incisal symmetry is refined with a Soflex disc (Figure 11.13H). The incisal embrasure is then reopened for a more natural esthetic appearance (Figure 11.13I).

Figure 11.13 **(A)** Malposed, supererupted, and chipped anterior teeth are evident in this before photograph.

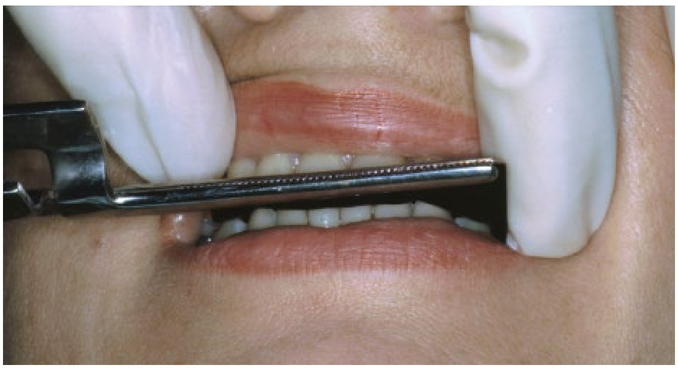

Figure 11.13 **(B)** Articulating paper is used to record the existing centric holding cusps and lateral inclined planes.

Figure 11.13 **(C)** Articulating paper is used to record the existing centric holding cusps and lateral inclined planes. Note the articulating paper marks on the patient's right side.

Figure 11.13 **(D)** Examples of alcohol marking pens (Masel, Inc., Bristol, PA, USA).

Figure 11.13 **(E)** After thoroughly drying the teeth, a black alcohol marker is used to outline the areas to be contoured.

Figure 11.13 **(F)** Vertical correction was accomplished by leveling the incisal edges of the central incisors and slightly shortening the incisal edges of the laterals.

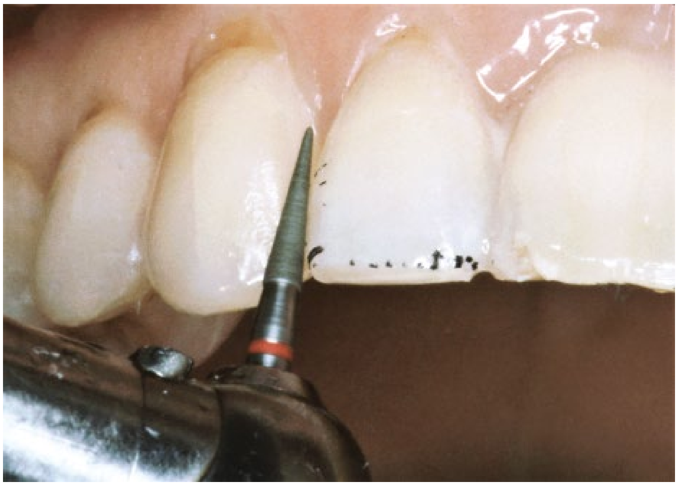

Figure 11.13 **(G)** Recontouring of the distolabial edges and line angles of the overlapping laterals helps to create better distolabial proportion and exposes more of the mesial surface of adjacent cuspids.

Figure 11.13 **(H)** The final incisal symmetry is created with an extra-coarse Soflex sandpaper disc (3 M, St. Paul, MN, USA).

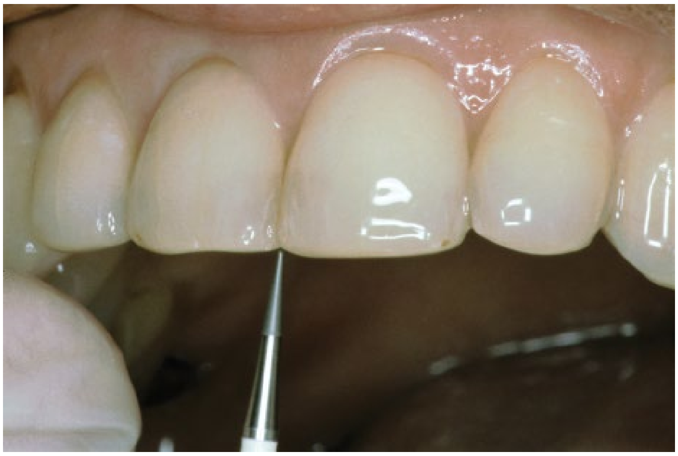

Figure 11.13 **(I)** An ET-3UF 8 μm grit diamond (Brasseler USA) is used to reopen and carve the incisal embrasure for a more natural esthetic appearance.

Figure 11.13 **(J)** Lingual shaping is done using an approximate 45° angle. This helps achieve a more natural look when the patient is speaking.

Figure 11.13 **(K)** Horizontal overlap, which is created by too-wide or poorly aligned incisors, is narrowed.

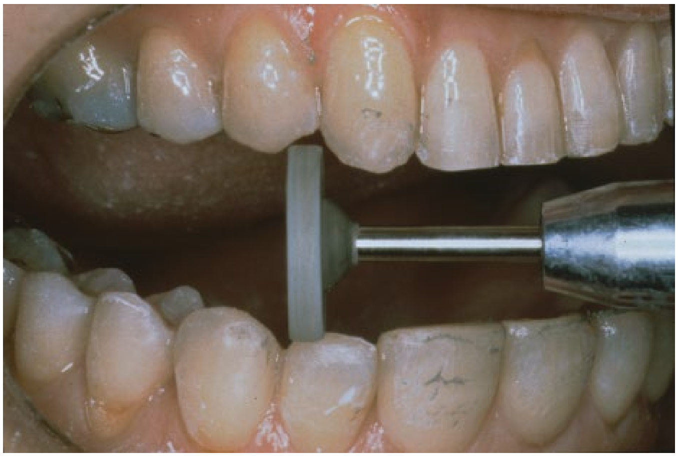

Figure 11.13 **(L)** The no-band wheel shape is used to finish the incisal edges of the maxillary incisors.

Figure 11.13 **(M)** Interproximal surfaces and incisal embrasures of maxillary central and lateral incisors are polished using the disc shape.

Figure 11.13 **(N)** Switch to the one yellow-banded wheel for further incisal edge and labial finishing.

Figure 11.13 **(O)** The one yellow-banded disc shape further smooths the incisal embrasures and proximal surfaces.

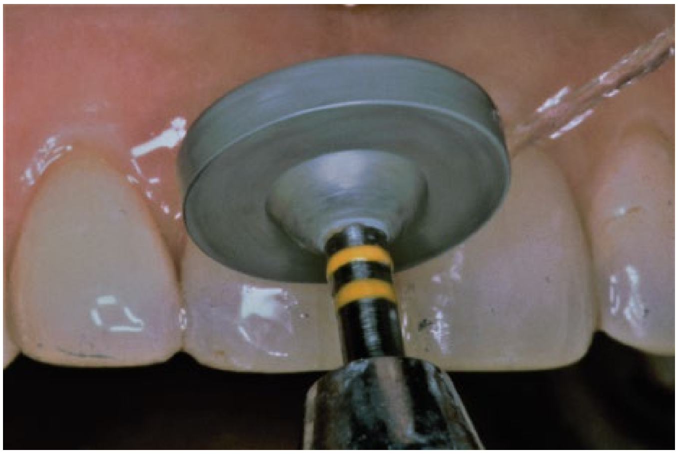

Figure 11.13 **(P)** The final finishing is done with the two yellow-banded wheel. Note how water is used to cleanse the tooth surface while reducing heat.

Figure 11.13 **(Q)** The two yellow-banded disc shape places the final finish on incisal embrasures.

Figure 11.13 **(R)** Retracted view before cosmetic contouring.

Figure 11.13 **(S)** Retracted view after cosmetic contouring shows the improved lower and upper incisal planes.

Figure 11.13 **(T)** Note how the supererupted maxillary right lateral and the lower crowding called unfavorable attention to the smile.

Figure 11.13 **(U)** This after smile shows how the lower incisal plane was improved. Shortening of the lateral incisors also helped to create a younger-appearing smile line.

Figure 11.13 **(V)** This full-face before photograph shows the unesthetic teeth and uneven smile line.

The patient's chin drops down during normal conversation, and this, combined with the typical labial angulation of the lower incisors, presents an oblique view of these teeth to most viewers. So, in order to achieve a more natural look when the patient is speaking, an approximate 45° correction angle is used for lingual shaping (Figure 11.13 J). Next, any horizontal overlap created by overly wide or poorly aligned incisors is reduced (Figure 11.13 K). The mandibular teeth are then finished from

Figure 11.13 **(W)** The full-face after photograph shows the dramatic effect cosmetic contouring had on facial appearance by helping to achieve an illusion of straighter-looking teeth.

the lingual surface to make them appear even. After the original reshaping, the patient is viewed again in the given position to see if there is any further contouring required. It is a good idea to vary both your and the patient's position, for example sit up, stand up, and lean back, and don't forget lateral views. All of these views are helpful to make sure the illusion of straightness is as complete as possible. If necessary, remark and repeat the above steps.

Enamel finishing can be done with gray mounted points found in the Cosmetic Contouring Kit. The Shofu, wheel shape, with no yellow band (Figure 11.13 L) is used to polish incisal edges and labial and lingual surfaces. The disc shape is well suited for interproximal and incisal surfaces (Figure 11.13 M). Remember to always use these in sequence: no band, then one yellow band, then two yellow bands or one white band (Figure 11.13 N–Q).

Before and after views can be seen in Figure 11.13R and S. In studying the before and after retracted views, you can see how the lower incisal plane was improved by cosmetic contouring. Also, note how shortening the lateral incisors make the central incisors appear longer, thereby creating a younger-appearing smile line. If occlusion is a limiting factor, then consider restoring the opposing teeth to allow for your esthetic contouring. For instance, if you feel it is necessary to shorten a mandibular cuspid, it may be possible to bond or veneer the opposing maxillary cuspid to close the resulting interocclusal space so that your occlusion will not be altered.

When looking at the before smile (Figure 11.13 T) one's attention is subconsciously drawn to the super-erupted maxillary lateral incisor which has a fang-like appearance. This preoccupation with the mouth tends to compete with the eye-to-eye contact that most individuals strive for in speaking with others. The dramatic effect that cosmetic contouring can have on the facial appearance is shown in Figure 11.13U–W. An illusion of straightness has been created.

Altering tooth form

Often the anatomic form of one tooth is altered to resemble another. A canine that has drifted or been repositioned into the space of an extracted or congenitally missing lateral incisor can sometimes be reshaped to resemble the missing tooth. Another example is the removal of part of the lingual cusp and reshaping of the labial surface of a first bicuspid so that it resembles a cuspid. Frequently, however, attempts to alter anatomic form do not produce the results that were hoped for. Nevertheless, in these cases, cosmetic contouring is still the most economical and least time-consuming method available, and the appearance may be quite acceptable. The next two cases are examples of how alteration of tooth form can create improved esthetics.

Clinical case: Esthetic shaping of incisal edges

Problem: A female, aged 24, presented with a worn cuspid (Figure 11.14A). She expressed a desire to have her anterior teeth "capped" to produce a more attractive smile but was willing to try cosmetic contouring first.

Treatment: Cosmetic contouring of the maxillary right cuspid is done by contouring the mesioincisal and distoincisal surfaces to open the incisal embrasures. New contours are created which give a softer look (Figure 11.14B).

Result: The patient was so pleased with the result that she no longer desired to have her teeth crowned. Most patients who want anterior esthetic improvement will usually ask to have their teeth crowned, or bonded. However, cosmetic contouring should always be considered as an alternative ideal or compromise solution.

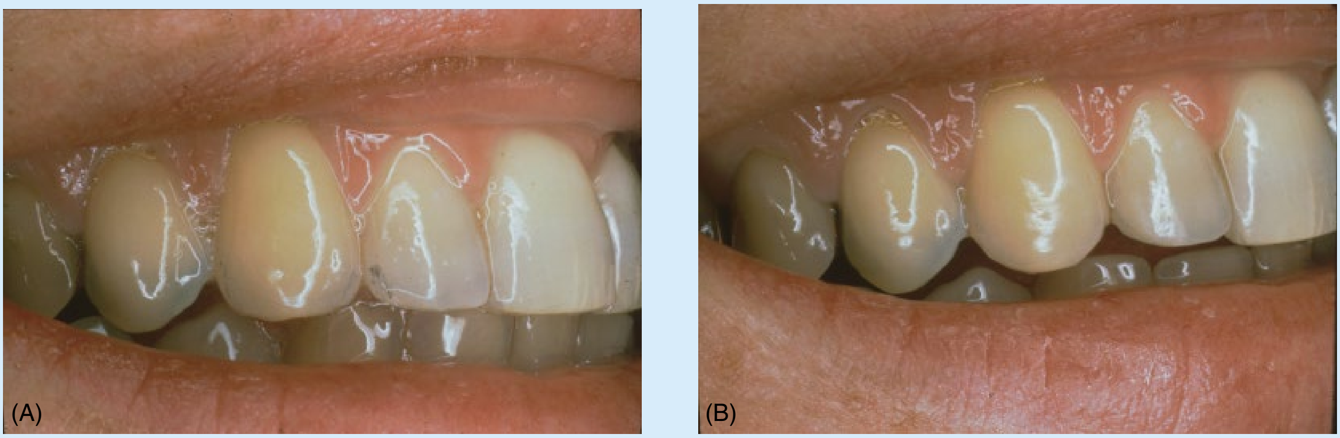

Figure 11.14 **(A)** This patient requested anterior crowns to produce a more attractive smile. **(B)** The mesioincisal and distoincisal surfaces of the maxillary right cuspid were contoured instead.

Clinical case: Changing cuspid anatomy

Problem: A female, age 31, presented with extremely long maxillary cuspids which gave her a "vampire" look. She stated that when she smiled her cuspids were so prominent that they detracted from her appearance (Figure 11.15A and B).

Treatment: The patient was told that a conservative procedure could be performed that could improve her smile. Cosmetic contouring of the labial surface of the cuspids was then done without exposing sensitive dentin (Figure 11.15C and D).

Result: The patient was extremely pleased at the dramatic improvement of her appearance that was accomplished in one appointment.

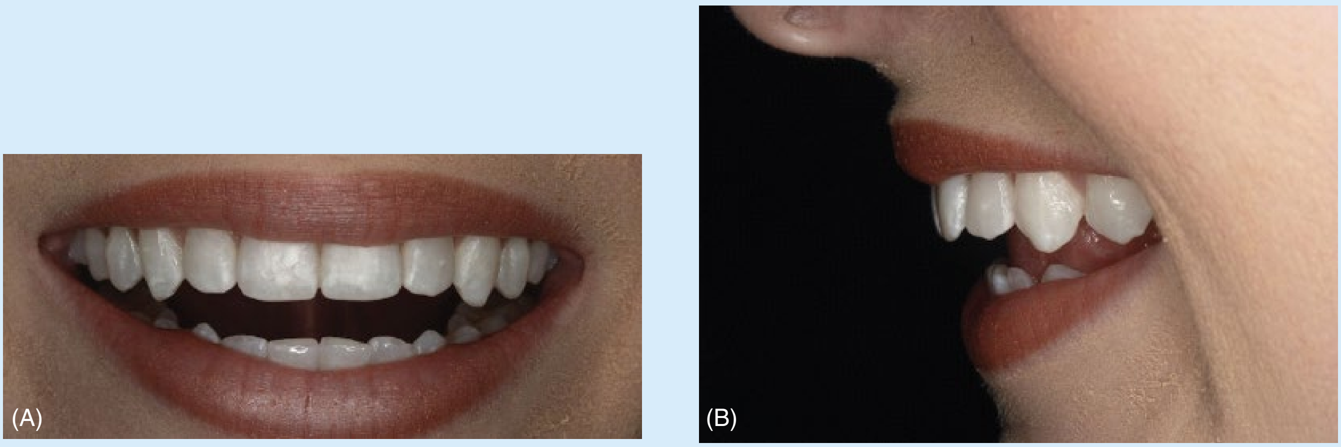

Figure 11.15 **(A and B)** This 31-year-old state beauty contestant winner had extremely long canines.

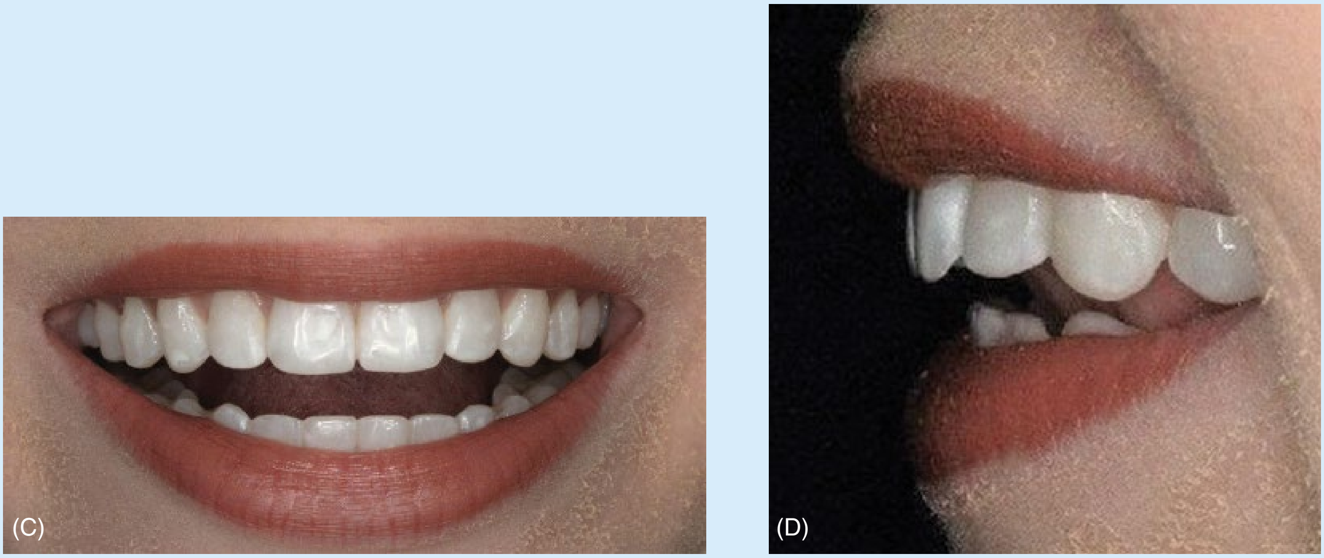

Figure 11.15 **(C and D)** After a 1 hour cosmetic contouring appointment, in which the canines were reshaped, the patient's smile line was improved.

Clinical case: Overlapping central incisors

The main objective in correcting overlapping incisors is to remove as much as possible of the tooth structure that overlaps the adjacent tooth by contouring the labial aspect of the labially malposed tooth and the lingual aspect of a lingually malposed tooth. This straightens the portion that overlaps the adjacent tooth and makes the long axis of the teeth more parallel to each other (Figure 11.16A–E).

An important consideration is the amount of tooth structure that will show when the patient speaks and smiles. This can be determined by having the patient repeat words that emphasize different lip positions. Also ask the patient to smile slightly and then to smile as widely as possible. If a compromise has to be reached, then make that determination during conversation so that the incisal one-third of the dentition—the part that shows

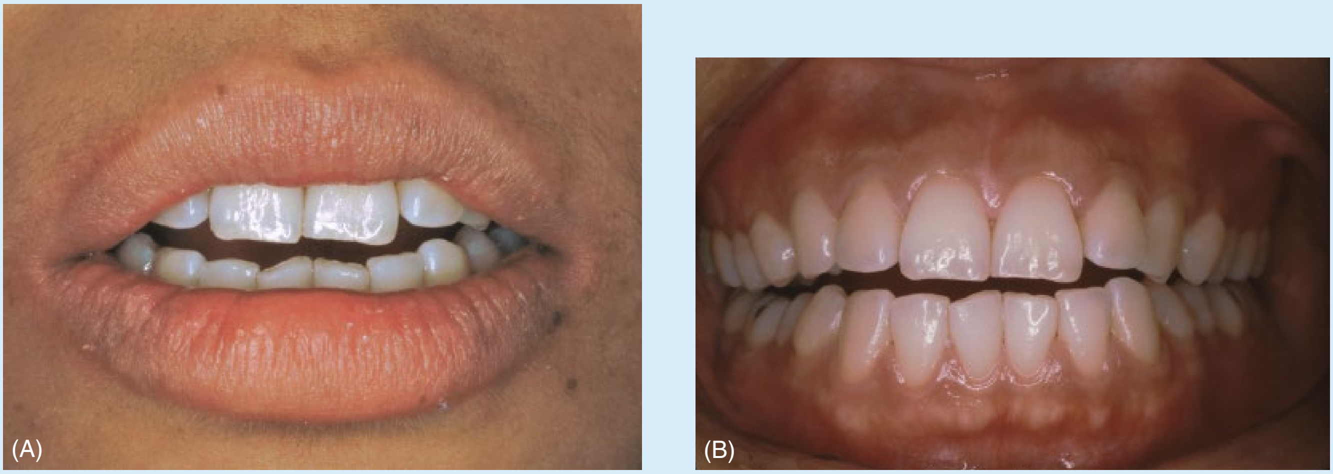

Figure 11.16 **(A and B)** This television producer wanted to improve her smile without wearing braces if possible.

Figure 11.16 **(C and D)** A 1 h appointment was all it took to help create an illusion of straight teeth and a new smile.

Figure 11.16 **(E)** The same patient 35 years later, with very little change despite presence of some bone loss. It has been the author's experience that if you maintain either centric or protrusive relations, the result will remain consistent.

most of the time—can be contoured to achieve the desired illusion of straightness.

One important point in reshaping is to make sure that the incisal embrasure between the teeth is reopened to at least 0.25–0.50 mm length. This is accomplished by using an extra-thin needle-shaped diamond (DET-3 or -4, Brasseler USA) (Figure 11.17A–C). This helps achieve an illusion of straightness. In the labiogingival area, the extension of an overlapping tooth is de-emphasized by blending the shape into the newly created contour.

Care must be taken in reducing the extended portion (circle) of an overlapping tooth (Figure 11.17A). One of the most common pitfalls in reshaping is to thin the tooth so much that the dentin shows through. If that happens, the tooth may appear discolored. The long axis of each of the teeth must be determined, as it will be used to correct the overlapping tooth. Usually the long axes of the teeth (lines a in Figure 11.17C) will vary from tooth to tooth when the lower anterior teeth are crowded (Figure 11.17C). Therefore, choose a parallel line (line b in Figure 11.17C) and do all of the mesial and distal reshaping with this line as the guide. Then reopen the incisal embrasure (Figure 11.17C). The following two cases are examples of two solutions to this problem—the first is solved with cosmetic contouring by itself and the second with cosmetic contouring and bonding.

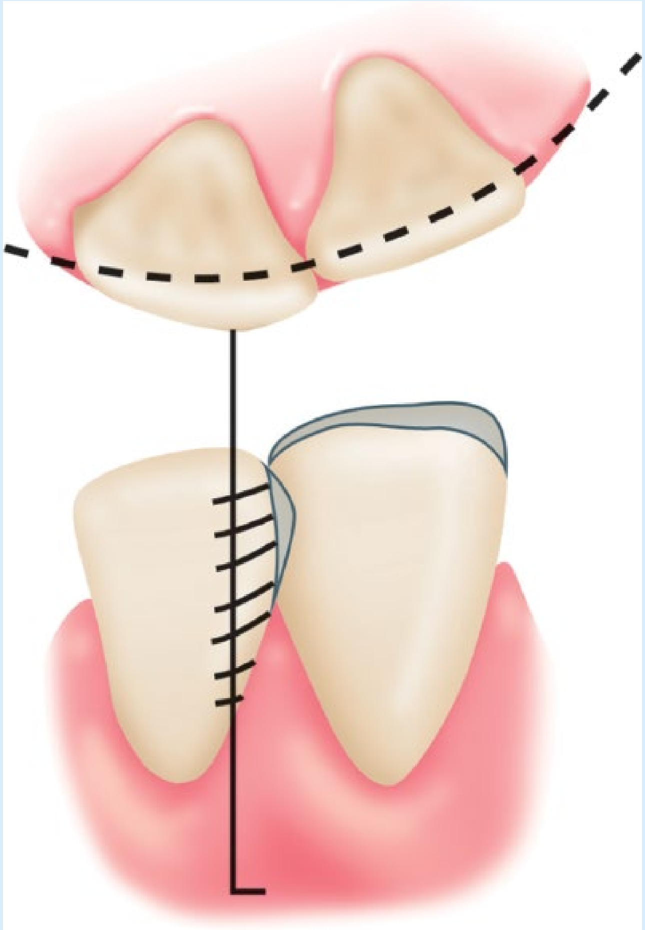

Figure 11.17 **(A)** These are the areas to contour to reduce the horizontal overlap and make the teeth appear straight.

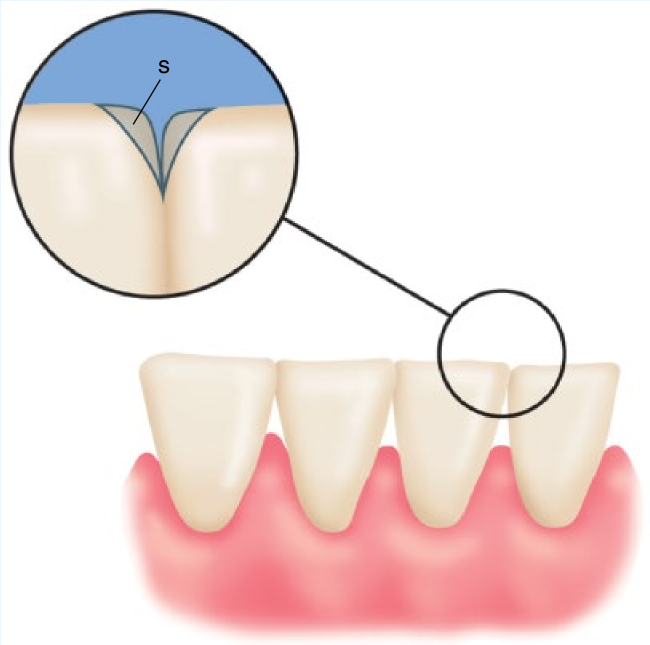

Figure 11.17 **(B)** An incisal embrasure(s) can break up a too-even, worn look at the incisal edge.

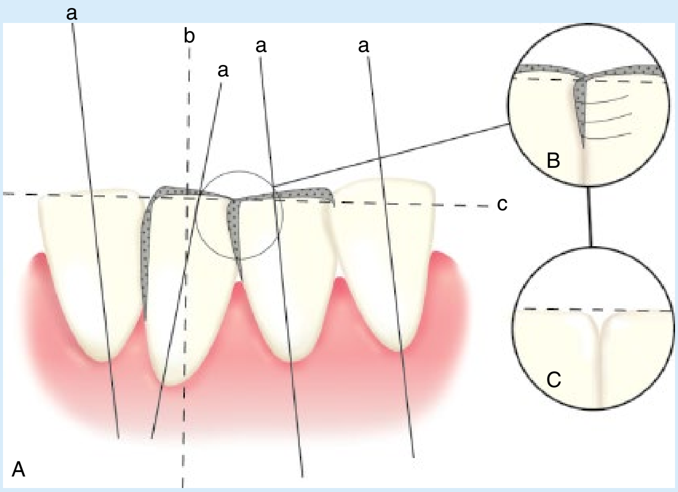

Figure 11.17 **(C)** The gingivoincisal angle of straightness between all the teeth must be determined as it will be used to correct the overlapping tooth. The long axes of overlapping teeth will usually vary when the lower anterior teeth are crowded; therefore, choose a parallel line (b) when doing your mesial and distal correction.

Clinical case: Reducing large teeth

Problem: A female, age 25, presented with extremely large, overlapping, and flaring central incisors (Figure 11.18A–F). Because of the arch alignment, the labioversion of the centrals called attention to their size. The patient's high lip line made it impossible to conceal the unesthetic appearance.

Treatment: Cosmetic contouring was selected as a compromise to orthodontics or crowns. The teeth on the diagnostic study casts were reshaped with a sandpaper disc, so that the patient could then visualize the anticipated result (Figure 11.18C). The areas to be reduced were marked in the mouth (Figure 11.18D). The procedure for reduction and polishing was followed, and the results can be seen in Figure 11.18E and F.

Result: A definite improvement is seen in the patient's smile, since the teeth are now in better proportion (Figure 11.18E and F).

Figure 11.18 **(A)** Unesthetic central incisors can benefit from cosmetic contouring.

Figure 11.18 **(B)** A high lipline made it impossible to conceal the unesthetic appearance.

Figure 11.18 **(C)** The diagnostic study casts were shaped with a sandpaper disc, so that the patient could visualize the final result.

Figure 11.18 **(D)** Areas to be reduced were marked with an alcohol marking pen.

Figure 11.18 **(E)** Note the more proportional appearance created by cosmetic contouring and polishing the central incisors.

Figure 11.18 **(F)** Cosmetic contouring improved this patient's smile. The teeth are now in better proportion.

Clinical case: Combination cosmetic contouring and direct composite bonding

Cosmetic contouring is an important adjunct to bleaching, bonding, veneering, crowning, or any other treatment designed to make the teeth look better. In fact, the procedure is indicated to some degree in almost every patient who wants to achieve the best smile possible. This is a case that illustrates the combined therapy of cosmetic contouring and composite resin bonding.

Problem: This female wanted to improve her smile which was marred by two protruding, wide central incisors (Figure 11.19A and C).

Solution: Cosmetic contouring narrowed the central incisors and composite resin was added to the labial surfaces of the lateral incisors. Figure 11.19D shows the occlusal view of this newly improved arch relationship.

Result: Better tooth alignment and a balanced light reflection produced a more symmetrical smile (Figure 11.19B and D). Anterior teeth that are in linguoversion typically can benefit from bonding or veneering to improve the alignment and arch form.

Figure 11.19 **(A)** This 35-year-old female's smile was marred by two extremely wide protruding central incisors.

Figure 11.19 **(B)** The after smile photo reveals a more symmetrical smile produced in part by the balanced light reflection made possible by building out the lateral incisors with direct composite resin bonding.

Figure 11.19 **(C)** The lingually tipped lateral incisors seen in this occlusal view needed to be built out labially with direct composite resin bonding.

Figure 11.19 **(D)** After bonding the lateral incisors with composite resin, there is an improved arch relationship.

Arch irregularity

Few of us are born with perfectly symmetrical arches. But most of us rarely notice minor deviations. However, a serious discrepancy is usually noticeable to the patient but less to the viewer. This is especially true of a canted arch as in Figure 11.20A–F. Treatment to correct arch irregularity ranges from orthodontics, including orthognathic surgery at times, to restorative methods such as crowns, veneers, bonding, and especially cosmetic contouring. Treatment of choice can sometimes be conservative if the cant is not too severe. Cosmetic contouring alone or combined with restorative dentistry can be a viable option as seen in Figure 11.20C and D.

Figure 11.20 **(A)** This patient was unhappy with her canted smile.

Figure 11.20 **(C)** The patient now has a more improved and symmetrical smile.

Figure 11.20 **(B)** By having the patient bite with a tongue depressor in place, you can easily see the amount of cant that needs to be corrected.

Figure 11.20 **(D)** The tongue depressor helps illustrate a more symmetrical arch, which was accomplished with cosmetic contouring alone, creating a straight illusion.

Figure 11.20 **(E)** This patient's lower and upper arch were affected by overlapping maxillary centrals plus lower crowding.

Summary

When I look at before and after smile results both in lectures and dental magazine publications I periodically see how the smile could have been improved through cosmetic contouring. The procedure takes an hour or less in most cases and it is a fee-based procedure. So what is lacking is remembering to examine each patient to see how much more you can improve his or her smile. I even ask my treatment coordinator or lead dental assistant to remind me if I fail to include cosmetic contouring in the treatment plan. In fact, there is a separate line devoted to the procedure in one of my treatment planning worksheets (Figure 3.17).

Figure 11.20 **(F)** Cosmetic contouring of both arches helped to hide the irregularities enhancing the smile of this young lady.

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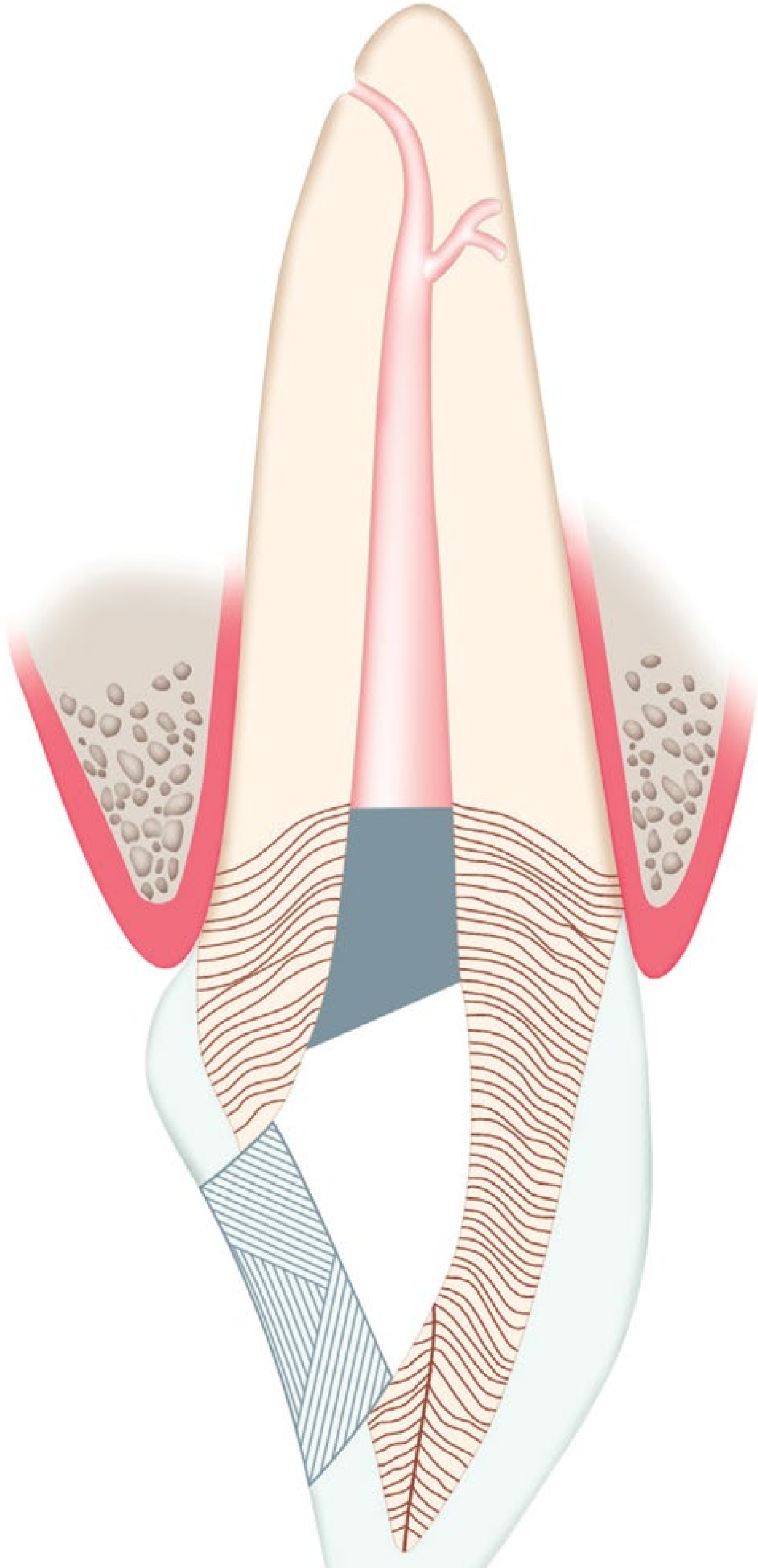

Chapter 12 Bleaching Discolored Teeth

So Ran Kwon, DDS, MS, PhD, MS and
Ronald E. Goldstein, DDS

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Ronald E. Goldstein's Esthetics in Dentistry, Third Edition. Edited by Ronald E. Goldstein, Stephen J. Chu, Ernesto A. Lee, and Christian F.J. Stappert.

Ask the average person how they would most like to improve their smile and the answer would often be "with whiter and brighter teeth." It is commonly known that people are responded to in a more positive manner when they have a dazzling, healthy smile. This chapter is about how we in dentistry can fulfill our patients' requests for a brighter smile through bleaching.

Most newly formed teeth have thick, even enamel. This enamel layer modifies the base color of the underlying dentin, creating a milky white appearance.[1] For many of your patients, that bright, white look can typify youth, health, and physical attractiveness. It is the look against which they measure the appearance of their own teeth.

For some, unfortunately, their teeth will seem dingy and discolored in comparison. Teeth become stained and discolored, sometimes before they even erupt, almost always as they age, for one or more genetic, environmental, medical, or dental reasons. The most common problems are the superficial color changes that result from tobacco, coffee or tea, or highly colored foods. Teeth that contain microcracks are particularly susceptible to these stains. Discoloration also occurs through the penetration of the tooth structure by a discoloring agent, such as a medication given systemically, excessive fluoride ingested during the development of tooth enamel, byproducts of the body such as bilirubin released into the dentinal tubules during illness, trauma (primarily the breakdown of hemoglobin), or pigmentation from the medicaments and materials used in dental repair. Wear and thinning of the enamel caused by aging, too abrasive cleaning materials, aggressive brushing, and acidic food and drink also can diminish the covering power of the white enamel, letting more of the darker-hued dentin show through.[1]

Severe discoloration of a tooth or teeth can be a major esthetic problem. If left untreated, this discoloration may produce social and psychological difficulties. Other chapters have described some of the ways in which dentistry has responded to patients' desire for whiter teeth, from full crowns to bonding and laminating with various veneers and inlays and onlays. For the appropriate patient, with careful diagnosis, case selection, treatment planning, and attention to technique, bleaching can be the simplest, least invasive, and least expensive approach to brighter teeth. Sometimes one office session is sufficient to change a patient's appearance dramatically. If considered as an adjunct to other procedures for correcting discoloration and other esthetic problems, bleaching extends promise to an even larger group of patients who seek more attractive teeth. This chapter will provide current concepts and the latest scientific evidence in tooth bleaching that can fulfill our patient's desire for a whiter and brighter smile.

Bleaching vital teeth

The earliest efforts to bleach teeth go back more than a century and focused on the search for an effective bleaching agent to paint on discolored teeth. As described in a detailed history by Zaragoza,[2] Abbot had introduced by 1918 the forerunner of the combination used to bleach vital teeth today: hydrogen peroxide and an accelerated reaction caused by devices delivering heat to the teeth.

In the early 1960s, Goldstein developed the first commercial bleaching light for in-office bleaching of vital teeth (Figure 12.1A–F).

The recent history of this procedure comprises the bleaching of stained vital teeth that became increasingly popular in the 1970s when a growing number of dentists saw how well it worked on the stains caused by tetracycline ingestion at critical developmental stages of the teeth.

Although many of the mechanisms by which bleaching removes discoloration may not be fully understood, the basic process almost certainly involves oxidation, during which the molecules causing the discoloration are released. The use of heat and light devices appears to accelerate the oxidation reaction.[3,4]

For the next 20 years, in-office bleaching or power bleaching by dentists proved helpful for this and other problems. More recently, dentists began combining in-office bleaching with further treatments that the patient continues at home. This combination is increasingly popular among dentists and patients alike, particularly because of the ease and lower costs of nightguard vital bleaching.

In the early 1990s, bleaching gained a new prominence in the public eye with the introduction and aggressive marketing of bleaching materials intended to be used without dental evaluation and monitoring.[5] The widespread acceptance of these products can also be seen as a disturbing trend due to the potential for misdiagnosis, use of bleaching for inappropriate conditions, poorly fitting mouthguards, and unesthetic or painful results. Bleaching materials applied inappropriately may make the existing situation worse, creating uneven color change or deleteriously affecting restorations. The availability of such products places additional responsibility on the dental profession to make people aware how well professionally applied bleaching works, or whether it works at all, depends on the discoloration itself, its cause, the length of time the discoloring agent has permeated the structure of the tooth, and other factors about which a dentist's advice and monitoring is critical.

A good visual examination usually will suggest the etiology of discoloration and consequently the appropriateness of bleaching as a treatment. The diagnostic workup should include pretreatment photographs, X-ray films, and an intensive prophylaxis to remove superficial staining that may be compounding more intrinsic discoloration. The presence and condition of all restorations must be noted, and special attention paid to the materials of which these are made. The medical history should focus on diagnosis of any systemic problems or medications that might have affected or be affecting tooth coloration. A behavior inventory should determine the possible contributions of tobacco, beverage, and foods. The workup should establish color baselines, note the condition of the teeth and mouth in general, and note the patient's tooth sensitivity in particular.

Figure 12.1 **(A)** In the early 1960s, Christensen showed individual teeth bleaching using a modified soldering iron.

Figure 12.1 **(B)** Also in the 1960s, Goldstein showed in-office bleaching using a modified photoflood lamp in order to bleach multiple teeth.

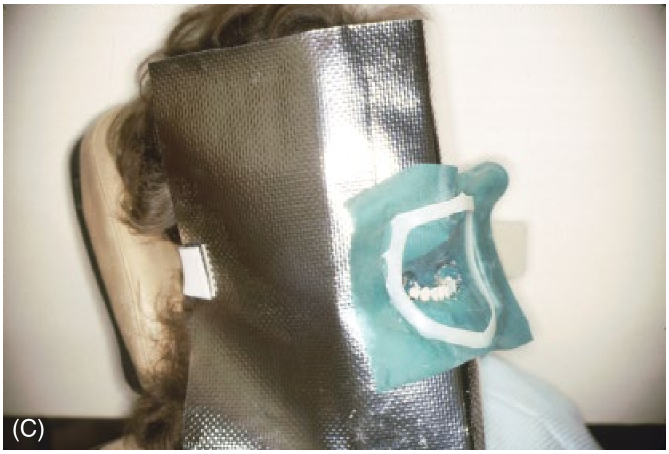

Figure 12.1 **(C)** Due to the excessive heat created by the photoflood lamp, Goldstein developed a bleaching shield that protected the patient's face.

Figure 12.1 **(D)** Goldstein later modified the bleaching light to better isolate the heat and light into a narrower zone for bleaching individual teeth.

Figure 12.1 **(E)** Later, more directed beam commercial lights were developed by Goldstein with Union Broach Company.

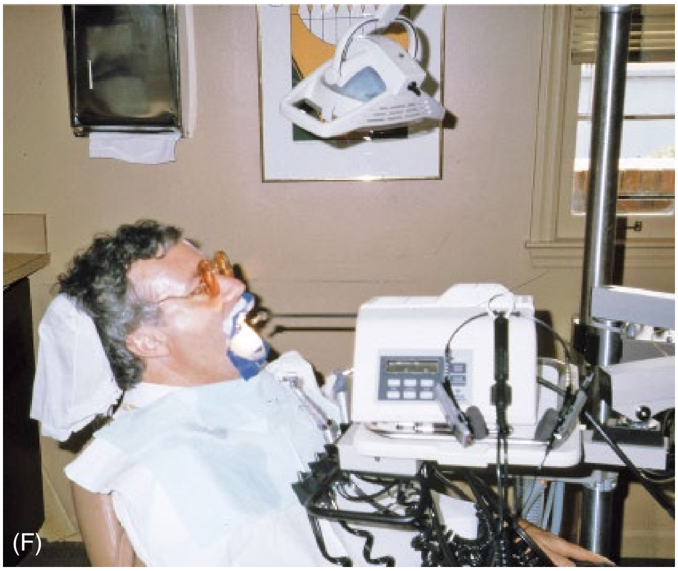

Figure 12.1 **(F)** A later version bleaching light had digitally controlled heat and light, as well as an individual instrument for bleaching single teeth.

Etiology of discoloration

Extrinsic stains

Extrinsic discoloration is caused by the accumulation of stains on the enamel surface and can be accentuated by pitting or irregularities of the enamel, salivary composition, salivary flow rates, and poor oral hygiene.[6] Various types of discoloration ranging from orange, green, brown, and black can be observed and are mostly a result of highly colored beverages or food. In combination with poor oral hygiene stains can be associated with chromogenic bacteria which can be easily removed by dental prophylaxis. Nicotine stains start as tenacious extrinsic stains, but over time absorb into the tooth and become an intrinsic stain that tend to be more difficult to bleach.[7] Drug-related tooth discoloration can be either extrinsic or intrinsic. The most common drugs causing extrinsic discoloration include chlorhexidine[8] oral iron salts in liquid form, essential oils,[9] and co-amoxiclav.[10]

Intrinsic stains

Unlike extrinsic discolorations that can be more easily removed by prophylaxis and bleaching, intrinsic discolorations are due to stain molecules within the enamel and dentin, incorporated either during tooth formation or after eruption.[11] Dental fluorosis is the most common cause of intrinsic discoloration because of the wide range of availability from multiple sources.[12] It was first reported by Black and McKay[13] in 1916, although the role of fluoride in causing these defects was not discovered for another 15 years. Histologic examination of the affected teeth will show a hypomineralized, porous subsurface enamel below a well-mineralized surface layer. This hypoplasia is termed endemic enamel fluorosis or mottled enamel.[14] The nature and severity depend on the dosage, duration of exposure, stage of ameloblast activity, and individual variation in susceptibility. Clinically, fluorosis presents as localized areas of white, yellow, or orange discolorations and in severe cases is accompanied with surface pitting or severe surface defects.[6] Bleaching is a good indication for fluorosis with brown pigmentation on a smooth enamel surface (Figure 12.2A and B). Localized white spots frequently seen in fluorosis have an unpredictable prognosis.[15] Bleaching will lighten the surrounding tooth color which may make the white spots less noticeable. However, in many cases the white spots tend to stand out even more. In such cases and in cases with surface defects, bleaching should be performed as an adjunctive treatment prior to esthetic restorative treatments including bonding or veneering. How the stain occurs is a significant factor in understanding and evaluating bleaching techniques.

Tetracycline stain

The success of bleaching for the yellow or brown stains caused by tetracycline discoloration was key to its place in the emerging field of dental esthetics. The devastating effect on tooth formation of as little as 1 g of tetracycline was recognized in the late 1950s,[16] with the first certain identification reported by a study of cystic fibrosis patients by Shwachman et al.[17] In 1970, Cohen and Parkins published a method for bleaching the discolored dentin of young adults with cystic fibrosis who had undergone tetracycline treatment.[18] The results were promising, and dentists concerned with esthetics began applying bleaching procedures to other stains and discolorations.

Teeth are most susceptible to tetracycline discoloration during their formation; that is, during the second trimester in utero to roughly 8 years of age. It is believed that the tetracycline particles are incorporated into the dentin during calcification of the teeth. Mello[19] reports that the probable mechanism by which tetracycline molecules bind to dentin involves chelation with calcium, which forms tetracycline orthophosphate, the cause of tooth discoloration. When tetracycline-stained teeth are exposed to sunlight, they gradually turn to shades of dark gray or brown. Cohen and Parkins[18] suggest that the reason the labial surfaces of the incisors darken while the molars remain yellow for a longer period of time is because of the different exposure to light.

Although the US Food and Drug Administration (FDA) issued a warning about the use of such antibiotics for treating pregnant women and children, unfortunately tetracycline cases are still seen.

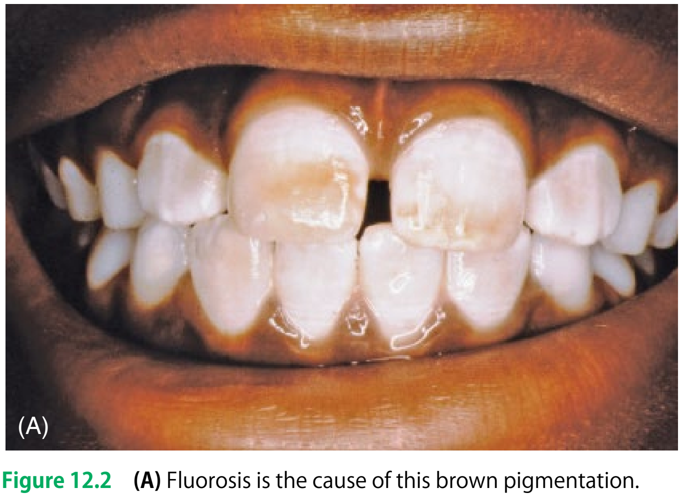

Figure 12.2 (A) Fluorosis is the cause of this brown pigmentation.

Figure 12.2 (B) Individual in-office tooth bleaching was effective in eliminating the stain and producing a more pleasing smile.

The severity of the stains depends on the time and duration of the drug administration and the type of tetracycline administered (more than 2000 variants have been patented). Because of these factors, tetracycline staining is extremely variable in its extent, coloration, depth, and location. Fluorescence is necessary for precise diagnosis and description but most cases fall into the three major categories of tetracycline involvement first proposed by Jordan and Boksman[20] in 1984. Each category has a different prognosis for successful bleaching.

1. First-degree tetracycline staining is a light yellow or light gray staining, slight but uniformly distributed throughout the crown without banding, or concentrated in local areas. It is highly amenable to vital bleaching, with good results usually in fewer than four sessions of office bleaching or one series of dentist-monitored home bleaching (Figure 12.3A and B).
2. Second-degree tetracycline staining is a darker or more extensive yellow or gray staining without banding. Although this type is responsive to vital bleaching, it may take five or more in-office treatments to obtain a satisfactory result. A combination of in-office/home matrix bleaching is the preferable technique (Figure 12.4A and B). Home bleaching alone may take 2–6 months.
3. Third-degree tetracycline staining produces severe staining, characterized by dark gray or blue coloration, usually with banding. Although bleaching may lighten these teeth to some degree, the bands may remain evident following even extensive treatment. Veneering techniques with opaquers are often necessary to achieve satisfactory esthetic results (Figure 12.5A and B).
4. Fourth-degree tetracycline, while not one of the original categories proposed by Jordan and Boksman,[20] includes those stains that some dentists believe are too dark to attempt vital bleaching[14] (Figure 12.6). However, these stains may not be too dark to try bleaching unless there is blue-gray stain at the gingivae.

Minocycline stain

Because tetracycline is incorporated in the dentin during calcification of the teeth, adults whose teeth have already formed appear to be able to use the antibiotic without risk of discoloration. However, recently a semisynthetic derivative of tetracycline has been found to cause staining on the teeth of adolescents who were being given the drug for severe acne.[21] Unlike tetracycline, minocycline is absorbed in the gastrointestinal tract and combines poorly with calcium. Researchers believe the tooth pigmentation occurs because of minocycline's ability to chelate with iron and form insoluble complexes. A study by Dodson and Bowles[22] suggests the minocycline pigment produced in tissues is the same or very similar to that produced by UV radiation. Since minocycline is used for a variety of infections as well as for acne, you should expect to see rising numbers of cases of this

Figure 12.3 **(A)** This is a good example of first-degree tetracycline stain, which is usually light yellow or gray, and slight and uniformly distributed throughout the crown with no banding or localized heavy concentration.

Figure 12.3 **(B)** Bleaching a first-degree tetracycline stain usually produces a good result like the one shown here, which is a combination of one in-office treatment plus home bleaching for 3 weeks.

Figure 12.4 **(A)** The darker and more extensive yellow stain seen here is typical of second-degree tetracycline stain.

Figure 12.4 **(B)** Although responsive to vital bleaching, second-degree tetracycline stain generally takes five or more in-office treatments, as this one did, to obtain a good result.

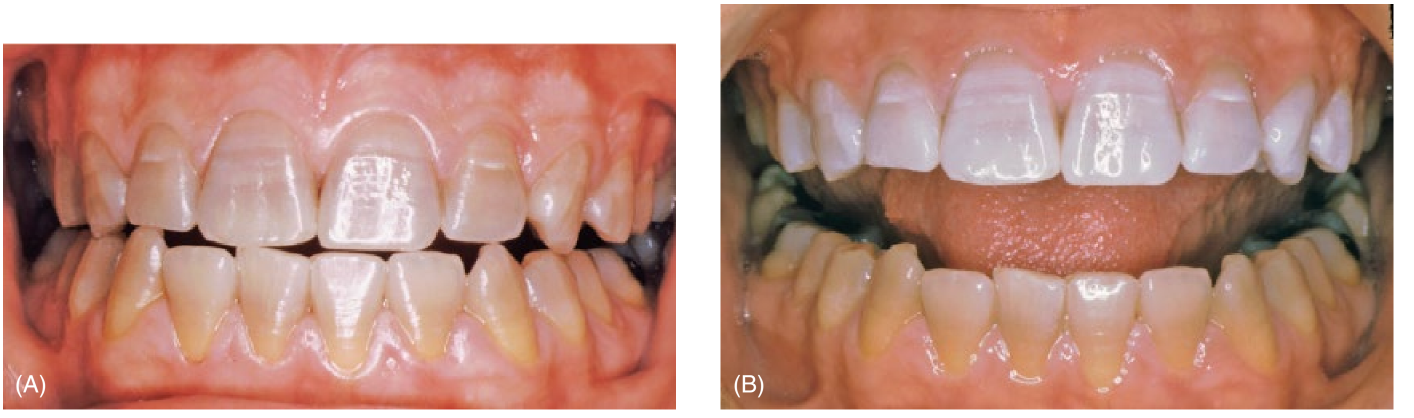

Figure 12.5 **(A)** Third-degree tetracycline stain generally does not respond well to bleaching. Depending on the patient's needs, a better result would be achieved with porcelain laminates. **(B)** This is an example of what can be achieved with multiple in-office visits. Although bleaching did lighten these teeth to some degree, the bands are still evident and the overall color would not be satisfactory to most patients. Nevertheless, there will be some patients who will prefer their own teeth lightened as much as possible rather than veneering.

Figure 12.6 This is a good example of what has been termed fourth-degree tetracycline stain, which is so dark that bleaching may not respond enough to please the patient. Patients can be persuaded to seek one of the veneering methods to accomplish tooth lightening.

discoloration and questions regarding its use should be included in the medical history of patients. Although these stains may be responsive to bleaching, severe banding of the stains may suggest laminating for a satisfactory result. In each situation, the treatment depends on the degree of lightening desired by your patient.

Several adult patients have presented with stained teeth similar to the patient seen in Figure 12.7A. In each instance, the patients stated that the teeth had severely discolored after they began taking minocycline. Although the stain is somewhat amenable to bleaching, there is no guarantee that the final result will match the patient's previous tooth color. As a case in point, the patient in Figure 12.7B did achieve a light shade. Nevertheless, she ultimately decided to have her teeth veneered so she could obtain a much lighter color.

Stain from dental conditions or treatments

Dental caries are a primary cause of pigmentation and may be seen as an opaque, white halo, or a gray discoloration. An even deeper brown to black discoloration can result from bacterial degradation of food debris in areas of tooth decay or decomposing fillings. Such problems should be corrected before bleaching is attempted. In some cases, repair and proper cleaning may negate the need for bleaching.

Restorations also frequently cause discolorations. Degraded tooth-colored restorations such as acrylics, glass ionomers, or composites can cause teeth to look grayer and discolored. Metal restorations, such as amalgams, even silver and gold, can reflect discoloration through the enamel and should be replaced with less visible materials such as composite resin before bleaching.[23] Restorative materials that have leaking margins may allow debris or chemicals to enter and discolor the underlying dentin. Again, in some cases, bleaching may then not be necessary once such changes are made. If amalgams cannot be replaced, however, bonding or veneering may be preferable alternatives.

Oils, iodines, nitrates, root canal sealers, pins, and other materials used in dental restorations can cause discoloration. The length of time these substances have been allowed to penetrate the dentinal tubules will determine the amount of residual discoloration and will, consequently, affect the success of bleaching. Metallic stains are the most difficult to remove. Endodontic materials and sealers have various staining potentials that cause intrinsic discoloration of the root canal filled tooth over time.

Stain from systemic conditions

Developmental defects of enamel or dentin can be associated with amelogenesis imperfecta, dentinogenesis imperfecta, and enamel hypoplasia. Amelogenesis imperfecta is a hereditary disorder of enamel formation involving both the primary and permanent dentition.[24] Discolorations associated with amelogenesis imperfecta tend to aggravate with time as the rough surfaces allow stains to accumulate more easily. Dentinogenesis imperfecta is a hereditary disorder affecting both dentitions, exhibiting abnormal dentin formation. Affected teeth exhibit slender roots, small or obliterated pulp chambers and root canals with enamel that easily chip away from the dentin.[25] Enamel hypoplasia is incomplete or defective formation of enamel matrix induced by systemic or local factors. Hematologic disorders cause a deposition of blood pigments in the dentin or enamel resulting in discoloration of the tooth structure. Bleaching can

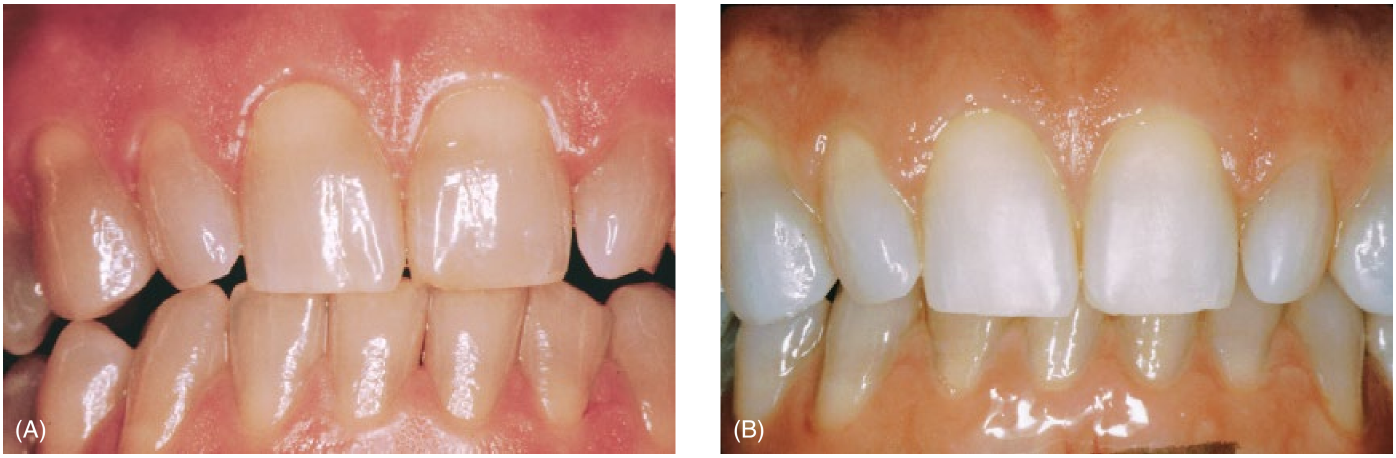

Figure 12.7 **(A)** This female took several doses of the antibiotic minocycline for her facial complexion. Shortly after, she began to notice some darkening of the teeth, which continued until they reached the color shown. She states that she had "white" teeth up until that time. **(B)** Six in-office treatments plus 1 month of home matrix treatments were used to obtain this result.

be quite effective for the discoloration caused by infusion of the dentin during development. Some examples are as follows:

- The bluish-green or brown primary teeth seen in children who suffered severe jaundice as infants. The stains are the result of postnatal staining of the dentin by bilirubin or biliverdin.
- The characteristically brownish teeth caused by destruction of an excessive number of erythrocytes in the blood cells that occurs in erythroblastosis fetalis, a result of Rhesus factor incompatibility between mother and fetus.
- The purplish-brown teeth color of persons with porphyria, an extremely rare condition that causes an excess production of pigment.

Other illnesses cause discoloration of the teeth by interfering with the normal matrix formation or calcification of the enamel.[26] Hypoplasia or hypocalcification can occur with genetic conditions like amelogenesis imperfecta and clefting of the lip and palate or with acquired illnesses such as cerebral palsy, serious renal damage, and severe allergies. Brain, neurological, and other traumatic injuries also can interfere with the normal development of the enamel. Deficiencies of vitamins C and D, and calcium, and phosphorus can cause enamel hypoplasia if they take place during the formative period. Bleaching is usually a less appropriate treatment than bonding, veneering, or crowning for these problems involving the structure of enamel.

Discoloration due to aging

With the aging population, an increasing number of your patients will be older. We no longer expect to lose our teeth as we age as our great grandparents did, nor do most persons in our youth-oriented society easily accept the changes in color, form, and texture of teeth that almost inevitably accompany aging. The type and degree of such changes will depend on a mixture of genetics, use and abuse, and habits. Years of smoking and coffee drinking have a cumulative staining effect, and these and other stains become even more visible because of the inevitable cracking and other changes on the surface of the tooth, within its crystalline structure, and in the underlying dentin and pulp. In addition to wear and trauma on the teeth, amalgams and other restorations placed years ago may begin to degrade.

Even with the most careful avoidance of or attention to such problems, our teeth are likely to become more discolored as we age, from both natural wear and exposure to normal environmental contaminants. The first change to occur is usually a thinning of the enamel. This may cause the facial surface of the tooth to appear flat with a progressive shift in color due to a loss of the translucent enamel layer. At the same time the enamel begins to thin, secondary dentin formation begins through a natural tooth protective mechanism in the dentin and pulp. This larger mass of dentin also begins to darken. The combination of thinned enamel and darkened dentin creates an older-looking tooth. For these types of problems, veneering will produce a better long-term result (Figure 12.8A and B).

For many of the discolorations seen in older patients, home matrix bleaching can be a safe, effective treatment option. Additionally, unless the enamel is too badly worn, in-office or combined bleaching can be an effective treatment. For many older patients, the short time required in the dental chair, relatively low cost, and lack of trauma involved, make bleaching an especially appealing treatment. Another reason why bleaching can be such an effective treatment for older patients is that in most instances the pulp has shrunk back, making it possible to use higher bleaching temperatures.

Contraindications to bleaching of vital teeth using in-office techniques

The following problems may suggest the use of other methods of esthetic improvement or may be more appropriate for dentist-monitored home bleaching:

- extremely large pulps, which may increase sensitivity
- other causes of hypersensitivity, such as exposed root surfaces or the transient hyperemia associated with orthodontic tooth movement

Figure 12.8 **(A)** The combination of thinned enamel and darkened dentin creates older-looking teeth.

Figure 12.8 **(B)** In this case, bleaching was followed by direct composite resin restorations for better long-term results.

- severe loss of enamel due to attrition, abrasion, or erosion
- teeth exhibiting gross or microscopic enamel cracking
- extremely dark teeth, and severe tetracycline staining, especially those with marked banding
- teeth with white or opaque spots: although bleaching will not eradicate these spots, the process can lighten the surrounding tooth structure and then the white spots can be eliminated with microabrasion or with bonding
- teeth in which there are restorations that must be matched or, especially, teeth that have been bonded or veneered
- extensive restorations: Koa et al.[27] suggest strongly that bleaching materials never come in contact with restorative materials. Their study of bleaching chemicals found some roughening on contact with all tooth-colored restorative materials, the greatest damage done to glass ionomer, the least to porcelain. (See also various studies referenced in the section on matrix bleaching in which the teeth have a longer exposure to the chemicals, although the chemicals are less invasive.)
- patients who are perfectionists: bleaching is not perfect, in the way veneers can be. This is especially true for severe stains. With darker tetracycline stains, for example, the majority of the bleaching will occur on the incisal one-half of the teeth. The remaining surfaces can only be partially helped by a selective bleaching solution and heat application.

For these patients, and others, you may find that a combined bleaching approach and restorative procedures like bonding, veneering, or crowning are indicated. For example, patients with Class V lesions which are eroded and sensitive may find there is too much discomfort with the bleaching process, either in the office or at home. In these instances, an alternative is to cover the sensitive areas with a dam substitute or temporize with a temporary filling while bleaching, and to bond the cervical after the color has been stabilized and the bond strength fully recovered.

Level of expectation

The "perfectionist" type of patient may not be happy unless the teeth resemble the concept of the "Hollywood star." However, others may enjoy and appreciate only a slight lightening of tooth shade (Figure 12.9A and B). It is essential that you thoroughly understand the color level your patient expects. Computer imaging can be of considerable help in this regard.

Figure 12.9 **(A)** Many patients will be satisfied with only a minimal result.

Figure 12.9 **(B)** The patient was happy after two in-office bleaching treatments.

Sequence of treatment

Simple discoloration generally can be effectively treated with in-office bleaching. An individual tooth discoloration would usually require an in-office individual bleaching instrument whereas generalized discoloration would need a comprehensive in- and/or out-of-office treatment. Classification should be based on the type of discoloration and whether it is generalized or individualized.

Teeth that have staining in one or more areas are usually treated differently than generalized staining. Although tooth contouring can sometimes make stains disappear if they are only in the first cell layers of enamel, bleaching the darker stain with repeated short treatments is generally the treatment of choice. Selective tooth isolation with the rubber dam is the best method for treating this problem (Figure 12.10). Teeth that have had traumatic injury can sometimes be bleached in-office, either by itself or combined with matrix bleaching, or by matrix bleaching alone. Selective placement can also be effective with traumatically involved teeth (Figure 12.11A–C).

Teeth that are yellowing due to heredity or age can usually be improved with both in-office and matrix bleaching. In most instances, bleaching teeth should be attempted before any other treatment is undertaken, with the exception of soft tissue management. In general, treat one arch at a time. This provides a good comparison of just how effective your treatment is

Figure 12.10 Rubber dam placement: in-office selective bleaching can be accomplished by carefully applying the rubber dam to expose only the teeth that require bleaching.

(Figure 12.12A–C). However, certain patients have limited time or want to maximize their dental appearance, so consider bleaching both arches simultaneously.

Combined bleaching and restorative dentistry

When combining bleaching with restorative dentistry, estimate the number of bleaching treatments in the office or at home before an acceptable result will be obtained, in order to calculate how long afterwards the restorative treatment could begin. Generally, this occurs 2–6 weeks after the last bleaching

Figure 12.11 **(A)** This female patient presented with a cervical stain on this previously traumatized yet still vital tooth.

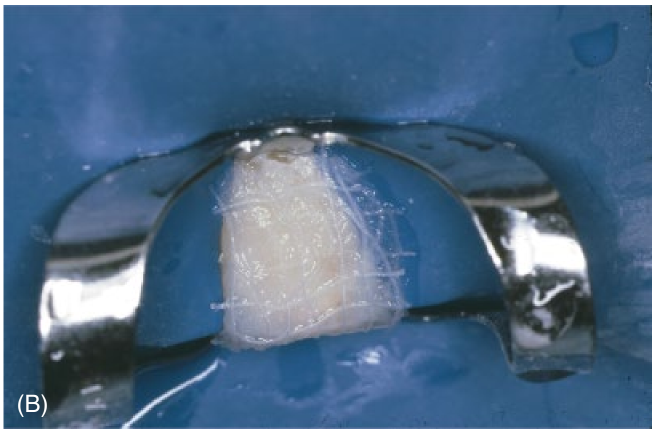

Figure 12.11 **(B)** The tooth was isolated with a rubber dam and treated with 35% hydrogen peroxide combined with a heat wand.

Figure 12.11 **(C)** Polishing with coarse pumice and external surface bleaching with heat successfully restored the patient's tooth color.

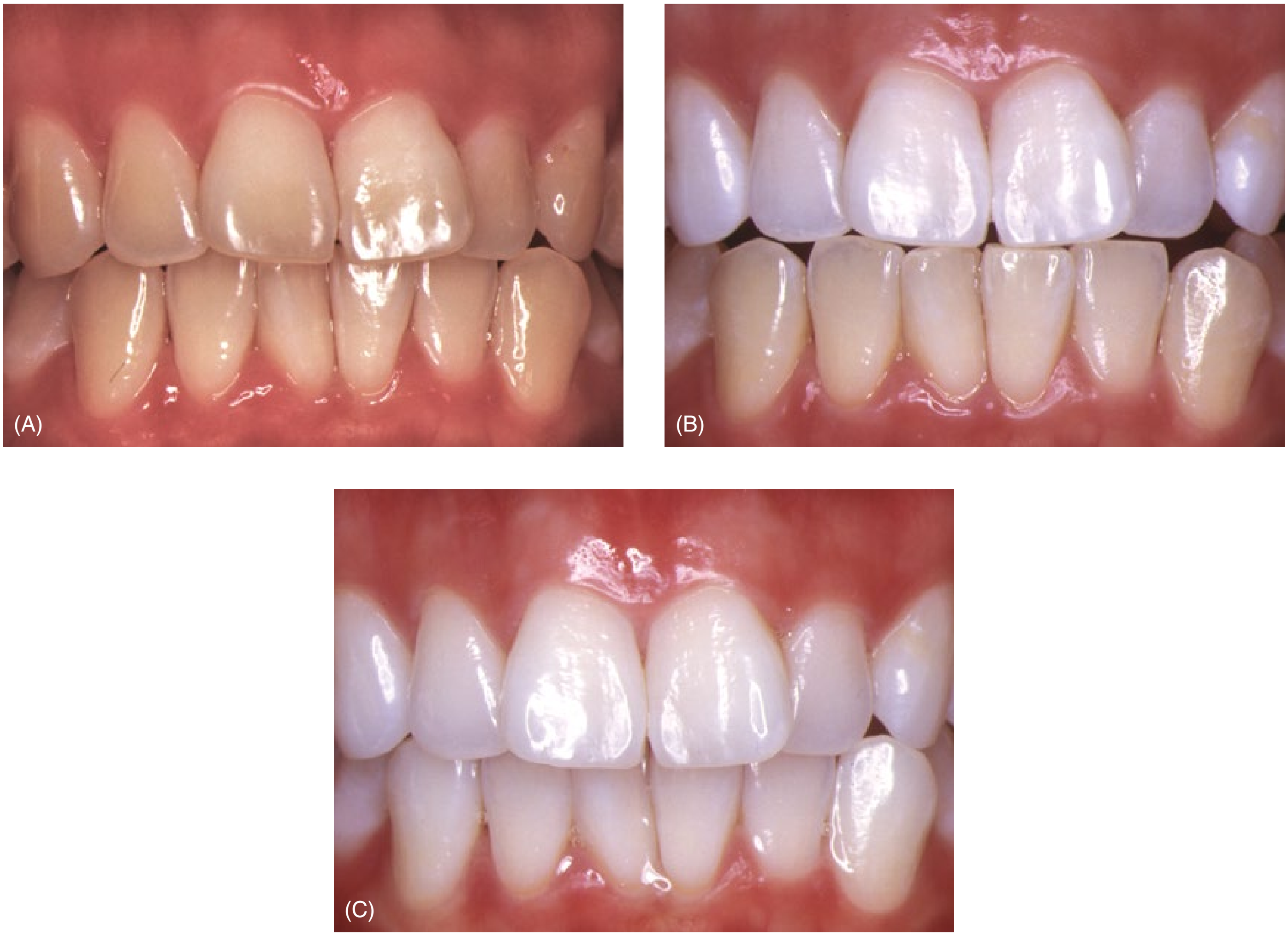

Figure 12.12 **(A–C)** In general, treat one arch at a time. This provides a good comparison of just how effective your treatment is.

treatment: for in-office bleaching alone, it is about 2 weeks but if at-home treatments are included then add an additional 4 weeks. Eight weeks from the onset of this combined bleaching approach is usual. Some patients are happy with the bleaching regimen alone but others will desire bonding or veneering as the total treatment.

Bleaching combined with minor restorative treatment

Many times bleaching will be combined with simple composite resin bondings, veneers, or all-ceramic crowns to meet the expectations of the patient regarding a beautiful smile. Bleaching should be the starter treatment and restorative procedures should be postponed to 2–3 weeks after the last bleaching to select the shade for matching the final restoration and to wait for the recovery of the bonding strength to tooth structure.[7] In the event you must take a shade prior to seeing the final bleaching result, choose a lighter shade, and be prepared to darken the crown if necessary to match the final color. The patient should be warned that additional matrix or in-office bleaching may be necessary from year to year or after several years in order to keep the adjacent teeth matched to the new crown or crowns.

Bleaching combined with orthodontics

It is generally preferred to bleach teeth before orthodontia is initiated if ceramic or metal brackets will be bonded to the teeth because the bonding impregnates the enamel and thus makes it more difficult to bleach. However, it is acceptable to straighten the teeth first, remove the brackets, and clean the teeth of all bonding materials before bleaching. In this case, a Prophy-Jet (Dentsply) should be used, followed by a mild etching before the first bleaching treatment to make sure there is no bonding material remaining on the teeth.

It is also possible to do a combined technique when a removable orthodontic positioner is being used to move the teeth (Figure 12.13A). The bleaching solution can be added to one or both arches in the clear orthodontic positioner. A breathing space can also be created in the splint between the arches (Figure 12.13B). When minor therapy with removable appliances or invisalign is underway, bleaching can also be done simultaneously.

Figure 12.13 **(A)** Bleaching solution is added to this removable orthodontic positioner.

Figure 12.13 **(B)** If both arches are being straightened and bleached, a breathing space can be created in the combined matrix/retainer. This special dual-therapy appliance represents a real time saver for the patient.

Bleaching in patients with multiple caries, abrasion, and erosion

Deep cavities in the esthetic zone that require tooth-colored restorations should be addressed prior to bleaching. Deep caries lesions should be removed and filled temporarily with glass-ionomer fillings. The final tooth-colored restoration can be placed after bleaching to provide a natural color match. Abrasion and erosion areas that need bonded restorations should be bleached first. If home bleaching is performed, the custom-fitted tray can be adjusted so that the bleaching gel will not contact the abraded or eroded area. During in-office bleaching the protective resin barrier can be placed over the affected area, so that the highly concentrated bleaching gel will be applied only on sound tooth surfaces. Once the teeth have lightened Class V composite resin restorations can be placed to match the lightened teeth. Recently, the use of home bleaching for the prevention of cervical caries lesions due to dry mouth has been suggested.[28]

Bleaching combined with periodontics

Generally, bleaching follows oral disease control and management of any periodontal disease. If there is evident periodontal inflammatory disease or gingival hyperplasia that covers the cervical enamel, bleaching should be postponed until the swelling has subsided to expose the healthy clinical crown. If the sequence is reversed, a color differential may result in the subgingival unbleached area. However, if advanced bone loss is present and surgery will mean raising the tissue well onto the root surface, it may be advisable to perform an in-office power bleach with adequate rubber dam protection before periodontal therapy is undertaken. This would make it easier for the tissue to hold the dam in place at the cementoenamel junction, rather than having the cervical root surfaces being exposed to the bleaching solution.

In the event that the patient already has root exposure, you may need to mask those areas with artificial dam material (Ultradent or Den-Mat) and seal the defects with composite resin to prevent any leakage of the bleaching solution from damaging these areas.

Bleaching for children

Children with discolored teeth may be good candidates for bleaching especially if trauma has taken place, but there are several caveats. The larger pulps of children can lead to greater sensitivity when office bleaching is performed and one should be especially careful to avoid irritation of the pulp, including not using heat. If a child has an adequate number of teeth to hold a matrix in place, dentist-monitored home bleaching may be preferable (Figure 12.14A and B). However, you will need to make the child understand that less-than-perfect home care will tend to leave plaque on teeth, diminishing the effect of bleaching. It is imperative that the teeth be clean before bleaching at home. Disclosing tablets or solutions may be effective tools in helping less-than-meticulous brushers see what they are missing. And you must forewarn the child and parents that bleaching will need to be repeated as new teeth erupt.

Bleaching for elderly patients

Older patients are excellent candidates for bleaching, especially to improve the yellowing that can occur with age, but their teeth must be basically free of defects and restorations. In fact, since the pulps often have receded, there usually will be little or no sensitivity present during the bleaching process. This means you will be able to use photooxidation or heat as a method of choice. Older patients can withstand higher heat when the illuminator (Union Broach) or bleaching light or even laser is used, which should permit faster results.

Office bleaching will most often be the technique chosen by the elderly who wish to have lighter teeth. Although they may have more time for home or matrix bleaching, their patience with all the ramifications of matrix bleaching may not be sufficient. In addition, if there is any problem with the intraoral tissues, matrix bleaching could be contraindicated. Dry mouth syndrome, periodontal disease, or advanced bone loss are all conditions that may influence the choice of bleaching technique. If you find that your patient's soft tissues become irritated with matrix bleaching, switch to resin barrier protected office

Figure 12.14 **(A)** This child had an adequate number of teeth to hold a matrix in place.

Figure 12.14 **(B)** Dentist-monitored home bleaching was performed for good results.

bleaching. For many older patients, the short time required in the dental chair, relatively low cost, and lack of trauma involved make bleaching an especially appealing treatment.

Recording the baseline color

The baseline color should be recorded and can be accomplished with the use of shade guides or special electronic devices for color measurement. There are many shade guides available, and the decision on which to use should be according to the ease of use and the purpose of color evaluation. The VITA classical introduced to the dental profession in 1956 is still the most widely used because of its ease of use and broad availability. The major drawback of the VITA classical guide is that there are no uniform distribution between the individual color tabs and the lack of lighter shade tab than B1. The VITA Toothguide 3D-Master shade guide has facilitated the matching of color by evaluating three components of color—value, chroma, and hue—separately into three steps. However, the 3D system has caused confusion for the dentists who have adjusted to the linear system over such a long time. In 2007, Paravina[29] introduced a new linear bleached shade guide for the purpose of monitoring color change during bleaching. The advantages of this system are that it is easy to use, there is uniform color distribution between the tabs, and there are very light bleaching shade tabs available. Regardless of the shade guide system used, the most common way to record the baseline color is to take a picture with an intraoral camera with the shade guide tab as a reference next to the tooth. With the advancement of technology special devices for color measurement have become available which are not influenced by the human eye, environment, or light source, and which produce reproducible data. Shade systems include spot measurement devices like Shade Eye-NCC (Shofu) and Easyshade (Vita), as well as complete tooth measurement devices such as the Spectro Shade Micro (MHT Optic Research), ShadeScan (Cynovad), Shade Vision (X-Rite), and the Crystaleye. The benefit of using complete tooth measurement devices in tooth bleaching is the ability to print out a smile analysis that can effectively motivate the patient into the treatment (Figure 12.15A–D). However, the color measurement procedure has to be performed tooth by tooth, making it time consuming, and the cost has limited its use to a limited range of dentists.

Techniques for in-office bleaching of vital teeth

Discolored vital teeth can be successfully bleached with highly concentrated hydrogen peroxide gels at the chair side. In-office whitening provides an alternative to home bleaching, especially when patients desire faster results and demonstrate low compliance in wearing a tray at home. In-office whitening can be performed on selective teeth, on one arch or even on both arches where speedy treatment is desired. Generally, the whitening effect is noticed immediately after a single session. However, generally a single session is not enough to achieve optimal results and for maximum bleaching several appointments are required. Ideally, in-office bleaching can be combined with home bleaching to obtain faster and whiter results. No matter which form of concentrated hydrogen peroxide or bleaching apparatus is used, it is essential to protect the tissue.

Preparation and application of bleaching material

See Figure 12.16A–M.

1. Record the baseline color with a shade guide and take a photograph with the selected tab next to the teeth to be bleached. This provides an excellent data baseline and record of pretreatment that will be useful in determining needed follow-up. Because bleaching can be incremental with a gradual change, patients easily forget their initial shade and are surprised to see how their teeth actually were.
2. Free the teeth of all surface stains and plaque with a Prophy-Jet (Dentsply) or similar cleaning device. Special attention should be given to patients who have recently completed orthodontic treatment. Remnants of bonding materials might interfere with the penetration of bleaching materials and adversely affect the bleaching result.

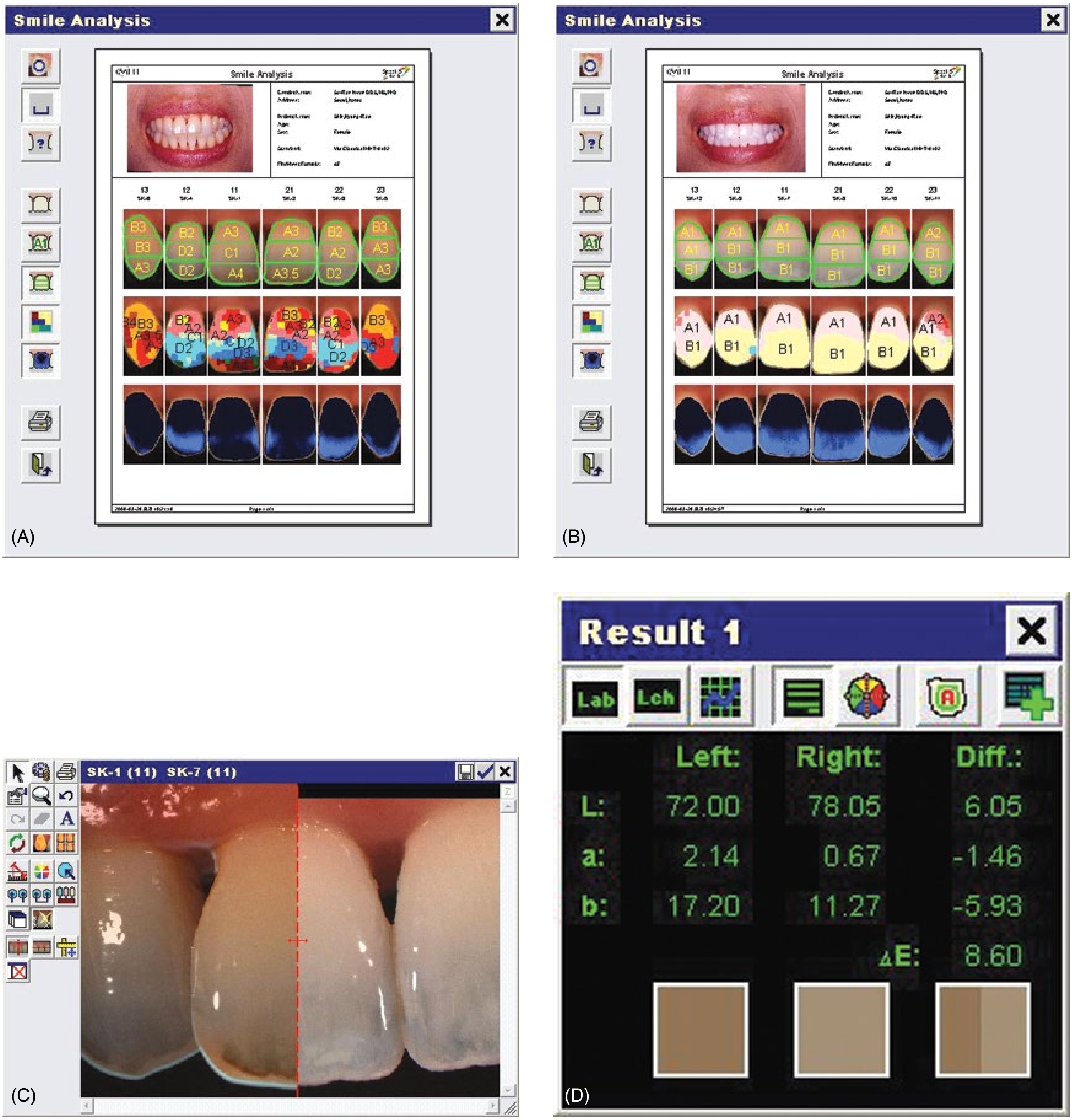

Figure 12.15 **(A–C)** The benefit of using complete tooth measurement devices in tooth bleaching is the ability to print out before and after smile analyses that can effectively motivate the patient into the treatment. The before and after images can also be synchronized. **(D)** Measuring the color change as expressed as ΔE.

3. Take steps to protect the patient from bleaching materials, light, and/or heat used. Explain in detail the necessity of the patient to protect their eyes with safety glasses until they are told to remove them.
4. Select the proper size of cheek retractors to protect and stretch the cheek and lips. The conventional rubber dam has been replaced by the use of cheek retractors and gingival protectors, due to the use of hydrogen peroxide gels or paste that can be easily localized onto the tooth surface.
5. Place cotton rolls, gauze, and saliva absorbent triangles to maintain a dry field. Dry the mucosa and place a resin

Figure 12.16 **(A)** Record the baseline color with a shade guide and take a photograph with the selected tab next to the teeth to be bleached.

Figure 12.16 **(B)** Free the teeth of all surface stains and plaque.

Figure 12.16 **(C, D)** Dry the mucosa and place a resin barrier (Opal Dam, Ultradent) to cover approximately 0.5 mm of the cervical area of the tooth and extend 2–3 mm onto the gingiva.

Figure 12.16 **(E)** Apply the highly concentrated bleaching material homogeneously onto the tooth (Opalescence Boost, Ultradent).

Figure 12.16 **(F)** Place a precut linear low-density polyethylene wrap (Saran wrap) onto the teeth to prevent evaporation of the active material and create a good seal.

Figure 12.16 **(G)** Use cotton pliers to seal the wrap around the incisal edges.

Figure 12.16 **(H)** Double check whether there are areas allowing any leakage of the bleaching material applied.

Figure 12.16 **(I)** The bleaching material is activated to facilitate the bleaching process.

Figure 12.16 **(J)** Remove the wrap and the bleaching material after 40–60 min.

Figure 12.16 **(L)** Remove the resin barrier with the explorer tip.

barrier to cover approximately 0.5 mm of the cervical area of the tooth and extend 2–3 mm onto the gingiva. Confirm with mirrors that there are no exposed areas of gingival and that all embrasure areas are protected. Light-cure the resin barrier and double check whether there are areas allowing any leakage of the bleaching material to be applied.

6. Apply the bleaching material homogeneously onto the tooth. Place a precut linear low-density polyethylene wrap (Saran wrap) onto the teeth to prevent evaporation of the active material and create a good seal.[41] Activate with light according to the manufacturer's directions.
7. Remove the bleaching material with a high-suction tip and rinse the teeth with copious amounts of lukewarm water. Depending on the severity of the discoloration new bleaching material can be applied and repeated several times to achieve maximum bleaching results.
8. Finish the in-office bleaching session with a 2% neutral sodium fluoride gel for 5–10 min to minimize sensitivity and remineralize the superficial enamel layer that might have been affected by bleaching. It is always best to whiten the upper and lower arches separately so that the patient can see the color change. For maximum bleaching another bleaching session can be scheduled with an interval of a week, or bleaching can be continued at home with a matrix in which case in-office bleaching would serve as a jump-start treatment to speed-up the whole process.

Figure 12.16 **(K)** Remove the remaining bleaching material with a high-suction tip and rinse the teeth with copious amounts of lukewarm water.

Figure 12.16 **(M)** Finish with a 2% neutral sodium fluoride gel for 5–10 min.

Apart from the dentist's decision to use a heating or light catalyst device, which is a matter of preference, there are several differences in the actual bleaching procedure to consider, depending on the etiology and severity of the discoloration as follows:

- The number of treatments required will differ. For teeth stained by coffee, tea, or other substances, a dramatic difference can appear in only one or two visits. This is also true for many cases of fluorosis-stained teeth. For tetracycline-stained teeth, three or more visits are generally required even if combined with an out-of-office matrix technique. We believe it is psychologically advantageous to prepare the patient for a longer sequence and to check carefully as the treatment proceeds, treating every 2–4 weeks.
- The solution itself will vary, depending on the severity of the stain. For most bleaching, a 30–35% concentration of hydrogen peroxide is used.

The patient needs to be told that the teeth may appear chalky because of dehydration and that they will darken over the next

Figure 12.17 **(A)** Before in-office bleaching.

Figure 12.17 **(B)** Following in-office bleaching treatment.

few days after treatment, although to a shade lighter than the previous one. Some patients experience heightened sensitivity to cold for 1–2 days and should avoid cold weather and cold drinks or food. Most patients are able to alleviate any discomfort in this period by taking two acetylsalicylic acid, acetaminophen, or ibuprofen tablets every 4–6 h. Caution patients that an annual "touch-up" bleach usually will be recommended for the removal of any new accumulated stain.

The longevity of tooth color change has been found to vary widely between patients.[30] This may be in part because of the inability of patients to remember change. Rosenstiel et al.[31] report only 1 of 10 young adults who received one vital bleaching treatment were able to see the effects of the treatment past 1 month, although colorimetry could still detect change. The best clinical evidence that color change is taking place is to check the upper to lower cuspid areas. Before-treatment photographs are especially important so these areas can be compared for both the patient's and your use in determining color change (Figure 12.17A and B).

Microabrasion

In cases of severe enamel stains on isolated teeth, you can use a microabrasion slurry (Prema, Premier, Opalustre, Ultradent), a combination of hydrochloric acid (muriatic acid) and pumice with mechanical abrasion, which will etch the enamel slightly to facilitate stain removal (Figure 12.18A–C). Another alternative is to use air abrasive technology (American Dental Technologies, Sunrise, or Kreativ). Although several seconds with air abrasive can remove certain stains, you must be prepared to bond the enamel surface if the technique is not successful. You can also use "macro-abrasion" as per Bodden and Haywood,[32] with friction grip diamonds or carbides with Soflex disk polishing.

Matrix bleaching (nightguard vital bleaching)

Matrix bleaching refers to bleaching procedures that the patient uses outside the dental office. Wearing a matrix fabricated by the dentist, the patient is able to apply bleaching material to the affected teeth while at his or her office, exercise facility, driving a car, or almost any place in daily life.

Nightguard vital bleaching has proven to be quite successful, with 9 out of 10 patients experiencing a lightening of their teeth in 2–6 weeks' application time.[5] There are three basic forms of matrix bleaching, involving different levels of dentist participation and supervision. Many patients who desire a rapid and effective result prefer a combined approach in which in-office bleaching is bolstered and continued by matrix bleaching sessions, enabling close monitoring of the process by the dentist. However, some patients prefer to use matrix bleaching only, still relying on the dentist's diagnostic and monitoring abilities. And finally, there is a growing trend toward whiteners sold over the counter that are intended for home use by unsupervised individuals. These three forms of matrix bleaching are discussed below.

Power and monitored matrix bleaching: a combined approach

The combination approach of one in-office bleaching session, using the stronger bleaching solutions with a heat/light device to speed the chemical reaction, and a sequence of matrix treatments controlled by the patient provides the most effective result seen to date.[33] With optimal patient selection, treatment, and compliance, the results of the dentist-monitored power/matrix bleaching provides the most predictable of all the bleaching techniques. The power bleach achieves immediate results. The creation of a matrix to fit the patient's own mouth increases the efficiency and safety of the home bleach sessions. The continuous nature of the matrix bleaching sessions with a milder solution permits refreshing of the bleaching when the brightening effect begins to regress, as occurs in all bleaching processes.

The Kor whitening system follows a very specific protocol, with both an in-office and an at-home whitening component. The first step requires home bleach trays to be made in Kor's lab in California, USA. Once delivered, the patient uses the trays to apply both bleach and desensitizer for 2 weeks. After the 2 week

Figure 12.18 **(A)** This 16-year-old boy was concerned about the hypocalcification in his maxillary central incisors.

Figure 12.18 **(B)** A series of three microabrasion sessions (Opalustre, Ultradent) was sufficient to remove the hypocalcification.

Figure 12.18 **(C)** The patient was pleased with his new, improved smile.

time period, the patient will undergo one or two sessions (depending on the severity of the stain) with Kor's in-office material.

Indications for power/matrix bleaching of vital teeth

Many of the conditions for which in-office bleaching has been appropriate are also appropriate for the power/matrix bleaching, although the patient must recognize that the matrix bleaching segment of the treatment depends on a milder bleaching solution. Compliance with the prescribed regimen is essential for success. The indications for which matrix bleaching is most often suggested are as follows:

- yellowed or discolored teeth in first degree and moderate second degree
- moderate yellow and/or brown tetracycline stains, and intrinsic stains (brown and yellow, as well as light to moderate gray), although the success depends on the severity and the ability of the teeth to absorb rebleaching as well as patient compliance
- patients who are not candidates for in-office bleaching because of hypersensitive teeth, time restrictions, financial considerations, or psychological objection to rubber dam placement.

Contraindications for power/home bleaching of vital teeth

- Extremely hypersensitive teeth as described in contraindications for bleaching, but also transient hypersensitivity that may occur with prolonged application. For example, in certain patients a potentiated 15% urea peroxide or a 10% hydrogen peroxide can lead to tooth sensitivity if worn more than 1–3 h per day. Instead, substitute with a lower concentration of carbamide peroxide (5–10%).
- Other hypersensitivity reactions, such as burning sensations, sore throat, nausea, irritation, or edema. These may indicate allergic reactions.
- Lack of compliance, whether through inability or simple unwillingness to wear the appliance the necessary 1–3 h per day.
- Severe discoloration, including cases for which all bleaching is assumed to be ineffective except as an adjunctive therapy.
- Teeth with extensive restorations may be contraindicated as well. Several studies have suggested in-office and matrix bleaching products cause degradation of resin composite surfaces,[27,34–36] although others disagree.[37] The costs of replacement may be an additional factor.

Preparing the patient for matrix-monitored bleaching

First use the appropriate procedure above for diagnosis, and preparation, for bleaching of the discolored teeth.

1. Take color photographs to provide a standard for comparison against the initial session. This will be especially useful since the patient has more control over deciding when renewal is needed.
2. An impression of the arch to be treated is made with an alginate or other accurate material, and a cast of durable stone is poured and trimmed. With the appropriate trimming of the cast, the vacuum-formed matrix will adapt completely over the cast with minimal creasing. Modeling clay or block-out compound may be used to block out significant undercuts. In addition, you may wish to incorporate a die spacer to create a reservoir.
3. A plastic nightguard-like matrix is used to completely cover all teeth to be treated and minimize the exposure of the gums to bleaching solution. It is constructed on a vacuum-forming machine. According to Haywood,[39] the best prosthetic material is a 0.9 mm clear soft material (Soft-Tray, Ultradent). Thin materials also diminish chances for a temporomandibular joint or occlusal problem.
4. Again, appropriate trimming is necessary to minimize injury to the soft tissue. In particular, the palatal portion and the majority of the matrix covering the gingival tissue must be removed with a scalpel or hot knife while the material is still on the model and with scissors, diamond disc, or a carbide acrylic trimming bur once it is removed from the model. Further adjustments must be made at the time of patient try-in. Trim the gingival margins as close as possible to the cervical margin of the teeth. The objective is to keep bleaching material in contact with the tooth surface and away from the tissue. Selective bleaching can also be accomplished by carefully trimming the matrix to include only the teeth to be bleached (Figure 12.19A and B).
5. Instruct the patient to place a drop of solution in the appropriate space around each tooth corresponding to the areas to be lightened, as in the written instructions given to the patient. The most common regimen is between 1 and 4 hours daily use from 4 weeks to 6 months (for tetracycline stain). Some companies recommend wearing the matrix up to 20 hours per day with the bleaching gel changed every 2–4 hours, but such long-term exposure of the soft tissue to bleaching materials has not yet been researched adequately. Most dentists, however, suggest 1–3 hours daily with one application or changing the solution once during that time. One suggested regime is to arrange the first session on the same evening as the power bleaching, with subsequent sessions every night for 3 weeks. Another is to have the gel worn every other night for 6 weeks (for laboratory procedures for bleaching tray fabrication see Figure 12.20A–H).

Most matrix bleaching uses 10–15% carbamide peroxide rather than the 35% hydrogen peroxide used in in-office procedures. However, several companies manufacture a three-tier bleaching approach beginning with a 5 or 6% solution and followed a week or so later with a solution percentage increased to 10 or 12%, and finally to a 15–17% solution. The advantage is to reduce possible patient sensitivity by beginning with lesser concentrations of hydrogen peroxide. The greater the concentration of urea peroxide and the thicker the material, the quicker the results will be and the less wearing time will be necessary. In our experience, more viscous solutions work best; they stay in the tray better and appear to provide the necessary time for the H_2O_2 to diffuse into the tooth, since the viscosity seems to prevent the saliva from breaking down the H_2O_2. The total diffusion into the enamel may allow for the tooth to be bleached more effectively from deeper within this enamel layer. In summary, 15% solutions work faster than a 5% solution, thicker gels generally work better than thinner ones, and dispersants with pigment are superior to those without.

The combination of power bleach and continued home treatment by the patient means there is little or none of the usual degradation of the lightening effect usually observed after the first in-office bleach since the home bleaching begins immediately and continues over the next 2 weeks. The costs of in-office bleaching with multiple appointments are lowered, the patient has control over when the bleaching is to be enhanced, and there is minimal exposure of the tissue to the bleaching agent.

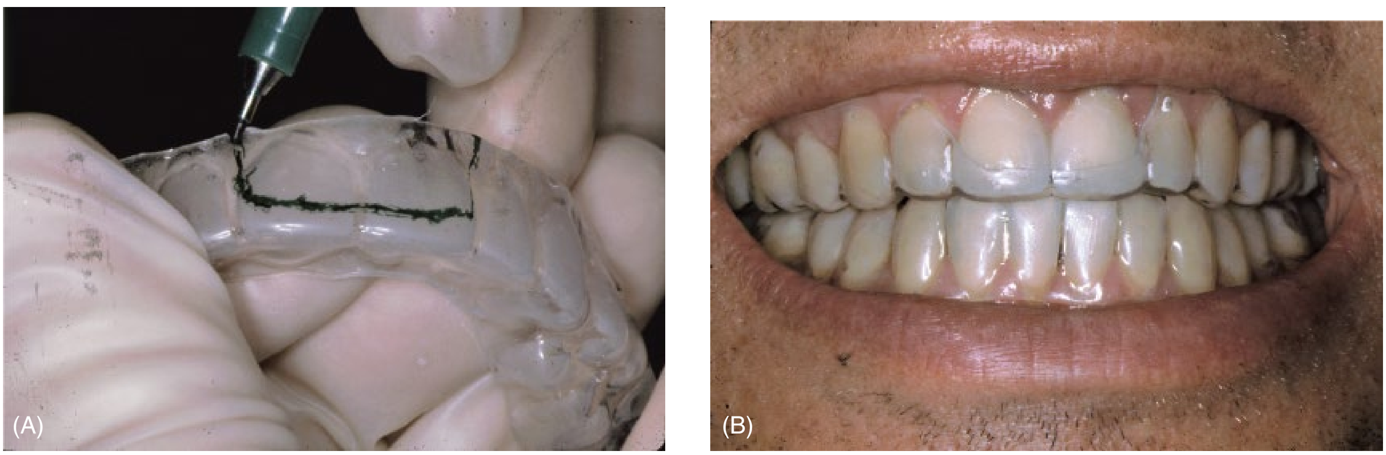

Figure 12.19 **(A, B)** Selective bleaching can also be achieved with matrix bleaching by removing specific areas in the matrix.

Figure 12.20 **(A)** An alginate impression of the arch to be treated is made, and stone is poured carefully to avoid any bubble or void formation.

Figure 12.20 **(B)** The stone model is trimmed so that the base is flat and parallel to the occlusal plane.

Figure 12.20 **(C)** The gingival margin on the stone model is redefined with a sharp instrument to create a better seal around the tray margin.

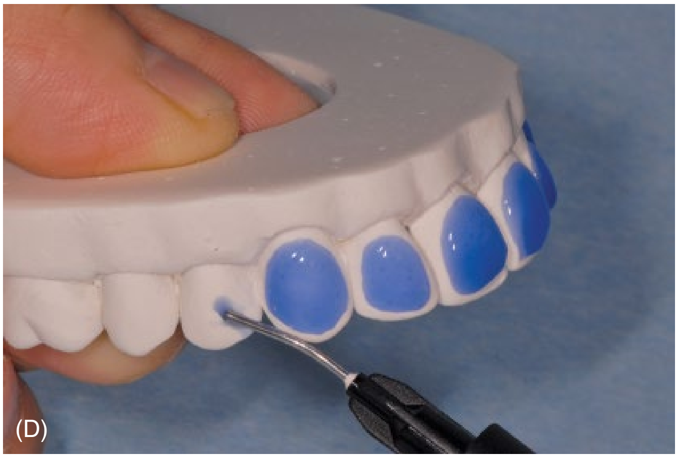

Figure 12.20 **(D)** A thin layer of block-out resin can be placed on the buccal surface as a reservoir for the bleaching material.

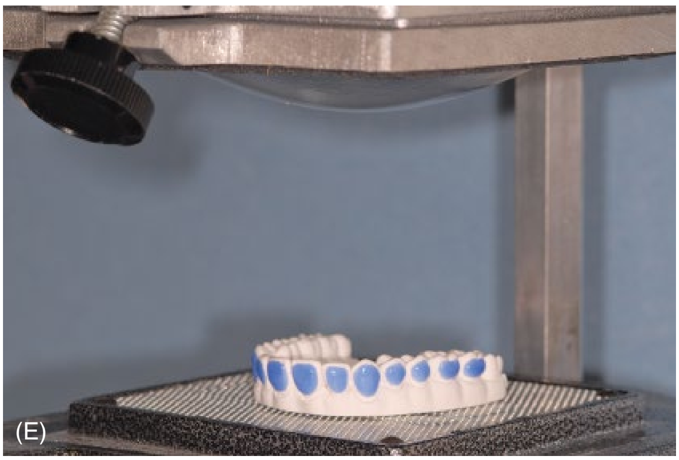

Figure 12.20 **(E)** A soft and thin sheet is heated in a vacuum-forming unit until it sags 12 mm.

Figure 12.20 **(F)** The tray is trimmed with sharp scissors approximately 0.5 mm away from the gingival margin to create a scalloped pattern on the buccal surface.

Figure 12.20 **(G)** The lingual border is extended 2 mm from the gingival margin in a straight pattern.

Figure 12.20 **(H)** The finished tray is cleaned and stored in a tray case until delivery to the patient.

Home bleaching without dental supervision (over-the-counter systems)

When the mouthguard vital bleaching technique burst upon the scene in the late 1980s, product claims often exceeded the proof of research or clinical experience. As Haywood outlines in a detailed history of the FDA's influence on home bleaching,[5] before the FDA stepped in to attempt to control home bleaching products intended for over-the-counter sales, there was virtually no control on ethical advertising to the public. People were buying various kits and products that in many cases were contraindicated for the very problem they were trying to solve. Although some people asked the advice of their dentists before embarking on their purchased treatment package plan, many did not.

The controversy over home bleaching has been an interesting, and in many ways helpful, time for dentistry. In 1991, the FDA ruled that the use of carbamide peroxide in the form advocated for home bleaching constituted a new drug use and hence was subject to new drug approval process. The agency did not make a distinction between the home bleaching provided by dentists and the home bleaching kits the consumer could pick up in a department store. (Thirty-five percent hydrogen peroxide used for in-office bleaching was considered to be "grandfathered" because of its long time use for this purpose.) Because of this ruling, manufacturers were forced to submit evidence to back up their claims of the efficacy of bleaching materials, or to demonstrate these materials' safety. Consequently, many small manufacturers faced closure because they lacked the resources to do so, and inferior products were more likely to be taken off the market. The ruling also forced manufacturers of materials sold directly to dentists to examine whether their products could meet the new drug standards.

The FDA appears to have reconsidered its position, especially concerning distinctions between home-bleaching agents meant for use under dental supervision and those meant for sale to the general public. Possible negative effects would include a restricted supply market to the dentist, with the removal of adequate but less costly materials. However, there have been many positive effects already, including a public made more aware of the risks of unsupervised home bleaching, increased funding for research in this area, a recognition by many general dentists that they must stay current with laboratory and clinical research literature for the good of their patients, and a greater involvement by the dental organizations in the federal and public arenas.

The earlier sections have described the advantage of having a dentist involved in home bleaching, with the correct diagnosis and decision on appropriate treatment, the recognition and management of side effects, and the use of more potent or highly viscous materials. Other reasons, as outlined by Haywood,[5,40] include the following:

- A thinner, softer, better fitting mouthguard can be constructed, increasing patient comfort and minimizing side effects due to tissue or tooth irritation.
- Not subjecting the person to the dangers of using boiling water in the self-fabrication of the mouthguard.
- Adjustment of the occlusion on the mouthguard to minimize any potential temporomandibular joint problems.

Tooth sensitivity during vital bleaching

Tooth sensitivity during bleaching is the most prevalent side effect to treatment, and the dental office should be prepared to offer treatment options. Tooth sensitivity experienced during bleaching can be treated actively or passively by the dentist. Passive treatment consists of reducing either the duration of each treatment (fewer hours) or the frequency of treatment (skip days). Originally, the only active treatment cited was the use of a neutral fluoride gel placed in the tray at the onset of sensitivity. Some current bleaching products now incorporate a neutral fluoride with no apparent compromise of the bleaching process (15% opalescence with fluoride, Ultradent). The mechanism of action of fluoride is as a tubular blocker.

Another active approach to treating sensitivity involves the use of 5% or less concentrations of potassium nitrate applied in the bleaching tray. Potassium nitrate is generally found in desensitizing toothpastes, which are applied via brushing.

This application technique generally takes 2 weeks to see results. Because the application of toothpaste in a bleaching style can cause gingival irritations in some patients, dental companies have now introduced products of potassium nitrate with and without fluoride in a base barrier (Desentize, DEN-MAT; UltraEZ, Ultradent; Relief, Discus Dental). The mechanism of action of potassium nitrate is different from that of fluoride. Potassium nitrate is thought to act to chemically depolarize the nerve to inhibit refiring[7] and is a good adjunct for any type of chronic sensitivity, as well as bleaching sensitivity.

Maintaining bleaching results

Although both in-office and matrix techniques can produce effective results, the advantage of the latter technique is that it will allow for touch-ups or retreatment as necessary. As long as the matrix continues to fit properly, new solution can be given to the patient for an additional series of bleaching treatments every few years or as needed. Generally it may be 3 years before retreatment is desirable.[40,41]

In-office bleaching of nonvital teeth

The pulpless tooth is frequently an excellent candidate for bleaching. The fact that the pulp is already nonvital immediately removes one of the major concerns of in-office bleaching; that is, the intense heat will cause damage to the pulp. While you should remain within the upper limits of the normal range of heat due to possible internal or external resorption, the ability to use higher temperatures without causing the patient discomfort will enable you to increase the rate at which the bleaching agent is effective. However, for many patients, custom-designed matrix bleaching trays may be used.

Garretson[42] first bleached nonvital teeth at the turn of the twentieth century. The presence of a pulpless chamber inspired dentists such as Pearson[43] to use chemicals with both bleaching capability and oxygen-releasing capability to provide the same activation of bleaching as heat does in bleaching for nonvital teeth. He left his bleaching agent, Superoxol, in the pulp chamber for 3 days. Nutting and Poe's "walking bleach" technique[44] went another step: Superoxol and sodium perborate are sealed in the pulp chamber for as long as a week. A range of choices is important in treating nonvital teeth since the discoloration can range from mild to extreme.

Etiology of discoloration

Although nonvital teeth are subject to external and other stains, the primary discoloration of the nonvital tooth is likely to come from within the pulp chamber itself, resulting from pulp degeneration, with or without hemorrhage. Pulp hemorrhage is more likely to cause pronounced discoloration than pulp degeneration not accompanied by hemorrhage. In fact, according to Ingle,[45] the greatest amount of discoloration seen is in the traumatized anterior tooth. Nutting and Poe[44] also list necrotic pulp tissue with pulp hemorrhage as the factor most frequently responsible for tooth discoloration. Trauma severe enough to cause pulp death also causes the rupture of blood vessels into the pulp chamber. The blood from the ruptured vessels is driven into the dentinal chamber where the red blood cells undergo hemolysis, exuding hemoglobin. This released hemoglobin is further degraded, releasing iron, which forms a black compound by combining with hydrogen sulfide to become iron sulfide. The resultant necrotic tissue contains various protein degradation products that create the familiar grayish-black discoloration of the tooth.

After pulp necrosis, the most frequent cause of discoloration is an incomplete root canal in which pulpal debris is left in the tooth. Pulp remnants, residual tissue in the pulp horns, filling material, and medicaments all can lead to discoloration. Spasser[47] has noted that color changes also may be caused by a root canal sealer containing eugenol, Canada balsam, or precipitated silver. Since nonvital teeth are deprived of tissue fluid, fluid may penetrate them more easily than vital teeth.

Whatever the cause, the degree of discoloration is directly related to the length of time between pulp death and treatment. The longer the discoloring compounds are in the chamber, the deeper the penetration into the dentinal tubules and the greater the discoloration. Discoloration of long duration presents the greatest challenge to successful treatment.

Contraindications to bleaching of pulpless teeth with concentrated hydrogen peroxide (35%)

It remains as true as when Nutting and Poe first stated it more than 50 years ago:[44] prudent case selection is vital to a successful esthetic result. The primary requirement for bleaching is the existence of an adequate root canal filling. Contraindications include the following:

- small amount of remaining dentin
- extensive restorations: there may not be sufficient tooth structure to make bleaching worthwhile
- restorations with composite or acrylic resins, since as Cohen and Parkins[18] point out, the bleaching technique probably causes temporary dehydration; however, this may only be a problem if your patient does not want or need to replace his or her restorations following bleaching
- cracks and hypoplastic or severely undermined enamel
- discoloration by metallic salts, particularly silver amalgam; the dentinal tubules of the teeth are virtually saturated with the alloys and no amount of bleaching with available products will significantly improve the esthetic quality of these teeth.

Techniques for bleaching pulpless teeth

The choice of techniques employed for bleaching pulpless teeth will depend on the degree of discoloration and patient compliance. In all procedures, the purpose is to allow the bleaching agent to release oxygen in a concentration high enough to

Figure 12.21 **(A)** This young woman was self-conscious about her discolored central incisor.

Figure 12.21 **(B)** After an adequately sized access opening was made, gutta percha is removed to slightly below the gingival line.

Figure 12.21 **(C)** After bleaching, the patient's nonvital tooth blends in nicely with her other teeth.

penetrate the stained dentinal tubules and neutralize the discoloration (Figure 12.21A).

Preparation

Preparatory procedures are similar whether in-office or walking bleach techniques are to be used.

1. Isolate the tooth or teeth. To protect the patient's tissues from the highly concentrated bleaching material, use a well-fitted rubber dam of heavy material. The size of the hole punched is also important; too small a hole will cause the dam to tear. Since tears can allow leakage, a torn dam should be removed and the cause for the tear found and corrected. A ligature may be placed around the tooth if desired but this is not usually necessary. Before placing the dam, the gingivae should be coated with Oraseal (Ultradent) as a precaution against damaging the periodontal tissue if some of the bleaching material should seep through the dam. After the dam is sealed, the lubricant may be applied with a cotton applicator on the labial and lingual surfaces. Meticulous care must be taken to ensure the tissue is completely protected. When the dam is in place, additional lubricant can be used in the interdental spaces by using a small plastic instrument. Extreme caution also must be used to ensure that the solution does not come in contact with the lip, which could result in an unsightly disfiguring lesion with extensive edema. (However, these lesions generally heal without scarring.)
2. After isolation, the tooth is meticulously cleaned. Any caries in the crown should be excavated and any leaky or washed out restorations replaced.
3. Establish a lingual opening of sufficient size to secure proper access to the entire pulp chamber and orifice of the root canal. B. Seidler (personal communication to R.E. Goldstein) suggests using a #8 round bur for initial entry into the chamber and for removal of the necrotic tissue. A smaller bur should be used in lower anteriors and in those teeth in which pulp recession would be evident radiographically.
4. Remove all debris and the surface layer of dentin within the pulp chamber with a slow-rotation bur. The freshened dentin permits easier penetration of the bleaching material. Since the dentin will be bleached as well as the enamel, the more mature the tooth and the greater the amount of dentin present, the longer the effect will be retained following bleaching. For this reason, preserve as much dentin as possible.

5. In endodontically treated teeth, the root canal filling material should be removed to a depth of 2–3 mm apical to the cervical line. This distance may be extended if the gingival recession has been severe. Ingle[45] recommends that the root canal filling be removed to a level well below the height of the labial gingivae, although Grossman[47] recommends that the root canal filling extend only to the gingival margin (Figure 12.21B).
6. Remove any surface stains visible on the inside of the preparation with a bur. The apical seal should be checked and secured at this time.
7. The entire preparation should be swabbed with acetone or xylol to dissolve any fatty material and facilitate the penetration of the bleaching agent into the tubules. The chamber should then be blown dry.
8. Cover the root canal filling with zinc phosphate cement, polycarboxylate cement, glass ionomer, or Cavit, 2 mm thick, since bleaching agents may affect the root canal sealer. Bleaching should never be attempted on any tooth without a complete seal in the root canal since the agent could escape through a porous root canal filling and cause the patient extreme discomfort. If this should occur, heavy sedation will be required to mask the pain, and removal of the bleaching agent and the root canal filling may be required to restore comfort.

Some improvements can be obtained in difficult cases by sealing H_2O_2 or sodium perborate wetted with H_2O_2 on a cotton pellet inside the pulp chamber between bleaching appointments. Bleach the teeth a little higher than the final shade desired to compensate for anticipated slight darkening (Figure 12.21C).

Inside-outside tray bleaching technique

This technique was described by Settembrini and Liebenberg[48] in 1997 to bleach the discolored tooth from the inside as well as from the outside with a 10% carbamide peroxide solution retained in a custom-fitted tray. The major advantage of this technique is that the nonvital discolored tooth can be bleached together with the adjacent vital teeth. However, the periodic insertion of whitening material and cleaning of the access cavity can be burdensome. There is also possibility of tongue irritation from the margins of the open access cavity. The preparation for the inside–outside bleaching technique is the same as for the walking bleaching technique up to the placement of the barrier material.

1. Deliver a custom-fitted tray and 10% carbamide peroxide solution to the patient.
2. Give instructions on how to insert the bleaching gel into the cavity and into the tray.
3. Show the patient how to clean the open access cavity with the use of an empty syringe.
4. Have the patient return to the office, once the teeth have whitened.

Out-of-office bleaching technique (or walking bleach)

Follow the same preparation techniques given earlier.

1. On a glass mixing slab, prepare a bleaching paste of peroxyborate monohydrate (Amosan) or sodium perborate and enough 35% hydrogen peroxide to form a thick white paste.
2. Fill the entire preparation with the bleaching paste, leaving adequate space to place a temporary restoration and sealer (Figure 12.22). Make certain that the seal is effective as moist paste can damage tissue if it leaks into the pulp chamber. One method is to carefully apply a solvent (Prep Dry, PrimaDry [Ultradent]) around the enamel margin and flow a medium-stiff mix of Cavit to close the area. If the patient experiences a burning on the tongue, rinse until the sensation is gone.

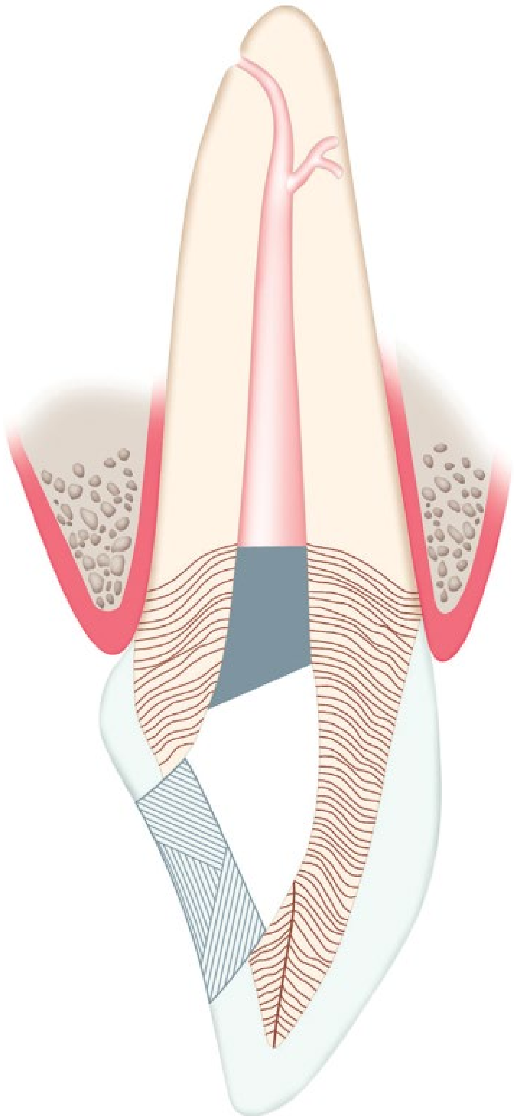

Figure 12.22 The walking bleach requires an effective seal for the bleaching paste to remain active. From reference 61.

3. Have the patient return in 3–5 days. If the degree of bleaching is not sufficient, repeat the entire procedure. Again, a slight overbleaching is desirable since teeth tend to darken slightly after the final bleach.

Finishing

On return to the office after completion of the inside–outside or conventional walking bleaching technique, the orifice to the nonvital tooth is debrided and temporarily sealed for 2 weeks with a noneugenol-containing temporary cement. A noneugenol-containing material is used to avoid future contamination of the acid-etched composite restoration, which will be used to close the orifice to the canal and make any final minor color adjustments by varying the composite color internally. Placement of the final restoration is delayed for 2 weeks to allow the oxygen generated during bleaching to dissipate from the tooth and the shade to stabilize. The presence of residual oxygen in the tooth results in the reduction of bond strengths[7] and an artificially light shade. Two weeks after termination of bleaching, the bond strength potential will have returned to normal,[7] and the shade will have stabilized. This shade stabilization (a slight darkening) is thought to occur from the change in optical qualities of the tooth after residual oxygen generated during the oxidation process of bleaching has diminished. Two weeks after a completion of bleaching, the temporary stopping is removed, and the orifice is occluded using an acid-etched composite as follows:

1. Remove the cotton or bleaching paste and swab the preparation throughout with acetone or xylol.
2. Air dry internally and throughout the bleached crown to penetrate and seal the dentinal tubules and to maintain the tooth's translucency. Use several coats of a clear dentin bonding agent to prevent recurrent coronal stain.
3. Etch the marginal walls with 35% phosphoric acid to assure good mechanical bonding. The entire restoration is placed at one time and finished properly to assure good marginal adaptation.
4. Apply a dental bonding agent and cure before filling the cavity with composite resin restorative materials of the lightest shade esthetically compatible with the tooth. Use a composite with a good dentin bonding agent, being careful to etch the enamel walls before restoring the final area. A microfill or polishable hybrid is the best material to use because it allows a polished surface to blend with the adjacent enamel surface. A typical result is seen in Figure 12.23A and B.

Planning for continued treatment

You must use your clinical judgment to decide if rebleaching would effect greater improvement. If the tooth shows significant improvement, then the solution chosen obviously contained the solvent for the stain and rebleaching is likely to continue improvement. Conversely, if results are not obtained, bleaching out the discoloration may not be possible. It may be advantageous to employ one or two parts of HCl in such instances as an added solvent before abandoning the procedure as ineffective. Try at least three to four visits.

You also must use your clinical judgment about the length of time a tooth is likely to remain bleached. Spasser[46] notes that the determining factors include the amount and depth of the external enamel cracks and the integrity of the marginal seal of the restoration. Hayashi[51] reports that discoloration may also recur in time from penetration of pigments in the saliva into the dentinal tubules. To help prevent pigment penetration into the dentin, Grossman[47] recommends putting silicone oil in the cavity after bleaching. Silicone oil will not evaporate and has a low surface tension which will help the dentin retain it. If the discoloration occurs one to three years after the initial treatment, you can retreat using dentist-monitored home treatment.

Figure 12.23 **(A)** This severely gray-brown nonvital tooth is a good candidate for bleaching.

Figure 12.23 **(B)** A 3 week walking-bleach technique was sufficient to regain the original tooth color for this man.

Complications and risks

Cervical root resorption

Cervical root resorption related to intracoronal bleaching is a complication that was first reported by Harrington and Natkin in 1979.[52] Heithersay analyzed cervical resorption cases and reported that 24.1% were caused by orthodontic treatment, 15.1% by dental trauma, 5.1% by surgery, and 3.9% by intracoronal bleaching.[53] The combination of bleaching and history of trauma seems to be the most important predisposing factor for cervical resorption.[53] Several theories have been proposed to explain the mechanism of cervical root resorption. It has been postulated that the bleaching material may diffuse into the periodontal ligament and initiate an inflammatory reaction, denaturation of dentin proteins, or a decrease in pH, thereby activating osteoclastic activity leading to resorption.[54–56] Consequently, there is a special risk factor in young patients with relatively wide open dentinal tubules and in patients with a natural anatomic defect between the cementum and enamel at the level of cemento-enamel junction.[57] Application of heat leads to widening of dentinal tubules and facilitates the diffusion of hydrogen peroxide into dentin.[58] Higher risk of cervical root resorption associated with the thermocatalytic bleaching technique has reduced its use in intracoronal bleaching.[59]

Cervical root resorption is usually detected on follow-up radiographs and may present clinical symptoms as gingival swelling and sensitivity to percussion. Remineralization can be attempted at the early stage but if the resorption has progressed, exposure of the lesion with a crown lengthening procedure or forced eruption followed by an appropriate filling is required.

Color relapse

Optimal color match with adjacent teeth can be achieved after intracoronal bleaching. However, color relapse can be observed occasionally, which is presumably caused by the penetration of staining substances through marginal gaps between the tooth and the restoration.[60]

The future of bleaching

The history of bleaching has been one of continued improvements in bleaching materials, delivery systems, and devices to activate the bleaching action. In order to develop the ideal bleaching agent that is indicated for a specific discoloration, there needs to be more accurate ways to assess, quantify, and describe the discoloration. There also needs to be better understanding on the mechanism of bleaching so that dentists can better predict for which patient it will be most successful. The mechanism of color regression needs further investigation. Researchers and clinicians do not know why some patients' teeth remain stable over extended periods, while other patients' teeth regress in color. It is also not known whether the color regression is a result of recolorizing of the oxidized stain molecule or whether it results from the combination of new stains and the aging process.

And finally, the sudden surge of bleaching kits intended to be used with little or no dentist monitoring makes the need for more research into the long-term safety and effects of such materials imperative. Dentistry must maintain control of both research and treatment for maximum patient protection and success rates. As scientists learn more about bleaching efficacy, safety, and longevity, the technique will no doubt continue to be at the top of the list of esthetic modalities.

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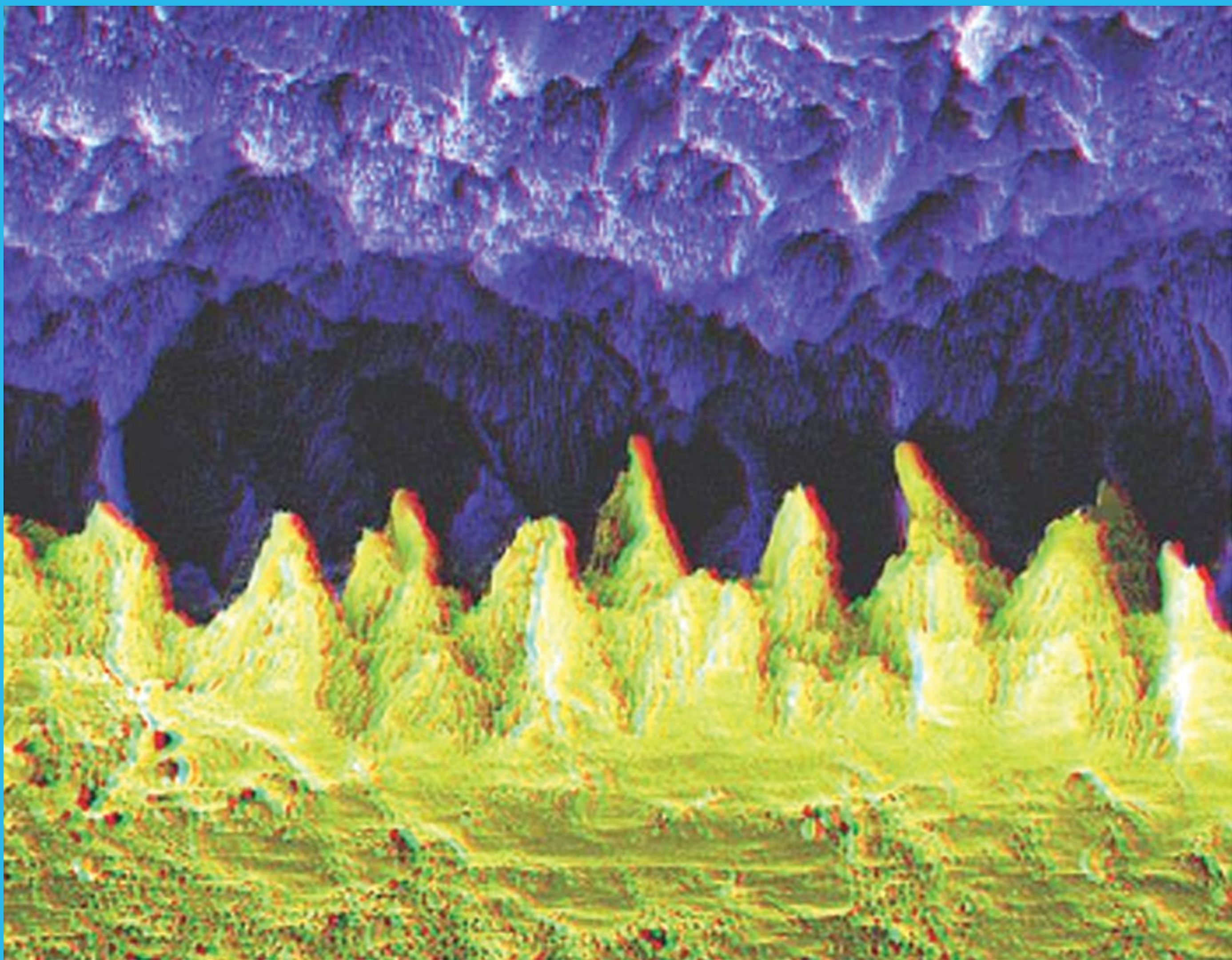

Chapter 13 Adhesion to Hard Tissue on Teeth

Roland Frankenberger, DMD, PhD, Uwe Blunck, DDS,
and Lorenzo Breschi, DDS, PhD

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Introduction

Resin composites do not adhere to enamel and dentin by themselves like, for example, glass ionomer cements. Therefore, after polymerization, marginal gaps would be the logical consequence. These would even be deteriorated by different coefficients of thermal expansion (tooth/restorative) and mechanical load.[1–12] Without appropriate pretreatment, strength, and durability, adhesion is impaired (Figure 13.1); therefore, adhesive retention is a fundamental prerequisite for resin composites.

Recurrent caries is still estimated to be one of the main reasons for resin composite restoration failure, especially in stress-bearing areas. The integration of adhesion concepts led to a breakthrough for the clinical use of resin composites.[13–26]

Adhesive dentistry gained considerable importance within the field of modern restorative dentistry and it is meanwhile established as daily routine. Only with durable adhesion to tooth

Ronald E. Goldstein's Esthetics in Dentistry, Third Edition. Edited by Ronald E. Goldstein, Stephen J. Chu, Ernesto A. Lee, and Christian F.J. Stappert.

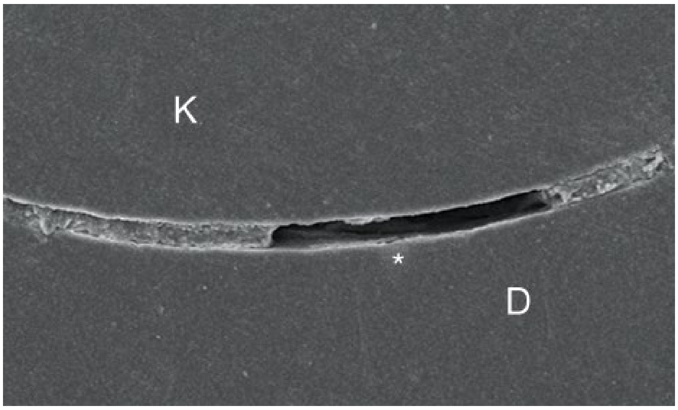

Figure 13.1 A gap under the scanning electron microscope (SEM; 1:500). K, resin composite; D, dentin.

hard tissues is it possible to reach the goal of true minimally invasive restorative therapy. Today, adhesive dentistry is based on minimum loss of hard tooth substrate by rotary burs during preparation and treatment of recurrent caries in the case of adhesive failure.

Basics about adhesion

Definitions

Adhesion means "bonding of different substances in tight contact." Molecular adhesion forces cause this when two bodies are close together. In most of these cases, there is a solid adhesive substrate and a liquid phase called adhesive.[27]

There are different explanations for adhesion phenomena. Rough and porous surfaces lead to mechanical and microretentive adhesion, while adhesive and substrate are able to act via chemical bonding such as ionic bonding, covalent bonding, hydrogen bonds, and van der Waals forces.[27–30] The majority of studies in the field of dentistry assume that the resin-enamel and resin-dentin bond are of a micromechanical nature mainly because chemical interactions have seldom been reported.[31–33]

Prerequisites

Tight contact (0.1 nm) is the main factor for adhesion. Bodies and surfaces, however, have direct contact only in special areas; therefore, a liquid phase must fill remaining spaces as a guarantee for increased wettability.[34–36] Ideally, the adhesion substrate provides high surface energy and the adhesive low viscosity (i.e. surface tension). Additionally, surface roughness is another important factor for adhesion by resulting in increased surface area. Micromechanical interlocking is caused by filling the gaps and irregularities between substrates.[12,37–39]

Chemical bonding exists when two atoms use the same electrons. Hydrogen bonds and attraction of polar groups are physical adhesion phenomena. To allow for chemical adhesion, distances of <0.7 nm have to be provided.[39]

Durable, tight contact is the most important prerequisite for strong bonds. Because it is not possible to bring two bodies into 100% tight contact, liquid phases ("adhesives") with good wettability are used to compensate for differing distances. In order to level this discrepancy, low-viscosity materials are used. An additional advantage is the combination of a substrate with high surface energy and an adhesive with low viscosity. When irregularities of bonded surfaces are more or less completely filled, micromechanical attachment is obtained. It is primarily of mechanical nature and based on rheological and geometrical effects.

Roughening of dental surfaces must be generated by appropriate pretreatment. Micromechanical interlocking is based on physical attachment of adhering parts and provided by filling of voids and irregularities.

Enamel bonding

The fundament of dental adhesion was published in 1955 with the introduction of the enamel etch technique by Dr Michael Buonocore.[40] Although Dr Oskar Hagger reported something similar[41] in 1948, the actual invention of enamel etching dates back to Buonocore.[34–36]

Adhesion mechanisms to enamel

Conditioning with phosphoric acid

With regard to clinical success, adhesion to enamel via phosphoric acid etching is estimated positively. It creates an ideal surface morphology (Figure 13.2) for micromechanical attachment of resin composites. Due to the different solubility of enamel prisms in their center and periphery, a rough structure is created and penetrated by unfilled or filled adhesives then bonded by polymerization. The resulting adhesion is sufficient to counteract the polymerization stresses of resin composites under clinical conditions. Furthermore, stabilization of previously weakened tooth structures occurs.[36–43]

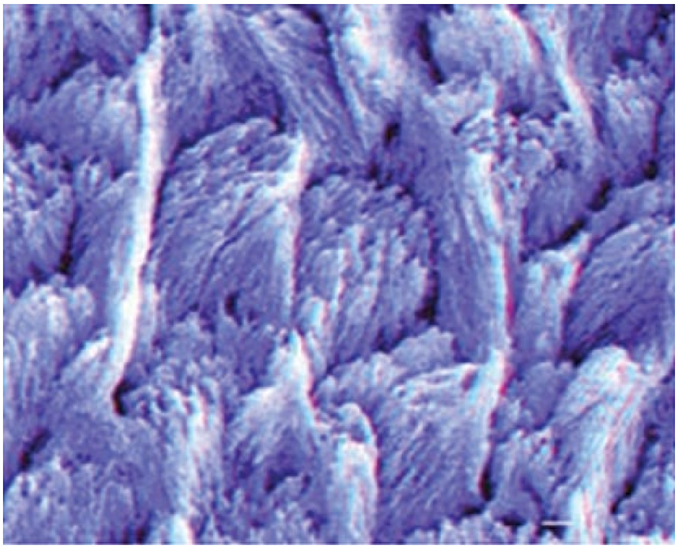

Figure 13.2 Etch pattern (bevelled enamel after 15 s etching with phosphoric acid, SEM, 1:3000).

Enamel consists of 98% inorganic material by weight, i.e. hydroxyapatite crystals. Crystallites form prisms, which differ in solubility by acids in various areas, providing a typical etching pattern. Prismless enamel is detectable only in very outer and not abraded layers (e.g. in pits and fissures). Etching time has to be prolonged to 60 s in order to dissolve prismless enamel areas. Phosphoric acid irreversibly removes about 10 μm enamel with a roughness of 50 μm underneath, the so-called etch pattern.[44]

The retentive etching pattern provides high surface energy allowing good wettability of etched enamel. Phosphoric acid products are normally provided as gel in concentrations of 35–40% applied for 15–60 s followed by rinsing with air/water spray to remove both acid and precipitates formed during acid etching. Shorter etching times are possible on prepared enamel. To guarantee successful wetting of the etched enamel surface, appropriate isolation has to be obtained during treatment to avoid contamination with blood, saliva, sulcus fluid, or oil. Any contamination impedes penetration of low-viscosity adhesives into the retentive surface and corroborates retention.

The optimum utilization of differently soluble enamel surfaces is possible when they are cut rectangularly during bevelling of cavosurface margins (Figure 13.3). With enamel prisms being cut longitudinally, the adhesive may only penetrate into the laterally loosened enamel parts.[44] The necessity of enamel bevels, especially in posterior teeth, was always controversial. Although several in vitro reports describe a positive effect,[45] there is no clinical proof for this paradigm.[25]

The concentration of phosphoric acid is of some importance, with 30–40% as the most effective concentration. Three-dimensional etching depth is increased up to 40%; however, higher concentrations dissolve less calcium and cause shallower etching patterns. Concentrations of <27% have less soluble precipitates. These concentrations are not gentle or as effective as higher concentrations, despite the claims of some advertisements. The ideal mix is 37% and 30 s.[46,47]

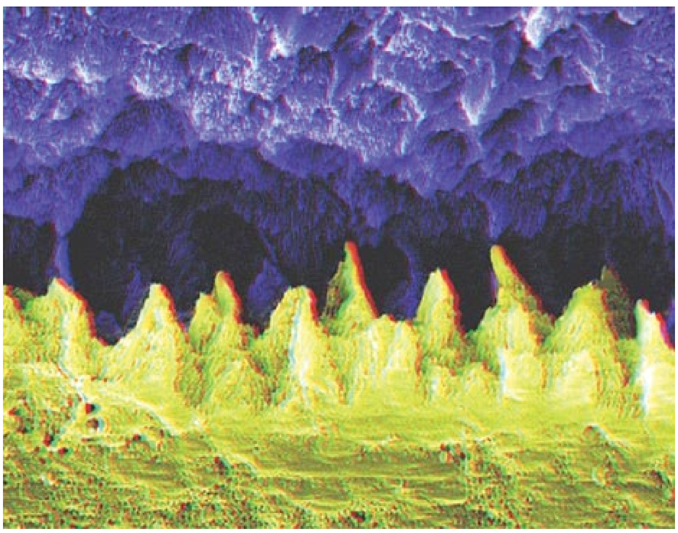

Figure 13.3 Micromechanical interlocking of resin tags (yellow) with etched enamel (blue) (SEM; 1:3000).

The actual bond to enamel is obtained by functional adhesives based on bis-GMA, sometimes diluted with triethylene glycol dimethacrylate (TEGDMA). Resin tags guarantee micromechanical interlocking. Another way in which micromechanical interlocking is guaranteed is by intercrystallite retention.[34–36,46,47]

In any case, separately applied primers have to be brushed no longer than 15 s on previously etched enamel in order to avoid any destruction of the fragile etch pattern.[42]

Self-etch adhesives

Having been actually developed for gentle conditioning of dentin, self-etch adhesives are also routinely used for enamel bonding. Based on market data these adhesives are the most popular in the world. These adhesives contain acidic primers or acidic monomer mixtures providing pH values of between <1 and 2. These adhesives are classified according to their acidity (Table 13.1).

Etching effects of these adhesives are normally less pronounced than after phosphoric acid etching, and enamel bevels are more mandatory than with etch-and-rinse adhesives. Both efficacy and durability of bonding to enamel, generated by self-etch adhesives, are debated in the literature. Our own results

Table 13.1 pH Values of Self-Etching Primers and Universal Adhesives

Strong (pH <1)	Adper Prompt L-Pop (3M Espe) AquaPrime & Monobond (Merz Dental) Xeno III (Dentsply)
Moderate (pH ≈ 1.5)	AQ-Bond (Morita) Bond Force (Tokuyama) Clearfil Liner Bond 2V (Kuraray) Clearfil SE Bond (Kuraray) Clearfil Protect Bond (Kuraray) Clearfil Tri-S Bond (Kuraray) G-Bond Plus (GC) Hybrid Bond (Morita) iBond GI (Kulzer) One Coat SE Bond (Coltène) Unifill Bond (GC) Xeno V (Dentsply) Peak Universal Adhesive (Ultradent))
Mild (pH ±2)	Contax (DMG) Futurabond U (Voco) iBond Self Etch (Kulzer) Optibond Solo Plus SE (Kerr) One-up Bond F (Tokuyama) Revolcin One (Merz) Prime&Bond Elect (Dentsply) Scotchbond Universal (3M Espe)
Ultra-mild (pH >3)	All-Bond Universal (Bisco) Adhese Universal (Vivadent)

have always been worse for self-etch adhesives compared to etch-and-rinse adhesives.[5] Studies from Berlin reported marginal quality of Class I restorations and clearly showed similar results. Other studies also confirm these findings. Several authors showed that the efficiency of self-etch adhesives in enamel may be increased by selective phosphoric acid etching of enamel margins.[27,48–52]

Phosphoric acid etching, however, can compromise the efficiency of self-etching adhesives on dentin.[53] Therefore it may be better to completely avoid dentin etching or at least limit it to 10 s or less.[54] This aspect will be discussed later together with the effect of phosphoric acid etching on dentin cavity walls.

Historical development

The first- and second-generation adhesives never reached clinically relevant efficacies because they only bonded to smear layers;[12,35,36,38,55,56] however, the adhesion of smear layers to underlying dentin was too low to counteract polymerization shrinkage of resinous materials. The first documented clinical success was accomplished with so-called third-generation adhesives such as Gluma (Bayer Dental), Syntac (Ivoclar Vivadent), or A.R.T. Bond (Coltène Whaledent). In this scenario, prepared enamel is selectively conditioned with 30–40% phosphoric acid[57,58] followed by the application of primers providing acidic monomer mixtures for smear layer dissolution on dentin. Under clinical circumstances selective enamel etching is nearly impossible. Therefore, simultaneous etching of enamel and dentin was desirable and was realized by the fourth generation including a simultaneous etching of enamel and dentin with phosphoric acid, which is removed by rinsing. After conditioning of enamel and dentin with phosphoric acid, the application of first a hydrophilic primer followed by a more hydrophobic adhesive is a characteristic of these fourth-generation adhesives.

Dentists' wishes for more simplification led to the development of the fifth generation as "one bottle bonds." Although the literature in the field mainly reflects inferior results with this generation,[59–68] its easier handling guaranteed marketing success. Phosphoric acid etching the dentin always has one central problem: the collagen network exposed after phosphoric acid etching must be penetrated by hydrophilic monomers and therefore the fibrils must not collapse; otherwise, penetration is insufficient.

To avoid this problem in general, sixth-generation adhesives were developed, without phosphoric acid etching, called self-etch adhesives, containing primer having acidic pH values. They allowed demineralization of enamel and dentin while simultaneously penetrating the demineralized structures, providing a depth of demineralized dentin identical to that of the penetrated area. The applied acidic components are intentionally not rinsed off to guarantee appropriate function of the priming parts. After the self-etching primer, a conventional adhesive is applied. Due to problems regarding chemical stability of monomers in acidic environments, earlier products had to be mixed before application. The primers of the more recent products are premixed, containing short-chain self-etch monomer mixtures that stay hydrolytically stable even in acidic pH environments.

Even more simplification was introduced with the seventh generation of adhesives, with self-etch systems being available with only one liquid. This consists of mixtures of hydrophilic and hydrophobic monomers, which are so acidic that they are able to act as etchant, primer, and adhesive in one. Earlier products were mixed; recent adhesives are non-mix versions.

Adhesion to dentin

It took a considerably long time to achieve first success in dentin bonding (Figure 13.4).[1,4,13,34,55,61,69–72] This was due to two major problems:

- Dentin provides a moist structure with tubules filled with liquid, resulting in considerable hydrophilicity. Therefore, it is difficult to bond hydrophobic resins to hydrophilic dentin surfaces.[14,16,44,57,65,73–86]
- After rotary treatment of dentin, a smear layer prohibits direct contact to underlying dentin.[4,13,30,55,87]

The transfer of an etch-and-rinse technique from enamel to dentin was initially unsuccessful.[34,88] As a result, the first clinical consequence from failures was to cover all dentin areas with liners and/or cements. This situation, however, provided only limited adhesion areas, especially for stress-bearing restorations. Therefore, in order to utilize the whole cavity surface, successful dentin bonding was desirable. The first success stories were recounted decades later. The development of different classes and stages of adhesive systems can be recognized in so-called generations, which have recently been displaced by functional classifications and numbers of steps.

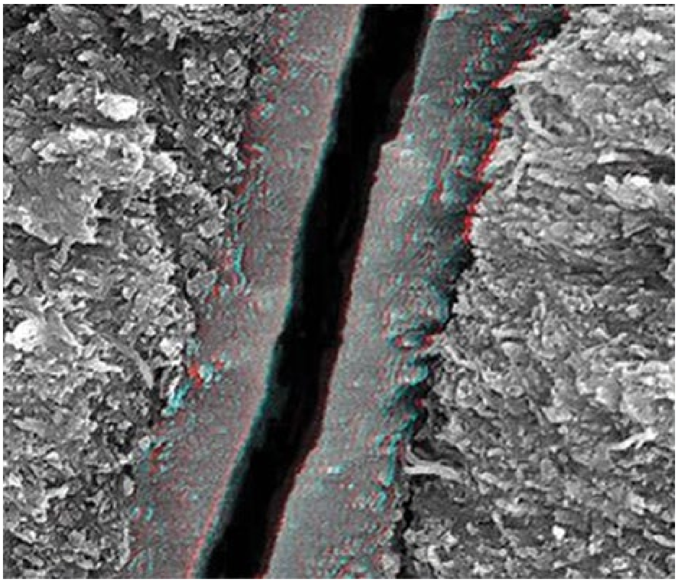

Figure 13.4 Dentin in a fractured specimen (SEM, 1:5000). The higher mineralized peritubular dentin is clearly visible; the intertubular dentin is less dense.

Adhesion mechanism to dentin

For strong and durable adhesion, hydrophilicity of the dentin substrate and the smear layer have to be handled. To remove the smear layer, two main approaches are available:

- application of phosphoric acid for about 15 s or
- application of acidic monomer mixtures.

Conditioning with phosphoric acid

It took a long time until it was accepted that phosphoric acid be applied not only to enamel but also to dentin. This technique was previously called 'total etching' because the entire cavity was etched by acid. More accurate is the term "etch and rinse" because self-etch adhesives also etch totally, emphasizing that phosphoric acid is removed by rinsing.

For the etch-and-rinse technique, colored 35–40% orthophosphoric acid gels are used. The acid penetrates along the dentinal tubules that have been opened by the acid (Figure 13.5).

The smear layer is completely removed; demineralization depth is around 5 µm.

The intertubular dentin is demineralized to 3–10 µm. The average irreversible dentin loss is 10 µm and the overall penetration is 20 µm; that is, altogether 30 µm without damage to the dentinal structures per se.[89,90]

The duration of phosphoric acid etching leads to different demineralization depths being additionally dependent on acid agitation during application.[91] After 10 s without agitation almost no dentin demineralization was found. With agitation, it increased to 3 µm. Sixty seconds with agitation result in 13 µm. In general, an application time of 15–20 s is recommended. Prolonged etching times lead to deeper demineralization and possibly suboptimal infiltrated areas[92] (Figure 13.6).

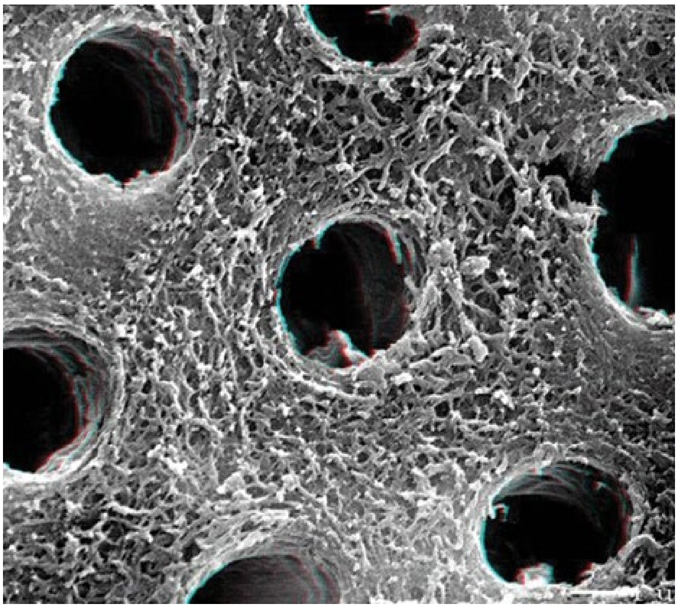

Figure 13.5 Dentin surface after etching with phosphoric acid for 15 s (SEM; 1:5000).

These deeper areas of nonpenetrated collagen are especially prone to biodegradation processes. Prolonged etching therefore may reduce dentin bonding performance.[68] With a thorough rinse step for 15 s the etch-and-rinse approach is finished.

Now the exposed collagen network has to be safely penetrated by monomers. Due to a low surface energy of etched dentin, surface-active components (primers) have to be meticulously applied.

To visualize the effect of enamel etching, at least the margins of the cavity have to be dried. This alone results in almost dry dentin in adjacent areas. So the collagen fibers may collapse and are consequently less receptive to penetration. The term "wet bonding" is directly derived from this particular clinical problem because wet or moist dentin after phosphoric acid etching avoids collagen collapse. It also guarantees better penetration and intact hybrid layers by sufficiently filling interfibrillar spaces.[93–95] However, the wet bonding issue has to be discussed relating to different solvents being present in primers or priming adhesives. Solvents act as monomer carriers bringing amphiphilic molecules to their place of action on the dentin surface. Possible solvents are water, alcohol, and acetone. The actual term wet bonding results from studies having been carried out with acetone-based adhesives only (e.g. Prime&Bond NT, Dentsply).[93–95] When acetone is used as solvent, it is true that exclusively moist dentin works as an adhesion substrate after phosphoric acid etching. Under clinical circumstances this is almost impossible to perform because etched enamel should be controlled for its frosty appearance to confirm appropriate etching. Therefore, the best way is first to dry and to guarantee good enamel etching and proper isolation against contamination, and second to rewet the surface with water to re-expand the previously collapsed collagen fibrils. This explains why ethanol- or acetone-based primers fall short on dry dentin.[66,68,93–95] From the clinical point of view, it is timely that *tert*-butanol was recently introduced as a less technique-sensitive solvent in XP Bond (Dentsply). Nevertheless, some rewetting is also recommended here.

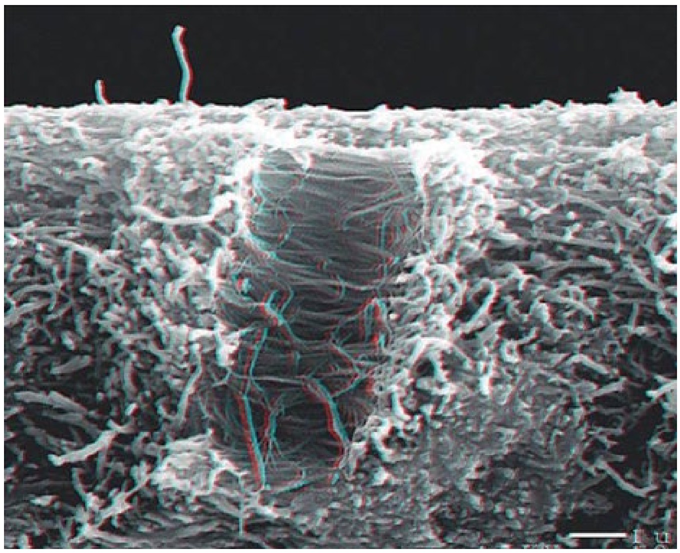

Figure 13.6 Fractured specimen from Figure 13.5 after critical point drying (SEM; 1:7000). Collagen fibrils are exposed by phosphoric acid etching.

Deficient primer penetration means that unfilled areas remain around some deeper areas of the demineralized matrix. This is referred to as "nanoleakage."[4,81,97] The incidence of postoperative hypersensitivities is of clinically higher relevance and is also a sign of incomplete resin penetration, allowing for fluid movement inside the dentinal tubules.

Less prone to the described wet bonding problem are water-based systems (Adper Scotchbond Multi-Purpose, 3M Espe) and water-/alcohol-based adhesives (OptiBond FL, Kerr), because the contained water obtains acceptable rehydration even in the absence of rewetting.[4,5,81,97,98] A simpler view shows that all multistep adhesives with separate primers and adhesives contain water. In contrast, all simplified two-step etch-and-rinse systems do not or do not sufficiently (<1%) contain water for incorporated rewetting.

Self-etch adhesives

The main advantage of self-etch adhesives is that incomplete penetration of previous demineralization should not occur. By making primers acidic with maleic acid or polyacrylic acid they are able to superficially demineralize enamel and dentin without prior etching with phosphoric acid. There are dentin-conditioning primers and enamel-/dentin-conditioning agents.

According to their ability to dissolve hydroxyapatite, the self-etch systems are classified (Figure 13.7) as strong or aggressive (pH <1), moderate (pH ≈ 1.5), or mild (pH ±2) (Table 13.1).[55] Neither dentin bonding nor enamel adhesion can be derived from the pH itself.[48–50,55]

The solvent of these self-etch agents must contain at least some water, because dissociation of acid is, in most of the cases, only possible in the presence of water. The acidic action is terminated by dissolved hydroxyapatite, evaporation of the solvent, and finally photo-polymerization. Demineralization depth and penetration depth are more or less the same here in order to remove excess solvent. These primers are solely air-dried, not rinsed off. To emphasize this aspect, some authors call these adhesive systems "etch-and-dry" systems. Since the applied monomer mixture is not rinsed off, parts of the dissolved smear layer, as well as dissolved parts of dentin, are integrated into the hybrid layer, i.e. as a hybrid complex.[57,58]

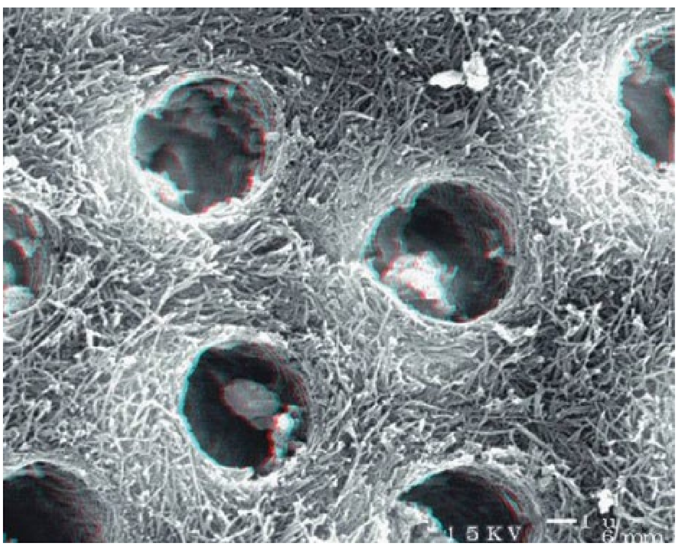

Figure 13.7 Etching effect of a self-etch adhesive on dentin (SEM, 1:4000): the intertubular dentin is demineralized to 1 μm, the orifices of the dentinal tubules are partially clogged with remnants of the smear layer.

Priming of the collagen network

Application of acids exposes an instable collagen "sponge." Primers always contain amphiphilic molecules with a hydrophilic end to penetrate the moist collagen network and a hydrophobic end for copolymerization with other monomers. Typical amphiphilic monomers are hydroxyethyl methacrylate (HEMA) or TEGDMA. These molecules impregnate the collagen parts by penetration and amphiphilic action.

Stabilizing by bonding agents

Primers consist of short chains for optimized penetration, while adhesives require longer, cross-linking monomers for stabilization of the whole interface. Reaching the interfibrillar pore volumes, all previously removed parts are replaced by the adhesive. Classical bonding agents, i.e. unfilled resins, consist of bis-GMA and urethane dimethacrylate (UEDMA), viscosity-decreasing TEGDMA and HEMA, and photo initiators for light-curability. The complex interface of previously demineralized dentin and resinous materials is called hybrid layer.[8,96,99,100]

Furthermore, adhesives flow into dentinal tubules generating resin tags. This leads to the effective sealing of the dentin. Unfilled resins need some time for appropriate penetration in previously generated pore volumes (10 s). Light curing of the unfilled adhesive resin is mandatory.

Adhesives with hydrophilic monomers working as primers are so-called primer-adhesives. Self-etching primer-adhesives are now called all-in-one adhesives because they act as etchant, primer, and bonding agent in one application step.

Classification of adhesive systems

Generally, four different working steps are present with adhesives to generate adhesion to tooth hard tissues (Figure 13.8):

1. enamel conditioning with phosphoric acid or self-etch primer mixtures
2. dentin conditioning with phosphoric acid or self-etch primer mixtures for exposure of the collagen network
3. dentin priming (application of short-chain, hydrophilic monomers for dentin wettability) for penetration of the exposed collagen network to generate the hybrid layer
4. application of a cross-linking adhesive for stabilization of the interfaces to enamel and dentin.

These different steps are differently covered by different adhesive approaches (Table 13.2).

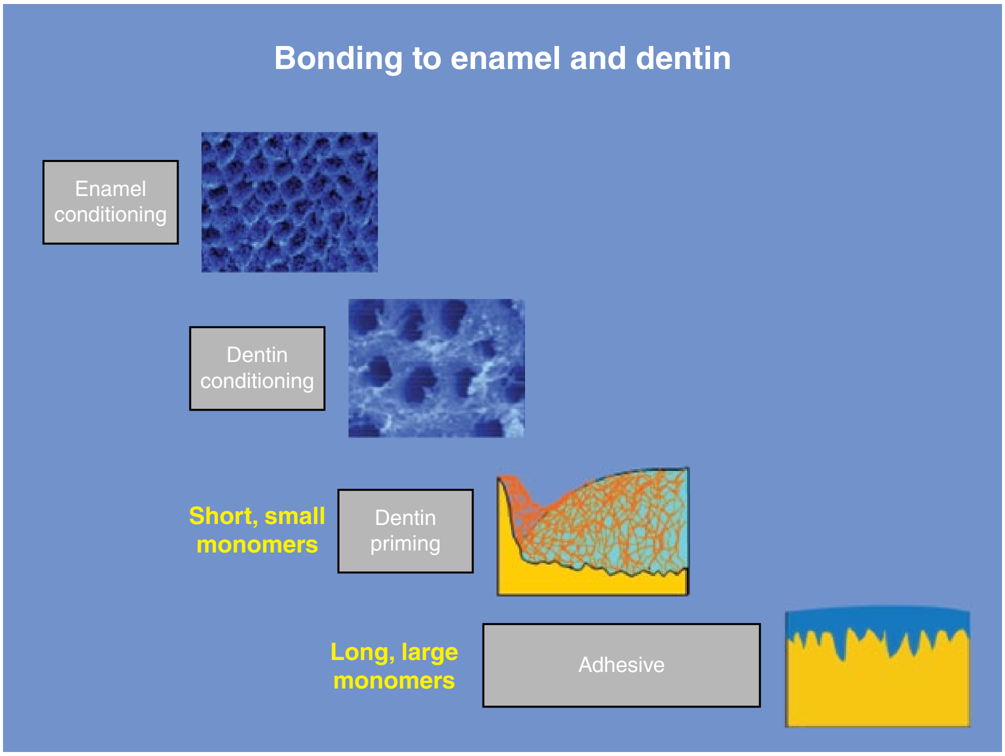

Figure 13.8 Fundamental steps for bonding to enamel and dentin.

Universal adhesives

The latest developments are so-called "universal adhesives." The idea behind these adhesives is to combine universal primers (e.g. Clearfil Ceramic Primer, Monobond Plus) with primers for conditioned enamel and dentin surfaces.

Universal primers are applied to ceramic surfaces like HF-acid-etched glass-ceramic, airborne Al_2O_3-particle pretreated oxide ceramics, as well as tribochemically pretreated ceramic or metal surfaces, either precious or nonprecious. The mixture of different monomers is able to enhance bonding to all mentioned surfaces after surface roughening by different approaches. This is a tremendous advantage in repairing insufficient restorations when it is not exactly known what kind of ceramic was used or if different material surfaces are affected at one site.[101]

Another—and the most important—approach of universal adhesive is to use the adhesive as an etch-and-rinse system, even on dried or on moist dentin surfaces, as well as a self-etching primer at the same cavity in order to facilitate handling in daily situations when adhesives are used. As mentioned before, it has been shown that the performance of self-etch adhesives in enamel may be increased by selective phosphoric acid etching of enamel margins.[27,48,49,51,52] However, it cannot always be totally avoided that phosphoric acid is also applied to dentin, which can cause some adhesives to show a decrease in efficiency.[53,54,102] Universal adhesives are developed to promote bonding to dentin as etch-and-rinse adhesive, independently of whether the phosphoric acid-etched surface is kept moist or dry, and as a self-etch adhesive. The first clinical data[102,103] as well as in vitro evaluations[104–107] show rather promising results. Today, MDP is incorporated into most universal adhesives, which was shown to be effective in reducing aging effects, primarily in self-etch mode,[33,108] which was attributed to nanolayering as well as chemical bonding to calcium in dentin.[108] However, most recent studies are also indicating that universal adhesives are also prone to hydrolytic degradation, primarily when used as etch-and-rinse adhesives.[108] So here the combination of selective enamel etching and using a universal adhesive in self-etch mode is recommended.[33,108]

Dark-curing adhesives

Bonding agents can be classified not only by working steps and kind of conditioning, but also in relation to the initiation of polymerization (Table 13.3). The majority of available adhesives are light-cured, and the predominant initiator is camphorquinone. Radicals for further cross-linking are part of the light-curable adhesive. Primers normally do not contain photoinitiators.

However, for some dual-curing (i.e. chemically initiated by addition of catalysts) build-up composites or luting composites, special dual-polymerizing adhesives are available (e.g. Clearfil New Bond, XP Bond + SCA). Before or after priming, these systems involve sulfuric acid salts for cross-linking of primer monomers. The adhesives contain benzoylperoxide which reacts with tertiary amines of dual-curing resin composites for luting. These systems gain more importance in the adhesive luting of root canal posts.

Table 13.2 Groups of Adhesives

Multi-bottle etch-and-rinse adhesives
Syntac Classic
A.R.T. Bond
Solobond Plus
Adper Scotchbond MP
Gluma Solidbond
Ecusit Primer/Mono
OptiBond FL
Solobond Plus
Single-bottle etch-and-rinse adhesives
Admira Bond
Adper Scotchbond 1
Cumdente Adhäsiv
Fantestic Flowsive
Excite F
iBond Total Etch
One Coat Bond
OptiBond Solo Plus
PQ1
Prime & Bond NT
Solobond Mono
Teco
XP Bond
Two-step self-etch adhesives
AquaPrime & Monobond
Clearfil SE Bond
One Coat SE Bond
OptiBond XTR
One-step self-etch adhesives
Adper Prompt L-Pop
Futurabond DC
Xeno III
AdheSE One F
Adper Easy Bond
Bond Force
iBond Self Etch
Futurabond M
Geanial-Bond
One Coat 7.0
OptiBond All in One
Tri-S-Bond
Xeno V+
Universal adhesives
Adhese Universal
All-Bond Universal
Clearfil Universal Bond
Futurabond M+
Futurabond U
G-Premio Bond
iBond Universal
One Coat 7 Universal
Peak Universal Bond
Scotchbond Universal
Xeno Select

Table 13.3 Dual-Curing Adhesives

Etch and rinse	Self-etch	Universal adhesive
Clearfil New Bond	Clearfil Liner Bond 2V	Clearfil Universal Bond
Excite DSC	OptiBond Solo Plus SE	Futurabond M+
Adper Scotchbond MP	Fantestic Flowsive SE	Futurabond U
Ambarino Bond	Futurabond DC	Scotchbond Universal
Clearfil Photobond	Hybrid Bond	
Cosmedent Complete		
CumDente Adhäsiv		
EnaBond		
Fantestic Flowsive		
LuxaBond		
One Coat 7		
OptiBond Solo Plus		
Prime & Bond NT		
XP Bond		

All-in-one adhesives must contain acidic components for conditioning of hard tissue surfaces. These acids neutralize the basic tertiary amine, which is important for sufficient initiation of dual-polymerizing resin composites. This leads to compromised bond strength of core materials to tooth substrate if all-in-one adhesives are used in combination with dual-cured resin composites.[8,109]

All-in-one adhesives create semipermeable membranes that enhance fluid penetration from the dentinal tubules through the adhesive layer and create droplets within minutes, risking interference with the hydrophobic composite resin.

Filled adhesives

Irrespective of the affiliation to different classes, there is one special modification of adhesives. By adding considerable amounts of filler particles (e.g. 48% in OptiBond FL Adhesive and 26% in OptiBond Solo Plus, Kerr) it was possible to increase adhesive performance.[13,44]

The resulting thicker, potentially elastic adhesive layer is reported to be beneficial for gap prevention in vitro (Figure 13.9). A similar effect is obtained with the so-called lining technique by use of flowable resin composites.[13,44] According to my own in-vitro results (R. Frankenberger) it is sufficient to apply one component (i.e. filled adhesive or a flowable). With a special focus on OptiBond FL, it must be stated that maybe this particular adhesive is also effective without fillers (Figure 13.10).[110] Film thickness and homogeneity may be enhanced with the addition of filler (Clearfil SE Bond, Fuji Bond LC, OptiBond FL, Gluma Solid Bond). An important point in this context is that filled adhesives with thicker adhesive layers have to provide sufficient radiopacity.[111] Whether additional fluoride release would increase adhesive effectiveness further and prevent recurrent caries is unknown.

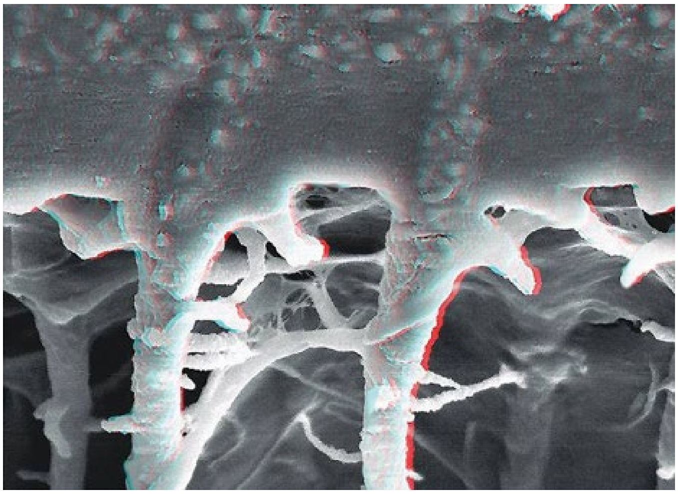

Figure 13.9 Resin–dentin interface of OptiBond FL (SEM; 1:5000). The filled adhesive penetrates the dentinal tubules and lateral branches.

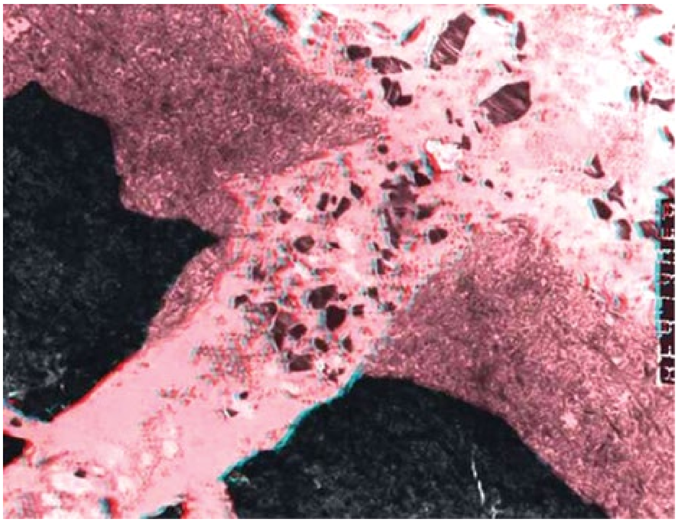

Figure 13.10 Specimen from Figure 13.8 under the transmission electron microscope (1:8000).

Valuation of adhesives

Figure 13.11 displays results of the author´s (R. Frankenberger's) own marginal quality evaluations in vitro during 1994–2013. It is clearly shown that many recent adhesives show diminished performance compared to the established ones.

The main findings were:

1. Simplification leads to less effectiveness.
2. Self-etch adhesives are overestimated regarding their enamel bonding performance.

These results are confirmed in the literature with the highest bond strengths and best marginal qualities with old-fashioned multistep adhesives.[103,112–114]

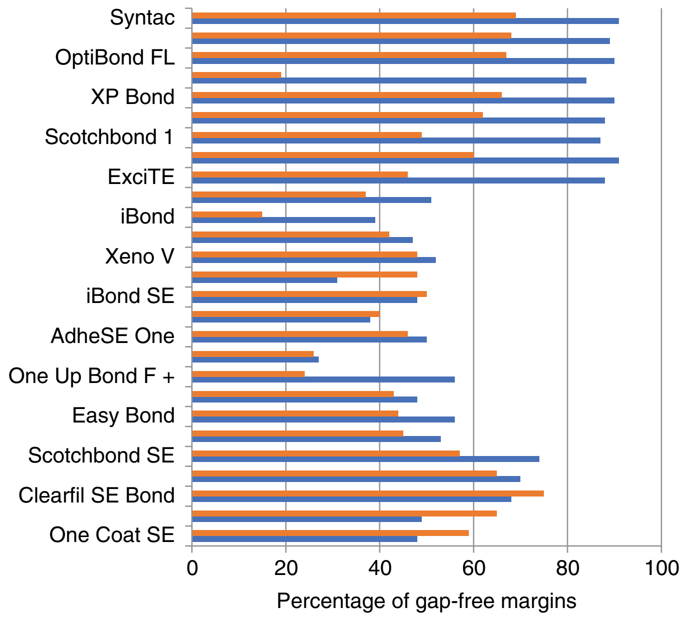

Figure 13.11 Percentage of gap-free margins after thermomechanical loading in vitro. Blue bars, enamel; orange bars, dentin.

Biocompatibility of adhesives

It is still believed that phosphoric acid etching increases dentin permeability and consequently the danger of damage to vital pulp tissues; however, the increase of permeability is related to cavity depth. Shallow cavities providing residual dentin thicknesses of >500 µm are not relevant for higher permeability.[115] Therefore, in these cavities some phosphoric acid etching is not detrimental. In the clinical setting, pulp damage is not caused by penetration of toxic substances from the resin. Pulpal inflammation is usually triggered by bacterial contamination in marginal gaps;[115,116] therefore, adhesives primarily protect the dentin by sealing it appropriately.

Deep cavities (<200 µm remaining dentin thickness) suffer a significant increase of dentin permeability, also potentially allowing for penetration of toxic monomers from primers or bonding agents. Furthermore, primers may be permanently thinned with dentinal liquid.[115,116] Clinically, <200 µm means already glimmering pulp tissues; therefore, a conventional calcium hydroxide lining is recommended (e.g. Kerr Life) covered by a resin-impregnated glass ionomer cement (e.g. Vitrebond).

Facing components of modern restorative resin composites, their biocompatibility is questionable on first sight.[117] The most important issue here is their correct use and a no-touch policy for dental personnel to avoid allergic reactions.[117]

Aging of the adhesive interface

Marginal discolorations, poor marginal adaptation, and loss of the restoration are frequent clinical findings related to exposed bonded margins.[118] In fact, despite excellent immediate and short-term bonding effectiveness for most of the dentin-bonding systems, the durability and stability of resin/dentin bonded interfaces created by some bonding agents (particularly the simplified ones) still remain questionable.[119–121] Interestingly, the new simplified adhesives exhibit not only the lowest bond strength values, but also the least predictable clinical performance when compared with multistep etch-and-rinse and self-etch systems.[30,122]

While enamel margins are more stable over time, the stability of the dentin–adhesive interface is strictly related to the intrinsic stability of the hybrid layer. Clinically, the aging of the hybrid layer involves both physical (occlusal chewing forces, and repetitive expansion and contraction related to temperature)[123] and chemical factors such as dentinal fluid, saliva, food and beverages, and bacterial products.[39,99,124] All these factors affect the single components of the hybrid layer: dentin organic matrix, hydroxyapatite, resin monomers, and residual solvents.

Different degradation patterns have been described, mainly related to the bonding approach: etch-and-rinse versus self-etch strategy.

Reliability and degradation of etch-and-rinse adhesives

Bonding with etch-and-rinse adhesive systems is achieved with the impregnation of the resin monomers into the demineralized substrate created by the etching agent that is rinsed away.[30,125,126] As previously mentioned, one of the major problems related to this approach is the incomplete infiltration of the adhesive into the demineralized dentin collagen network that frequently occurs due to several factors: collagen collapse, insufficient flowability of the primer/bonding agents, and presence of residual water that cannot be displaced within the collagen fibrils.[30,83,127–136] This suboptimal adhesive impregnation on the dentin surface (which is typical for the etch-and-rinse systems) determines nanoleakage formation; that is, presence of tracer along the interface at a nanoscale level (Figure 13.12).

This phenomenon is particularly evident in two-step etch-and-rinse adhesives versus the three-step systems due to the higher hydrophilicity of the primer and bonding agent that results in increased permeability, even after polymerization.[136–140] Interestingly, the higher permeability of the two-step etch-and-rinse systems was correlated with incomplete polymerization of these adhesives,[136–140] while better curing (and reduced permeability) can be obtained with the three-step systems that include a solvent-free and relatively hydrophobic resin coating as the last step of the bonding procedure.[141]

Additionally, the reduced polymerization and higher hydrophilicity of two-step etch-and-rinse systems determine increased water sorption[141] compared to the three-step systems. The presence of water within the hybrid layer determines hydrolysis, which is the primary reason for resin degradation within the hybrid layer created by two-step etch-and-rinse systems.[142] The disruption of covalent bonds between polymers in contact with water finally results in the loss of resin mass. This correlates well with the clinical performance of most hydrophilic two-step etch-and-rinse systems that show lower stability over time compared with the corresponding non-simple hydrophobic three-step systems.[129]

The presence of water additionally affects the stability of the adhesive interface due to degrading phenomena occurring to the collagen fibrils that are not fully encapsulated by the resin. This causes disorganization and further disruption of the dentin collagen fibrils, finally affecting the integrity of the hybrid layer.[143] It has been described that the breakdown of the collagen matrices can be attributed to host-derived proteinases, called matrix metalloproteinases (MMPs), incorporated within mineralized dentinal matrix during tooth development.[140–143]

The phosphoric acid application of 35% phosphoric acid (pH 0.7–1), typical of the etch-and-rinse approach, seems to be able to expose pro-MMPs trapped within the mineralized dentin.[118] Then the application of the adhesive blend reactivates the quenched collagenolytic/gelatinolytic activities of the endogenous enzymes contributing to the degradation of the collagen fibrils poorly impregnated within the hybrid layer.[133,144–146] An indirect confirmation of the role of endogenous MMPs in the degradation of the adhesive interface has been reported by using an MMP inhibitor to stabilize the bond over time. Interestingly, when used on acid-etched dentin as an additional therapeutic primer during the bonding procedure, an antibacterial agent with MMP-inhibiting properties called chlorhexidine resulted in the maintenance of the hybrid layer's collagen integrity over

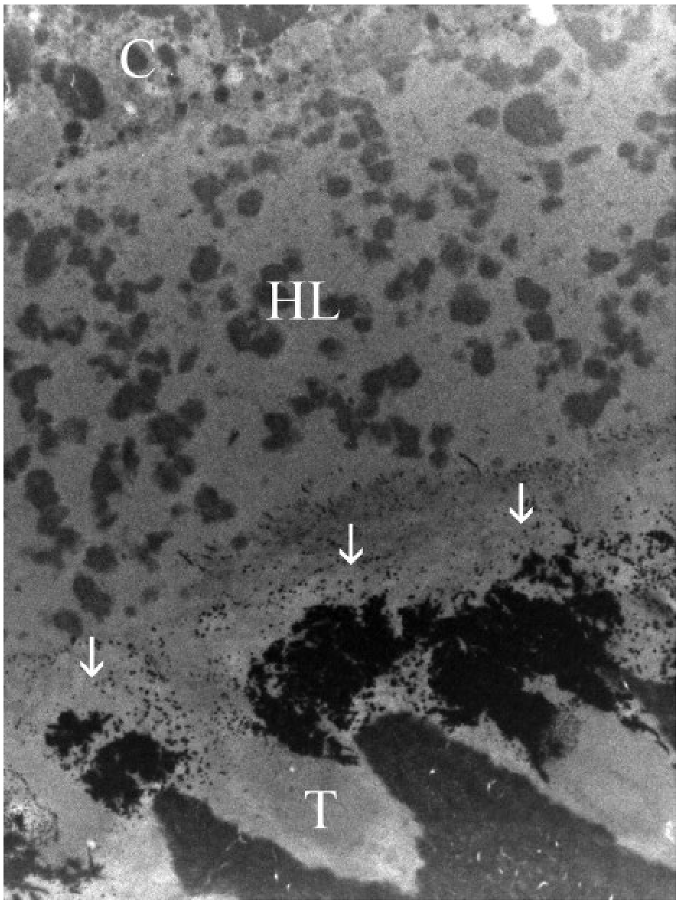

Figure 13.12 Transmission electron micrograph of the hybrid layer created by Adper Scotchbond 1XT (3M ESPE) aged for 2 years in artificial saliva. Extensive nanoleakage expression is shown (arrows). T, dentin tubule; HL, hybrid layer; C, composite resin.

time. This effect is used by rewetting the phosphoric acid-etched dentin after rinsing and drying with a 2% chlorhexidine solution. Similarly, promising preliminary results have been reported using collagen cross-linking agents to stabilize the collagen network. This approach showed not only increased immediate bond strength values but also improved bond stability over time, probably due to MMP inhibition.[145–147]

Reliability and degradation of self-etch adhesives

In self-etch adhesive systems, demineralization and infiltration of the acidic resin blends occur simultaneously,[148] thus no discrepancy between demineralization and infiltration (typical of the etch-and-rinse approach) has been described. Additionally, due to the lack of rinsing after etching, residual hydroxyapatite crystals remain available on the dentinal collagen. For this reason, the number of denuded collagen fibrils within the hybrid layer should be significantly less than in the etch-and-rinse system. However, some strong and aggressive one-step self-etch systems showed continuous etching after curing, leading to exposed collagen and accelerated bond degradation.

Similar to etch-and-rinse adhesives, self-etch systems (particularly the most simplified one-step systems) exhibit high permeability correlated with a low degree of curing and increased water sorption. As previously described for two-step etch-and-rinse systems, all these degrading phenomena seem to be strictly correlated with the high hydrophilicity of one-step systems and the difficulties with getting them to properly polymerize.[126,133,138,145]

Technique sensitivity: a problem and its solution

Etch-and-rinse adhesives

In contrast to enamel bonding, dentin bonding is considerably more technique-sensitive.[149] Bouillaguet et al. reported a different outcome of the same adhesives with different operators.[150] Peschke et al. simulated application errors with OptiBond FL, while Frankenberger et al. showed similarly catastrophic effects of errors for Syntac and Prime&Bond NT.[114,149] Any deviation from the recommendations for use decreased clinical performance. These errors were:

- overetching of dentin
- overdrying of previously etched dentin
- shortcuts in application protocols.

Overetching of dentin results in deeper demineralization zones, and potentially insufficient impregnation by primers. With time, these areas of naked collagen are subjected to biodegradation and hydrolysis. The first hints of insufficient interface forming are postoperative hypersensitivities.

During clinical use of etch-and-rinse adhesives, the problem becomes easily apparent: the whole cavity is etched with phosphoric acid. However, ideal etching times are 15 s for dentin and 30 s for enamel. When an uncontrolled flush of acid is applied many times a day, this idea is not achievable. Therefore, it makes sense to reduce the overall etching time to 15–20 s for both adhesive substrates without any decrease in performance.[151]

Overdrying of etched dentin causes collagen fiber collapse and should, therefore, be avoided. This is easily written but hard to realize. For an image of the frosty appearance of etched enamel, a certain drying process is necessary. This always leads to some dried areas on adjacent dentin. These areas are the only ones close to the pulp in proximal boxes of Class II cavities. Rewetting is the only solution of this particular problem. A microbrush is either sprayed with air/water mix from 25 cm away in order to generate some hoar frost or dipped into water or—as mentioned before—into a 2% chlorhexidine solution and dabbed on a paper tissue resulting in a moist but not dripping wet tuft of the microbrush. This microbrush is applied to the cavity, creating a slightly shiny surface in dentin. It can even be accepted that water also contaminates enamel margins. This is not crucial because primer solvents remove the water equally just like the interfibrillar spaces in dentin do. Water-based primers are easier to handle. They consist of 50% water, which is able to re-expand the collagen meshwork by itself. Therefore, water- and water/ethanol-based adhesives provide less technique sensitivity because rewetting is not as mandatory as with ethanol- and acetone-based systems.[66,96] Also, with less-technique-sensitive adhesives, rewetting is not forbidden. However, as mentioned before, rewetting can also be managed by chlorhexidine, which supports the longevity of etch-and-rinse adhesives. When working with water-containing components, it is fundamentally important to dry primers instead of gentle blowing them because the water must be safely evaporated. In contrast, it is easier with ethanol and acetone due to their higher vapor pressures.[66,96]

Air thinning of unfilled resins is also restricted due to technique sensitivity. The unfilled resin also needs some time to penetrate, and it should not be overly thinned by air due to the presence of an oxygen-inhibition zone that may counteract light curing. On the other hand, thicker layers of unfilled resins should also be avoided because, due to their lack of radiopacity, these zones may be misinterpreted as gaps in bitewing radiographs.

General problems with wet bonding and its transfer to the clinical situation still result in a remarkable amount of postoperative hypersensitivity with this class of adhesives. The reason is not primarily the presence of some aggressive phosphoric acid, but improper moisture management after the actual etching process.

Self-etching adhesives

All-in-one adhesives represent a revolutionary simplification because only one liquid needs to be applied. Nevertheless, technique sensitivity is not completely absent.[41,44,53,84,139,152–156] For example, most of the products must be repeatedly applied to generate measurable bonding,[5] which means that the timesaving aspect is almost gone.

The major issue with all-in-one adhesives is their permeability against water. Several publications have shown that these adhesives are permeable membranes even after polymerization.[5,23,97,157] The more hydrophilic the adhesive is, the less clinically promising its prognosis. Conventional adhesives with separate primers and separate hydrophobic bonding agents still prevail.[44,60,98]

Two-step self-etch adhesives also avoid phosphoric acid etching; however, they have separate liquids for priming and bonding. Today, this class of adhesives is estimated to be the most promising for durable dentin bonds with low rates of postoperative hypersensitivity.

Where dentin bonding is favorable with self-etch systems, effective enamel adhesion is still questionable. A viable solution is selective enamel etching with conventional phosphoric acid, followed by a self-etch adhesive. Dentin etching was beneficial with Syntac and A.R.T. Bond, though proved detrimental with AdheSE and Clearfil SE Bond.[157]

Recent all-in-one adhesives contain complex monomer mixtures that are able to etch, prime, and bond. This results in phase separation in many cases.[158] To avoid this, some all-in-one adhesives have to be strongly air-dried, although this may again lead to insufficient polymerization, as described above.[52] It is surprising that mechanical properties of adhesive mixtures have a stronger impact on performance than acidity itself.[48–51]

Light microscopy shows droplet formation with all-in-one adhesives being dependent on their hydrophilicity.[52,159] For example, HEMA-free G-Bond results in phase separation, while HEMA-containing Clearfil Tri-S-Bond and Xeno III showed droplet formation by osmotic blistering. Hybrid Bond, Absolute and iBond Self Etch exhibited both phenomena. OptiBond AIO revealed cluster formation of filler particles.[52]

This leads to special recommendations for use with this class of adhesives. Some adhesives allow evaporation of the solvent by gentle air stream (One Coat 7.0, "gently light air-stream"), while others require maximum air pressure (G-Bond). Finally, some adhesives must be air-thinned with increasing pressure (Bond Force).

Another clinically relevant problem is application time. This may be interesting from the marketing point of view; however, 5–10 s for G-Bond seems to be unrealistically short for thorough penetration (Figures 13.13 and 13.14). The resin–dentin interface improves considerably with multiple applications of adhesive (Figure 13.13) when compared to a single coating (Figure 13.14). It has to be taken into account that not only does dentin need to be treated during that period, but so does a thick smear layer of dentin after rotary bur preparation. Therefore, active application under continuous rubbing is recommended.[160,161] Altogether it can be stated that easier handling does not automatically mean less or no technique sensitivity.

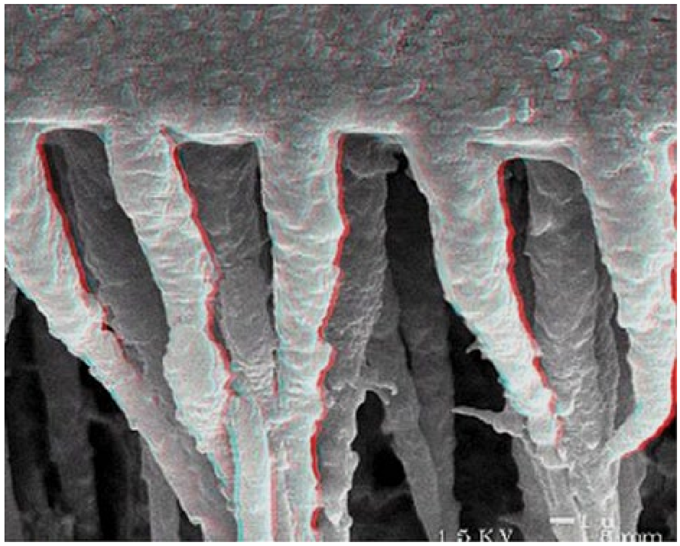

Figure 13.13 Resin–dentin interface of an all-in-one-system with five coats (SEM; 1:4000).

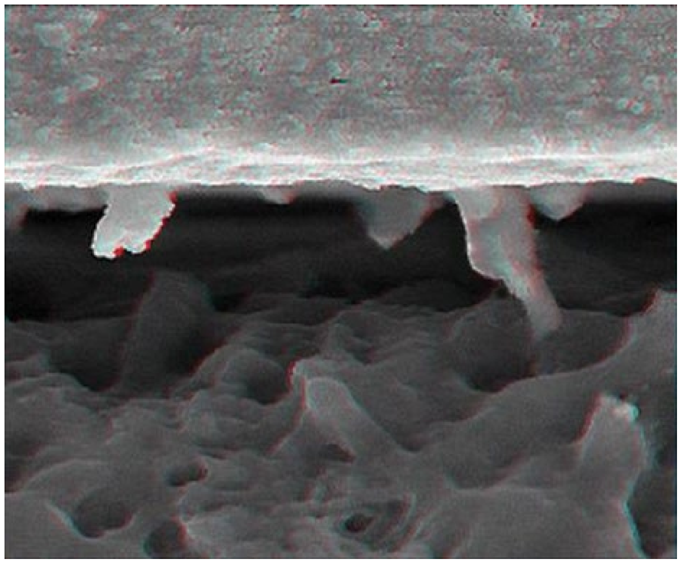

Figure 13.14 Resin–dentin interface of the same all-in-one-system as in Figure 13.13 with one coat (SEM; 1:4000).

Postoperative hypersensitivities

Postoperative hypersensitivities are mainly caused by fluid movement in dentinal tubules which irritates odontoblast processes.[120,122] This is mainly attributed to an insufficient adhesive dentin seal and not to cavity depth because hypersensitivities also occur in shallow cavities. The main reasons for postoperative hypersensitivities with etch-and-rinse adhesives are:

- overetching of dentin with phosphoric acid
- overdrying of dentin after phosphoric acid etching
- overwetting of previously phosphoric acid-etched dentin
- no or insufficient light curing of the adhesive.

Also self-etch adhesives may fail, this is mainly due to:

- smear layers too thick
- application times too short for smear layer removal
- insufficient evaporation of the solvent.

Under strict adherence to the adhesive's instructions for use and prevention of common treatment errors, enamel and dentin may be effectively pretreated, providing a tight and durable seal. The dentin seal is better than any cement linings use previously. Subjective contentment of patients is good; clinical outcomes are excellent.

Failure prevention: clinical application

Beside biological parameters like tubular sclerosis or caries-affected dentin, handling is a fundamental point in adhesive dentistry. Therefore, practical transfer is very important to guarantee a well-functioning seal of enamel and dentin.

Various clinical procedures were proposed to increase the immediate bond strength and reduce aging:

1. **Use of a hydrophobic coating**: since hydrophilicity of the simplified adhesives (two-step etch-and-rinse and one-step self-etch adhesives) has been shown to increase water sorption and bond instability, the use of nonsimplified bonding systems, such as three-step etch-and-rinse and two-step self-etch adhesives characterized by an hydrophobic coating with a nonsolvated bonding layer, should be preferred.
2. **Increased application time**: prolonged application times (beyond the manufacturer's recommendations) increase monomer penetration and favor solvent evaporation before light curing; this increases the immediate and long-term bonding of most adhesives.[51,160]
3. **Active application**: a continuous and active rubbing motion has shown higher strength and improved stability of the bond, particularly for two-step etch-and-rinse adhesives.[161]
4. **Enhanced solvent evaporation**: the adhesive layer must be carefully air-thinned because if residual solvent remains within the polymer network it could plasticize the polymer,[162] further affecting the adhesive's properties.[157]
5. **Extended polymerization time**: resin permeability and monomer elution are related to suboptimal polymerization of the bonding. When curing times (particularly of simplified adhesives) are extended beyond those recommended by the manufacturer, improved polymerization can be achieved with reduced permeability.[147,162,163] This contributes to stabilizing the bond over time.[30,133,148]
6. **Use of MMP inhibitors**: MMP inhibitors, such as chlorhexidine, used as a rewetting solution (e.g. 2%), stabilize the bond over time, this inhibiting the activation of endogenous dentin enzymes especially when using etch-and-rinse adhesives.

When using adhesives in a clinical setting the following steps should be followed:

- read the manufacturer's manual
- shake bottles before use
- all steps must be carried out under proper isolation, ideally with a rubber dam.

Recommendations for using etch-and-rinse adhesives

According to the results of a huge number of in vitro and in vivo tests the following products can be recommended as the so-called gold standard: OptiBond FL, Syntac, and Scotchbond MP.[59,70,162]

Nevertheless, correct handling has an important impact on long-term success in adhesive techniques:

- It is important to control the penetrability of the cannula of the etch gel prior to intraoral use. Otherwise uncontrolled flushes occur.
- The application of phosphoric acid always starts at the enamel margins and ends on dentin. When this is not possible, the whole cavity should be etched for 15–20 s.
- The acid, the precipitates, and dissolved tooth substrate must be rinsed off thoroughly for 15 s.
- The cavity-drying process has to be carried out with caution to prevent collagen collapse. Short air streams help to visualize the frosty appearance of etched enamel and prevent overdrying of adjacent dentin. *Rewetting is mandatory for adhesives without water addition.*
- Primers need time (30 s) to act on dentin. Rubbing accelerates chemical processes by continually supporting its activity with fresh monomer. Etched enamel should not be excessively rubbed. The solvent has to be evaporated but not overly dried (Figures 13.15 and 13.16).
- Unfilled resins should get some time (10 s) to penetrate into enamel and dentin. Also this layer should not be overly thinned.
- The adhesive has to be light-cured for 20 s with a sufficient light-curing unit.

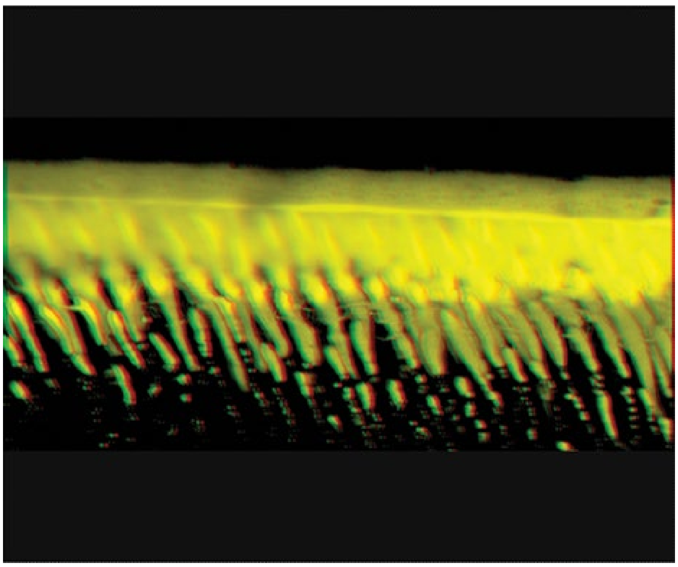

Figure 13.15 Resin–dentin interface under a confocal laser scanning microscope (CLSM; 1:2000). Hybrid layer and sufficient tubular penetration are visible.

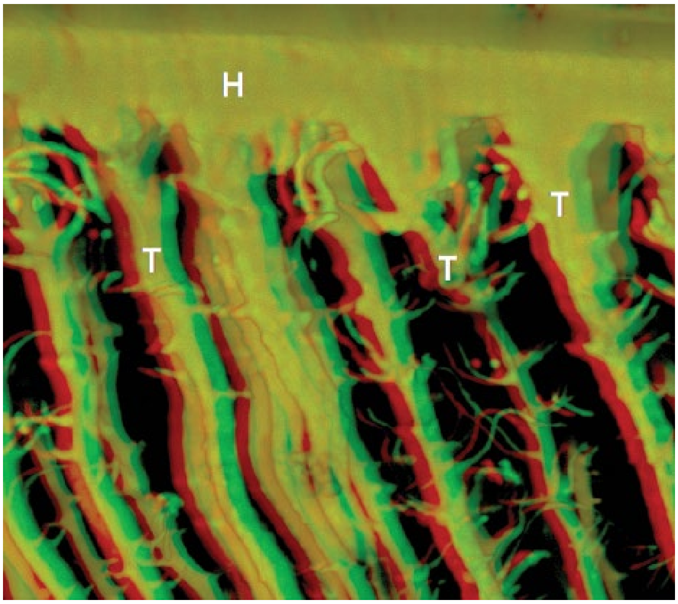

Figure 13.16 Resin tags (T) and hybrid layer (H) under a CLSM (1:3000).

Recommendations for using self-etching adhesives

According to the results of a huge number of in vitro and in vivo tests the following products can be recommended as the so-called gold standard: Clearfil SE Bond, and OptiBond XTR.[44,59,70,168]

Nevertheless, self-etching adhesives also need to be applied carefully in order to improve their performance:

- Systems which involve mixing need to be mixed sufficiently.
- The applied primers should be agitated (30 s) on enamel and dentin to enhance chemical reactions.
- The solvent has to be evaporated accordingly. Then the cavity has to provide a glossy appearance, indicating that no dry spots with insufficient wetting are present.
- In systems with separate unfilled resins, the bonding agent should not be overly thinned.
- The adhesive needs to be light cured for 20 s with a sufficient light-curing unit.

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Chapter 14 Composite Resin Bonding

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Whether it is used to replace an unsightly metal filling, to mend fractured teeth, to restructure badly spaced or crowded teeth, or to cover a series of discolored teeth, bonding remains the single fastest transformation of the mouth available to you as a dentist (Figure 14.1A and B). The patient walks in afraid to smile, with a hand in front of his or her mouth, and walks out more attractive, self-confident, and happy.

Development of the acid-etched enamel technique by Buonocore[1] and the BIS-GMA-based composite resin by Bowen[2,3] made possible the direct bonding of composite resin to the facial surface of stained, malposed, fractured, and other teeth requiring esthetic and functional improvement. As Phillips[4] said, the development of dental polymers and the technology for their use were the principal factors opening up the era of esthetic dentistry and improving and expediting the delivery of dental care. Esthetic dentistry accounts for almost half of gross dental income. Approximately 72% of restorations that replace existing restorations use composite resins.[5]

Bonding has been termed the most important discovery since the high-speed drill. Certainly bonding was the first of what

Ronald E. Goldstein's Esthetics in Dentistry, Third Edition. Edited by Ronald E. Goldstein, Stephen J. Chu, Ernesto A. Lee, and Christian F.J. Stappert.

Figure 14.1 (A) This 28-year-old dentist disliked smiling because of the spaces in her teeth.

Figure 14.1 (B) Not only were the spaces closed, but better shapes for the central incisors were also accomplished in the one-appointment smile makeover.

since have become numerous painless techniques in restorative dentistry, requiring no anesthesia and generally producing little or no discomfort. The technique has the additional advantages of minimal tooth reduction and reversibility. Furthermore, it remains one of the most economic restorative techniques in esthetic dentistry.

But most importantly for the field of esthetic dentistry, the esthetic success of bonding—its ability to change the shape of teeth as well as their color—encouraged dentists to move from a focus on individual teeth to the comprehensive consideration of the appearance of the smile and mouth. For the first time dentists began to share fully their patients' concern with not just how the teeth functioned but how they looked. Dentists concerned with esthetic restorations, and increasingly with esthetic improvements on what the patient might have been dealt genetically, became diagnosticians of facial anomalies.

Bonding has evolved through the years; its various roles in esthetic dentistry have changed dramatically. To some extent, bonding has undergone some of the same shift in emphasis as crowning underwent earlier. Teeth that would have been reduced and crowned without question in the 1960s were instead bonded with one of the new composite resins in the 1970s, especially after the introduction of high-intensity light curing to both control and strengthen the bond. Now, in the 21st century, porcelain veneers are being used for many of the same problems for which bonding previously appeared to be such a "miracle solution" (see Chapter 15). Porcelain veneers have many of the same advantages: minimal tooth reduction, little or no discomfort resulting in less need for anesthesia, and fairly rapid transformation since two rather than one appointments are necessary. Their increased expense, time requirement, and relative fragility must be weighed against their superior esthetic effect and longer esthetic life.

Yet no text that purports to cover esthetic dentistry as it is practiced today can relegate bonding to history. Bonding remains the treatment of choice for many conditions—and for many patients. As is true for bleaching, its lower cost has been one of the routes by which esthetic dentistry has become important and feasible for great numbers of people. The superior handling properties of today's composites, and new techniques that permit good adhesion to biologic structure as well as to dental materials, make bonding the treatment of choice in many circumstances where an esthetic improvement might otherwise not be achievable.

Furthermore, the new composite resins are substantially more resistant to wear than their predecessors. Placed under appropriate conditions and monitored routinely, many restorations can be expected to last a decade or more;[6,7] Bayne and his colleagues found that the failure rate of 899 composite posterior restorations—sometimes raised as reason to use other treatments than bonding—was in fact less than half that of conventional amalgams at 5 years, suggesting that even posterior composites can provide excellent long-term clinical service.[8] In fact, Maitland[9] (Figure 14.2A and B) has said that many of the failings sometimes ascribed to bonding can be avoided by attention to patient selection, material used, and techniques of preparation and finishing. Additionally, proper placement and careful attention to adhesive procedures is a must for the success of bonding.

There are several excellent books to which you can turn for detailed instructions on applying the technique to various situations.[10–17] This chapter makes no effort to duplicate those, but concentrates on some points that may enhance the esthetic effects of your own techniques. This chapter reviews briefly the categories of bonding in use today, based on the adhesive nature, the basic uses, and the materials and techniques that have broadened the use of bonding in esthetic dentistry. The description of the bonding procedure emphasizes an overlay technique that these authors have used for more than 40 years and found to overcome some of the difficulty in maintaining a long esthetic life for bonded teeth. And finally, the chapter concludes with the simplest and yet most overlooked role in esthetic dentistry: education of the patient in the maintenance of his or her new appearance through prevention, care, and an attentive eye to how dental professionals such as hygienists should approach the bonded teeth.

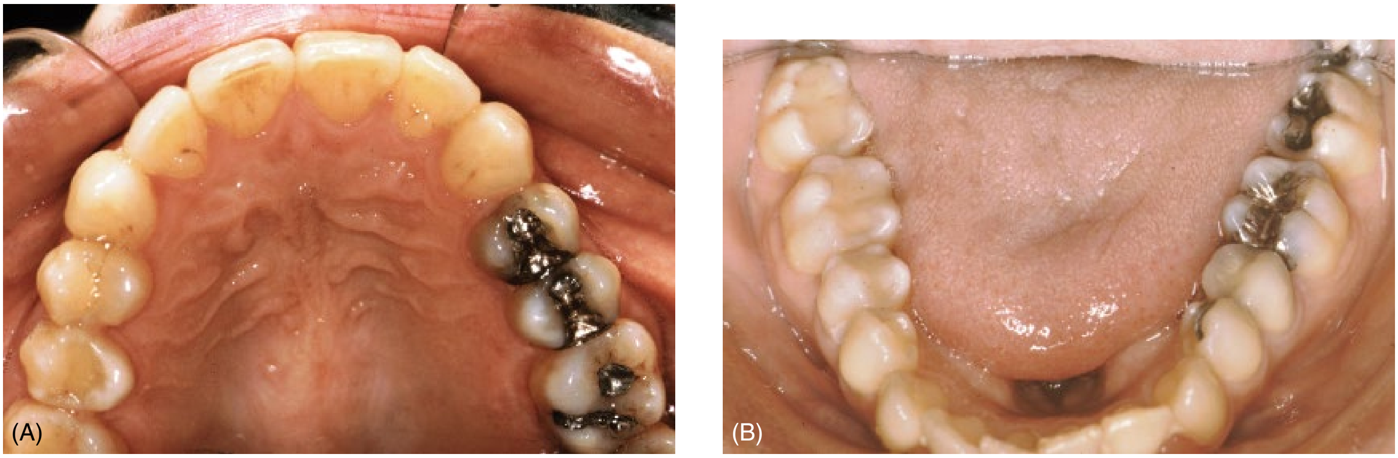

Figure 14.2 **(A, B)** These pictures depict a 10-year status of posterior composite restorations on one side and amalgam restorations that were placed on the other side at the same time. All restorations continue to be functional.

Basic categories of bonding in use today

The major reason that bonding is so useful in terms of conservative operative dentistry is that composite materials are directly bondable to tooth structure.[18] While bonding to enamel is by far the most frequently used, reliable, and predictable of all bonding procedures,[19] as can be seen in the listing of basic uses to follow, the ability of the newer materials to bond to all hard tissue and to dental materials continues to broaden the uses for bonding. Basic categories are as follows:

- bonding composite resin to enamel
- bonding composite resin to dentin
- bonding composite resin to other composites, glass ionomer, and porcelain
- bonding glass ionomer to dentin and enamel
- bonding porcelain to enamel and dentin
- bonding composite resin to metal.

Bonding is a highly esthetic method of obtaining both functional and esthetic restoration of individual teeth, using one or more of the above categories. Patients who appear to be difficult to please may be good candidates for bonding, since it is reversible.[20] This allows the flexibility of redoing or altering the shade for the types of patients who may find it difficult to accept an unchangeable porcelain laminate once it is irreversibly bonded into place. Bonding can be used as a transitional step to more complex procedures or drastic changes that be done through crowns or porcelain veneers or as a means to evaluate occlusal changes. Lately, this is called “transitional bonding;” it has the advantage to simulate complex procedures and test the definitive treatment plan. Bonding is also an excellent choice for closure of interdental spaces with mesial or distal composite resin augmentation because composite resin can be added for cosmetic purposes without any tooth reduction.[21] It has proved beneficial following orthodontic treatment to obtain proximal contact between adjacent teeth to improve retention. A possible contraindication for composite restorations would be in the patient who wishes to replace existing posterior amalgams and exhibits a high caries index and/or consistently demonstrates poor oral hygiene.[22] The esthetic effect, even more than the clinical success, will be based on the proper choice of materials and techniques used. With this in mind, bonding can be used in all five classifications of restorations as well as in repairs of chipped or fractured porcelain.

Specific requirements are that first, and most important, the esthetic need of the patient must be determined. This need filters down to the individual or requirement of specific teeth. It should be further based on a tooth-to-tooth analysis, upper-to-lower arch comparison, and examination of tooth and soft tissue, the smile, or a combination of all the above.

The esthetic need of a patient is determined by considering several parameters as follows:

1. Do you need to make the tooth or teeth more opaque, or develop a depth of color? (Figure 14.3A–E). Depth can be achieved by bonding the darker, more chromatic shade first, then adding incremental veneered layers of lighter or transparent shades.
2. What do you need to do to obtain your best color? This often means mixing and blending composites, or even tints or opaques, from different manufacturers.
3. For what purpose is the composite being used? For facial bonding? Occlusal pits? Class V? The composite(s) you select must, at best, be capable of withstanding the long-term functional stress placed on it by the intended restorations.

Available composite systems generally fall into the following categories:

- Those formulated to match a few shades most commonly found in the general public.
- Those manufactured in various opacities, “dentin-like” materials to replace dentin, “enamel-like” materials to replace enamel, and incisal or translucent shades to replace translucent areas or to provide translucent areas to the restoration. On certain occasions tints and opaquers help to create more difficult, multicolored shading (Figure 14.4A–C).

Figure 14.3 (A) Extremely dark tetracycline-stained teeth provide the most difficult challenge for direct resin full-veneer bonding. This 24-year-old student wanted a conservative and economical solution to her esthetic problem without reducing her enamel surface.

Figure 14.3 (B) To obtain the best natural-looking polychromatic tooth color, first mask the tetracycline discoloration with multiple layers of opaque (Cosmedent, Chicago, IL, USA). Next, orange/brown stain is applied as a thin stripe down the center of the labial surface to give the appearance of underlying dentin.

Figure 14.3 (C) Medium to light blue stain is thinly applied in a vertical stripe at both mesial and distal line angles to help simulate the appearance of enamel.

Figure 14.3 (D) Next, the preselected body shade is uniformly applied over the opaque and stained layers with the anodized aluminum GC3 instrument (Hu-Friedy).

Figure 14.3 (E) The final view of the polished restorations shows how the layered colors increase the appearance of naturalness. Over time, these restorations can be refinished and polished as necessary, which will renew their luster and layered colors.

Figure 14.4 **(A)** This 12-year-old boy presented with an emergency of a fractured left central incisor. Note the adjacent central incisor had an opaque incisal stain.

Figure 14.4 **(B)** After the initial body layer is applied, slight space is left for opaque incisal stains, to be followed by a translucent layer.

Figure 14.4 **(C)** The final result shows the effect of color blend, plus incisal stains.

Restorative uses

Class I restorations

These include pits and fissures that can be easily, quickly, and esthetically restored by composite resins with almost exclusive removal of decay, without the need for removal of sound tooth structure for mechanical retention. As an added bonus, the bonding of small grooves, defects, or pits in individual teeth is an excellent means of preventing either initial or further caries with little or no risk of tooth discoloration, as may be the case with amalgam.[23] Life expectancy is the longest in this category, with 10 or more years not being uncommon.

When matching an exact shade is important to your patient, be sure to make your shade selection before placing a rubber dam. In the event the tooth is discolored due to an old amalgam restoration, it may be necessary to select the shade from the adjacent tooth or remove the amalgam first. Then make your color selection.

Use a “stock” shade guide supplied by the manufacturer only to select several of the closest shades with which to do your actual shade trial bonding. To achieve the closest match, remove all of the old restorative material plus any stained tooth surface that might mar your esthetic result. Have all your materials ready, including a mylar strip and GCI#3 (Hu-Friedy). Place a small amount of composite resin on the tooth to be matched. Quickly apply the mylar strip using more pressure on one end of the composite so you will achieve a good range of color from thick to thin on the labial surface after polymerization. Then let the tooth regain its moisture until its normal color has returned. Make your shade comparison as quickly as possible, avoiding any long periods of tooth desiccation.

Typical Class I composite resin restorations on average last 5–8 years but the patient’s occlusal wear may dictate less than ideal longevity. However, the authors have had composite restoraations lasting well over 15 years in many instances. The advantage of the direct composite restoration is the ability to see microleakage in the form of marginal stain (Figure 14.5A–J). Although early detection of the stain can mean use of air abrasion and resealing the margin, if the patient does not schedule hygiene visits frequently enough (three–four times yearly) replacement of the restoration may be necessary.

Figure 14.5 **(A)** The defective existing composite resin restorations in the lower first and second molars have microleakage at the margins, fractures, and secondary decay. These restorations were functional for over 10 years.

Figure 14.5 **(B)** After removal of the defective restorations and secondary caries, a cavity cleanser is used, followed by a glass ionomer liner/base (Vitrebond, 3 M).

Figure 14.5 **(C)** Here a 37% phosphoric acid etch being placed on the enamel margins, which will be followed by a thorough washing with air/water syringe.

Figure 14.5 **(D)** Next a resin bonding agent is applied and polymerized.

Figure 14.5 **(E)** Layers of the chosen shade of microhybrid composite resin (Venus Diamond, Heraeus) are bonded individually with appropriately sized condensing instruments (#1 TNCIGFTI and #2 TNCIGFT2, Hu-Friedy).

Figure 14.5 **(F)** A reverse-ended carver is ideal for placing anatomy into the composite before final polymerization (#6 Composite Carver TNCIGFT6, Hu-Friedy).

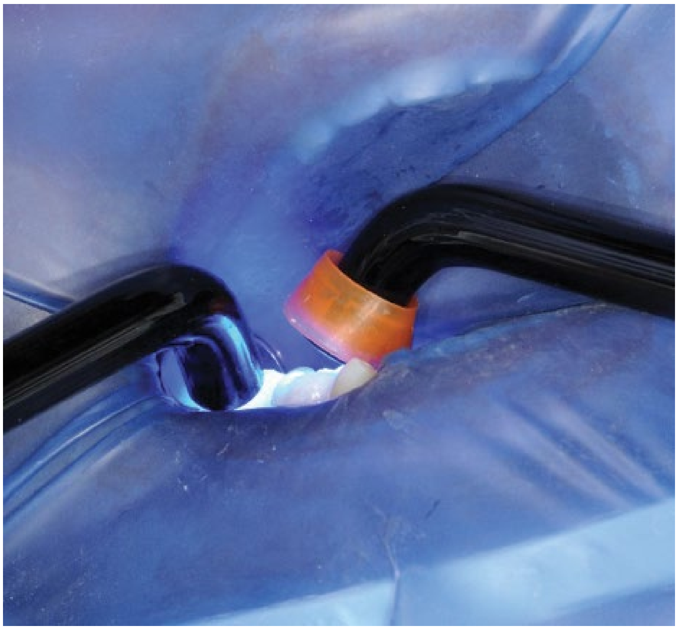

Figure 14.5 **(G)** Final polymerization is achieved and accelerated with a dual-light technique.

Figure 14.5 **(H)** The restoration is first finished using 30 µm diamond (ET6, Brasseler USA), to be followed by finishing burs of the same size.

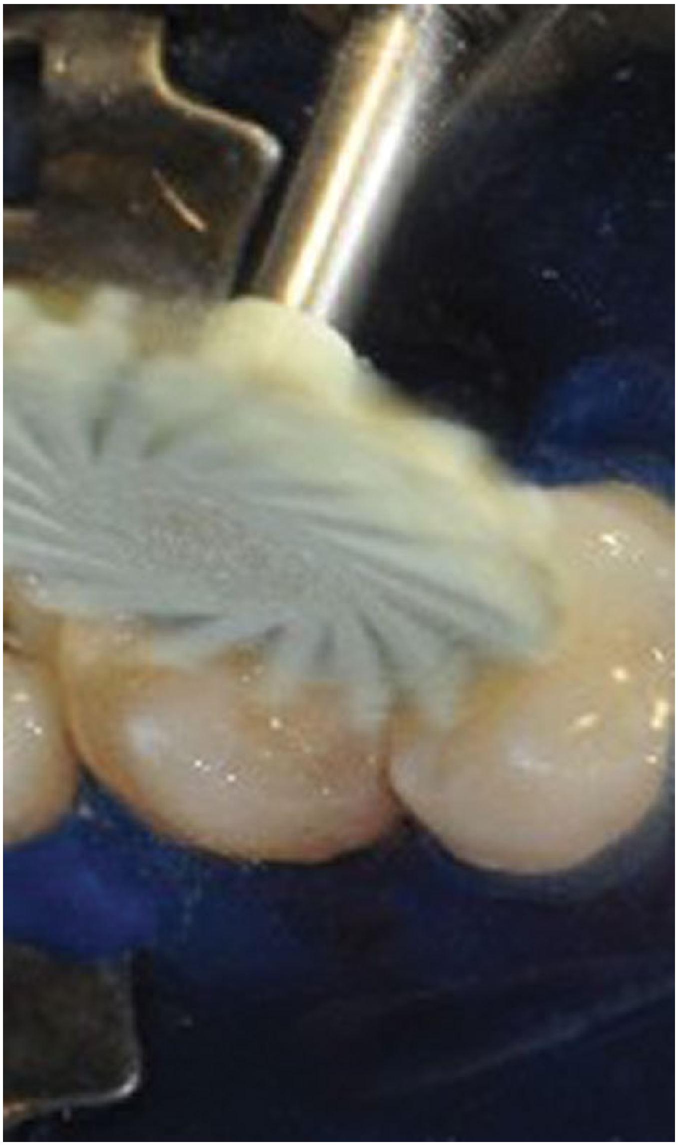

Figure 14.5 (I) The final restorations have been polished with impregnated finishers (Diacomp Featherlite, Brasseler USA).

Figure 14.5 (J) The final result.

Class II restorations

If conservative, these can be achieved, both functionally and esthetically, through composite resins. Tunnel preparations are ideal for composite resin or glass ionomer restorations. Functionally try to salvage as much tooth structure as possible. It is esthetically easier to blend in a composite to existing enamel instead of creating a new color. In addition to conserving tooth structure, Douvitas[24] notes that gap formation between resin and enamel occurs most visibly in the cervical wall of Class II restorations, which may be minimized by using a spherical, rather than rectangular, cavity preparation. This class illustrates quite well the role bonding often plays in making esthetic dentistry (as opposed to dentistry for function only) economically available to a larger number of patients. At times, there will be need for larger Class II restorations, especially on the mesial aspect of bicuspids where the labial margin would show if it were amalgam or gold and the patient wants to keep the cost lower than that for a porcelain inlay. This is permissible, provided the patient understands that the life expectancy may be considerably shorter for other restorative options.

Patients' main objection to amalgam restorations has been either the "silver," "black," or "metal" color of restoration and the darker-appearing enamel associated with these restorations. Esthetically, the Class II restoration can present special problems, especially with a large mesiolabial wall that needs restoring. The shade that blends well with the occlusal portion may not match the proximal wall. You may need to bevel the cavosurface margin of this wall or use a more translucent shade or blend a slight blue or violet tint into the proximal portion to obtain a better match (Figure 14.6A–E).

Indirect posterior composite restorations

Emphasis on bonding, esthetics, and tooth conservatism has prompted research for the optimal material for use in posterior tooth-colored restorations. Dental porcelain has basic problems including questionable wear of the opposing dentition, difficulty with modification and polishing in the oral cavity, and an inherently brittle nature. Polymer-based systems of the past, on the other hand, have lacked sufficient strength and wear resistance. Recent advances in polymer ceramic technology combined with new fiber developments have generated an entire genre of metal-free restorative materials.

These systems may provide the esthetics, biocompatibility, and enamel wear similar to an ideal resin material while encompassing the flexural strength and fracture resistance of metal-reinforced restorations for anterior and posterior areas.[25]

Although these materials are used frequently for posterior inlays and onlays, for the purpose of this book they are discussed in Chapter 15.

Class III restorations

These are the major use for composite resins today. Composite resin materials have become the most popular material for Class III, as well as Class IV and Class V, restorations.[26] These cavity classifications are excellent examples of the use of bonding for

Figure 14.6 **(A)** This lady fractured her previous bonded restoration. Due to the minimal amount of remaining enamel, it was decided to proceed with a direct bonded restoration rather full or partial ceramic coverage.

Figure 14.6 **(B)** Occlusal view of the preparation shows only thin labial and lingual walls of enamel remain.

Figure 14.6 **(C)** After a direct bonded Class II composite restoration was placed, final carving was completed with a 30-blade carbide (ETOS2, Brasseler USA).

Figure 14.6 **(D)** Tight contact was achieved by use of heavy wedging.

Figure 14.6 **(E)** The final restoration after finishing and polishing.

esthetic superiority as well as its economic pluses. As Croll and Donly[27] point out, when bonded composite resin restorations are placed, finished, and polished correctly, and a suitable shade and translucency of composite resin is used, Class III restorations can simulate perfectly the appearance of natural enamel and dentin, and they last for many years (Figure 14.7A–N). Composites come in almost every shade, range, translucency, and opacity. Acid etching seals the composite to the enamel for functional soundness. However, you may need to purchase additional shades from several different manufacturers to cover a complete range of color options. Shade selection for the Class III composite can be both time consuming and frustrating. The major problem is choosing a shade that will actually match after you have inserted and finished the restoration. Typically, the first thing you do is place a sample of the intended material on the tooth to be restored. The difficulty is to anticipate the correct amount of material thickness so the final result will match. A good method of accomplishing this is to vary the thickness of the sample by pressing harder on one end with the mylar strip so you will get a gradation of color and, therefore, get a better indication of just how close your shade will match with the estimated thickness.

Class IV restorations

These, including chipped or fractured teeth, are one of the main reasons for using composite resin. Frequently, bonding is the ideal solution, providing both the immediate answer to an esthetic emergency and a long-term, low-cost restoration. There is no reason to crown a tooth that has minor chips or a slight

Figure 14.7 **(A)** The replacement of discolored anterior restorations with composite resin comprises one of the largest percentages of esthetic restorative dentistry.

Figure 14.7 **(B)** The objective of replacement is to obtain invisible margins and a blending of color to match existing tooth structure.

Figure 14.7 **(C)** The basic tooth preparation for the Class III restoration consists of a reverse bevel and an overlaid margin that extends several millimeters past the bevel. This provides extended restoration longevity and a better color blend.

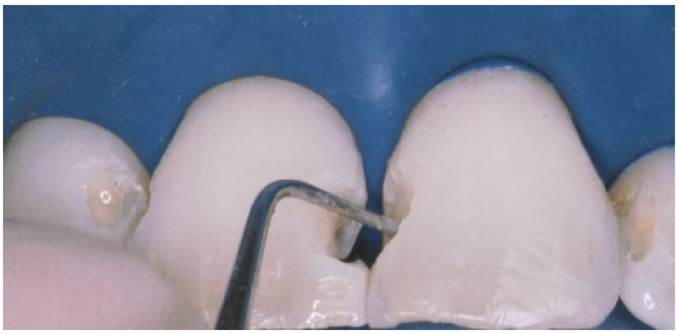

Figure 14.7 **(D)** After the old restorative material is removed and a reverse bevel is placed, light-polymerized glass ionomer liners are inserted with a Novatech PINT I I (Hu-Friedy).

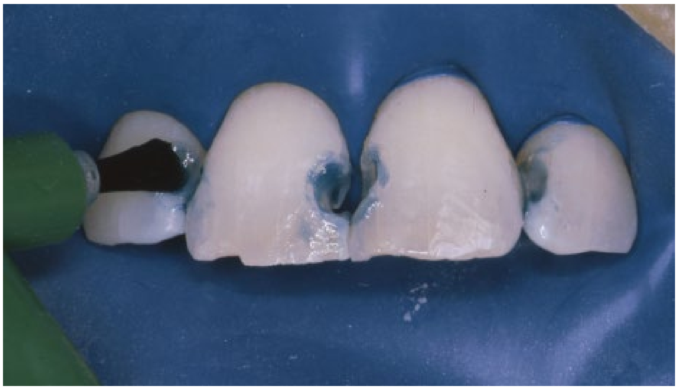

Figure 14.7 **(E)** Acid etching should be accomplished for 10–30 s depending on the composition of the tooth structure that is being etched.

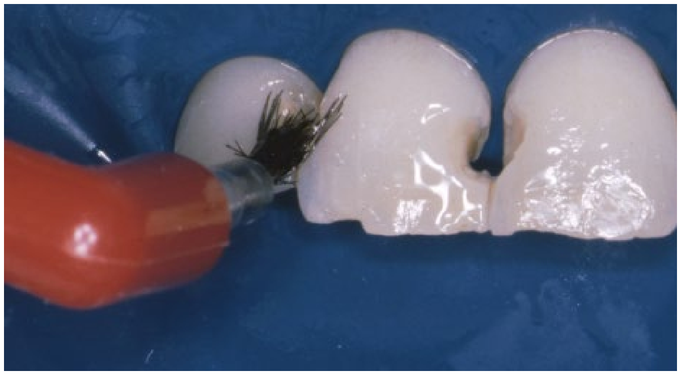

Figure 14.7 **(F)** Use different-colored brush handles (Centrix) to apply the various agents used in the bonding process. Here, a red brush is used to apply the final bonding agent, which is then polymerized.

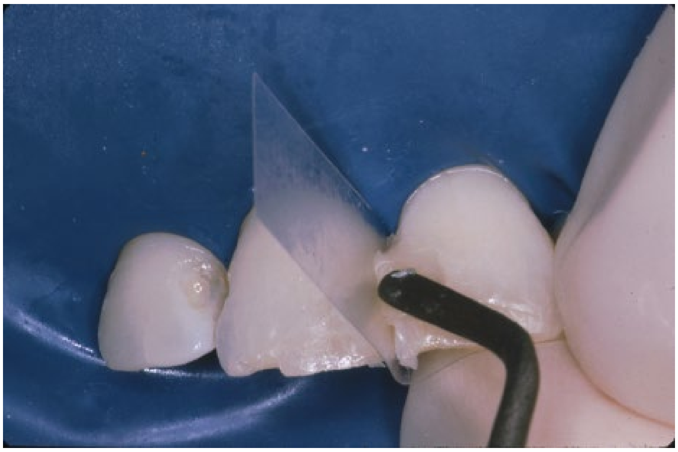

Figure 14.7 **(G)** The preselected shade of microfill composite resin is applied with a thin-bonded, nonstick composite instrument (#3 Extra-Flex TNCIGFT3, Hu-Friedy) in small increments and polymerized layer by layer. To increase the depth of color, consider using a slightly darker shade initially, followed by a lighter one, rather than one shade for the entire restoration.

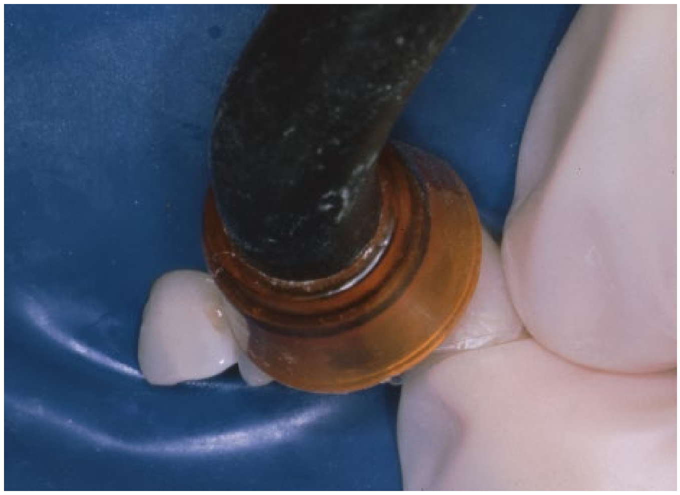

Figure 14.7 **(H)** A mylar matrix strip is loosely held to ensure separation and adequate thickness for proper finishing to occur. Polymerize each layer both labially and lingually for the time specified by the manufacturer as each increment of composite resin is applied.

fractured piece missing when a direct-fill light-polymerized composite restoration is more economic and equally functional and esthetic (Figure 14.8A–H). Minor chips of anterior and posterior teeth also can be repaired easily with composite resin with predictable success (Figure 14.9A and B).

Class V restorations

Caries and even large, eroded defects are generally handled with a microfill highly polished restoration, which is the treatment of choice. However, new materials with improved polishability, color stability, resistance to wear, and extended range of shades are suitable for Class V restorations. One possible disadvantage of microfilled composite, as stated by Davidson and Kemp-Scholte,[28] is its tendency to undergo hygroscopic expansion, which produces marginal overhangs. In the less-motivated patient, this may result in excessive staining and recurrent caries. When making a shade selection for Class V restorations, first note your patient's lip line. This is particularly important for patients with a medium lip line where the incisal-most margin will show during a wide smile. Remember there is a shadow created by the lip line that tends to emphasize the gray shades. Therefore avoid gray or translucent shades if possible, and select the more opaque shades for better blending (Figure 14.10A–J).

Labial veneer

As previously stated in this chapter, the quickest and most economic method of obtaining an esthetic tooth transformation is through the direct resin labial veneer. Although esthetic perfection may be more easily obtained with the porcelain veneer, the extra time and laboratory costs involved may make the procedure economically difficult for many patients. Therefore, composite resin bonding becomes the restoration of choice for these patients. The best candidate for the direct resin veneer is the monochromatic shaded tooth, since multicolored restorations are much more easily constructed in the laboratory (Figure 14.11A–D). However, if you take the extra amount of

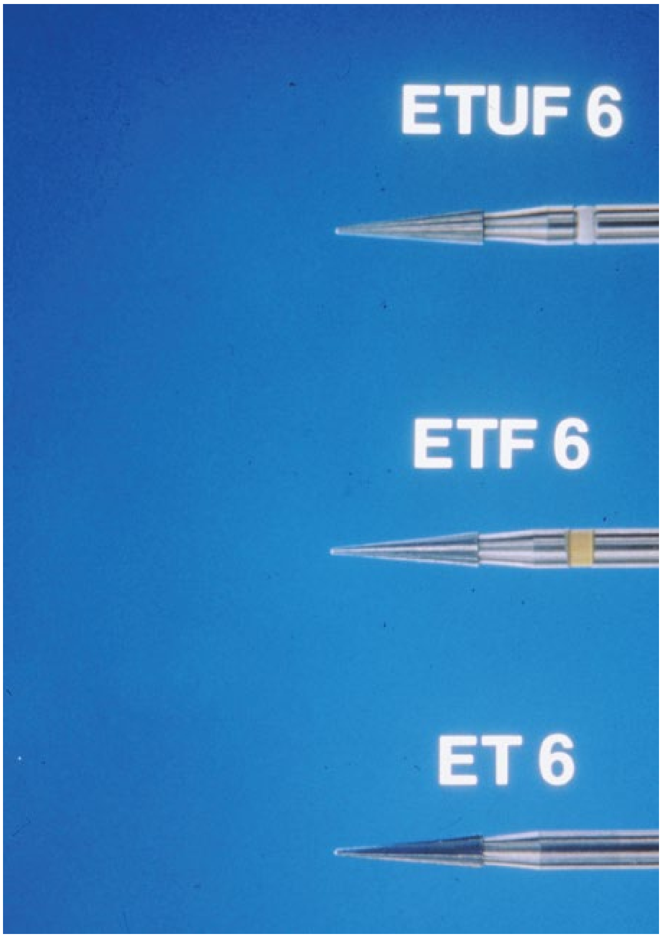

Figure 14.7 **(I)** The sequence for finishing requires an entry-level instrument of 8-, 16-, or 30-blade carbide (E.T. Burs, Brasseler USA) depending on the amount of excess composite present.

time and have developed the skill to master inlaid shades and stains, you will certainly be able to match almost any tooth with direct composite resin bonding (Figure 14.11E–J).

A potential dilemma arises when tooth deformity exists on approximately half of the tooth. Is it better to restore one half of the tooth and attempt to blend a potentially revealing margin or veneer the entire labial surface and extend the margin subgingivally? One instance where the veneer would be preferred is with the patient who wants to avoid periodic showing of a Class III margin. It is a better choice to veneer the entire labial surface and completely mask the tooth/composite margin. When doing so, consider improving the smile line by extending the labial surface in a buccal direction.

The bonded composite veneer also can be used with porcelain veneers or full crowns when economics is a problem. A good example of this technique would be to either use crowns or

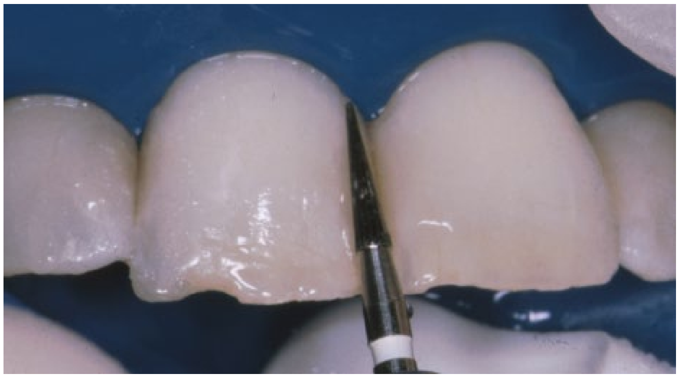

Figure 14.7 **(J)** Final labial finishing is done with the ET6UF 30-bladed carbide (Brasseler USA).

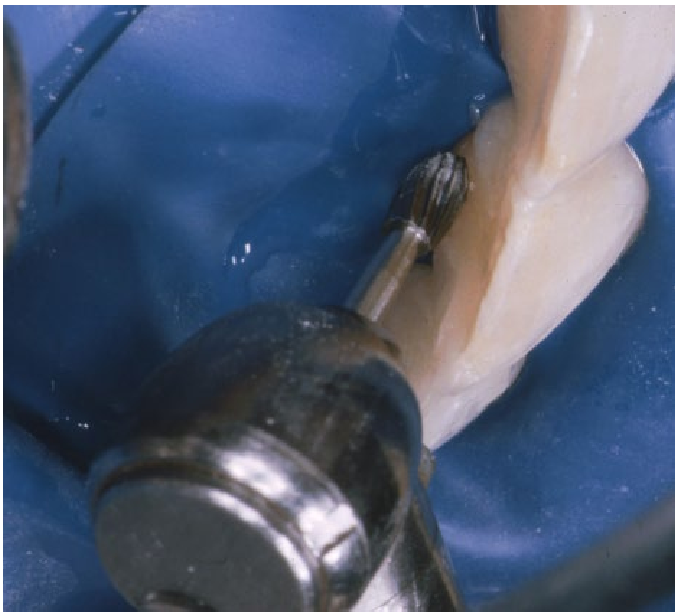

Figure 14.7 **(K)** The OS-1 finishing bur (E.T. Burs, Brasseler USA) is the perfect shape for lingual contouring.

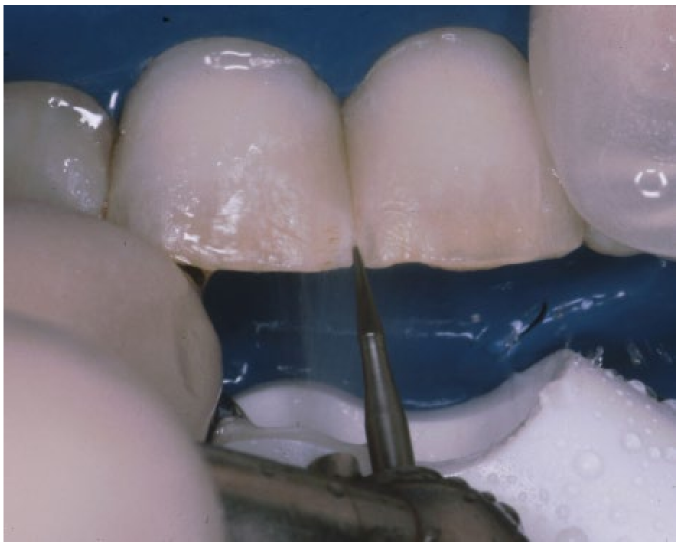

Figure 14.7 **(L)** The incisal embrasure is opened by an E.T. "cutting bur" (Brasseler 132-A).

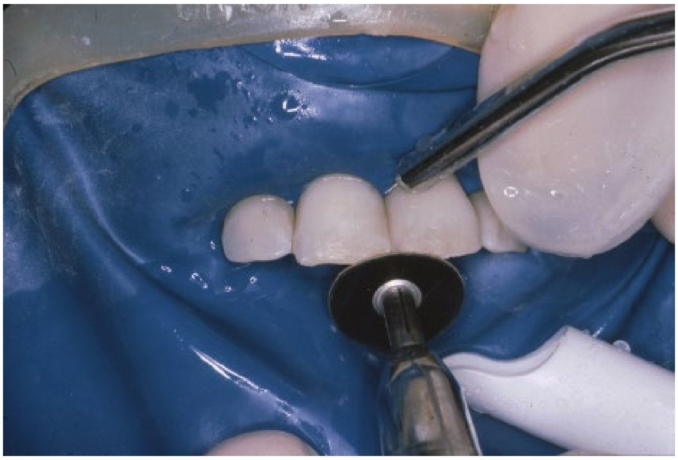

Figure 14.7 **(M)** A series of flexible sandpaper disks are useful for leveling and final polish (Sof-Lex, 3 M).

Figure 14.7 **(N)** If contact is too tight, an extra-thin abrasive diamond strip can be used to make it easier for the patient to floss (Premier Dental Products, Cosmedent, 3 M, Shofu, Brasseler USA).

Figure 14.8 **(A)** This 18-year-old fractured his right lateral incisor in a sports accident.

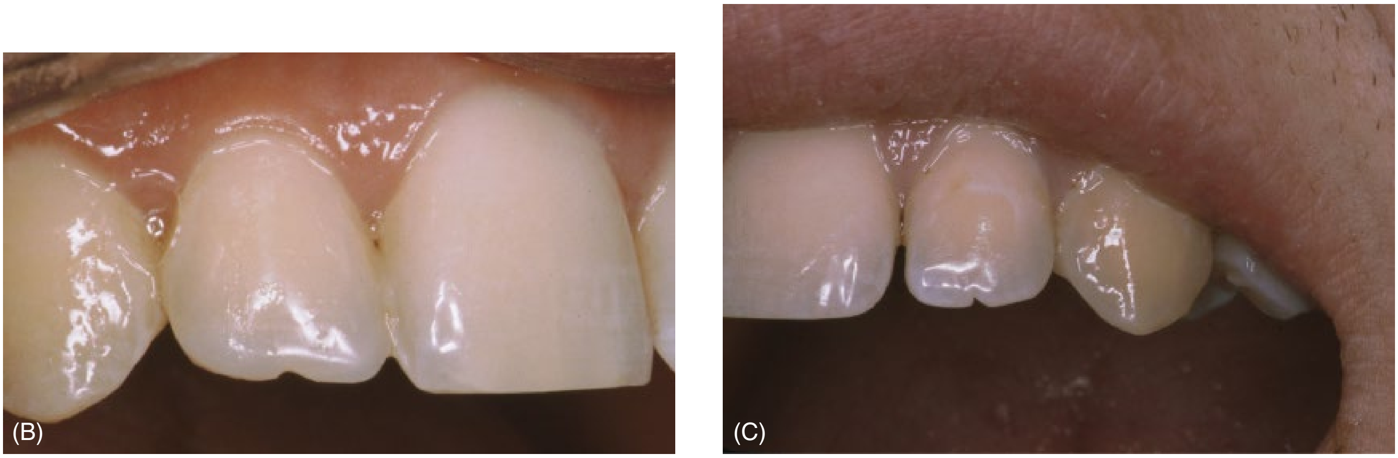

Figure 14.8 **(B and C)** The final bonded result shows a microhybrid composite resin with a color blend that successfully masks the restoration margin. Note the maxillary left lateral reveals an incisal notch that was also incorporated into the restoration of the right lateral.

Figure 14.8 **(D)** The overlay technique is used to repair the fractured tooth and includes a long bevel and a margin that extends well past the bevel. This technique is described in greater detail in this chapter.

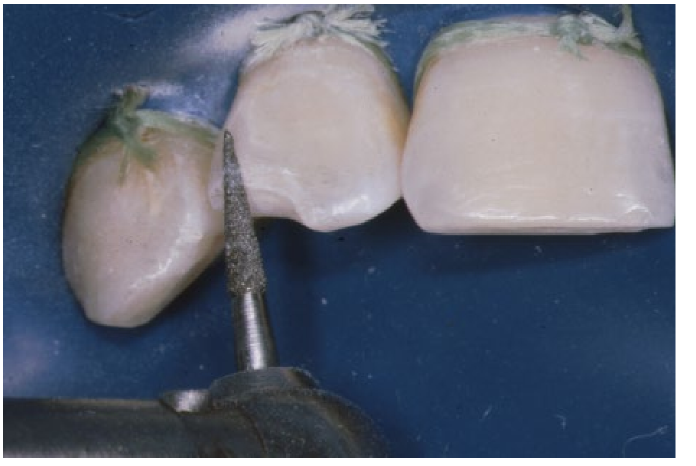

Figure 14.8 **(E)** Following shade determination and after placing the rubber dam, a long bevel is created using an extra-coarse diamond (AC2, Brasseler USA). It is also useful to roughen the enamel surfaces that will be bonded to increase surface retention.

Figure 14.8 **(F)** The entire facial and lingual surface are etched with 37% phosphoric acid etch and rinsed thoroughly.

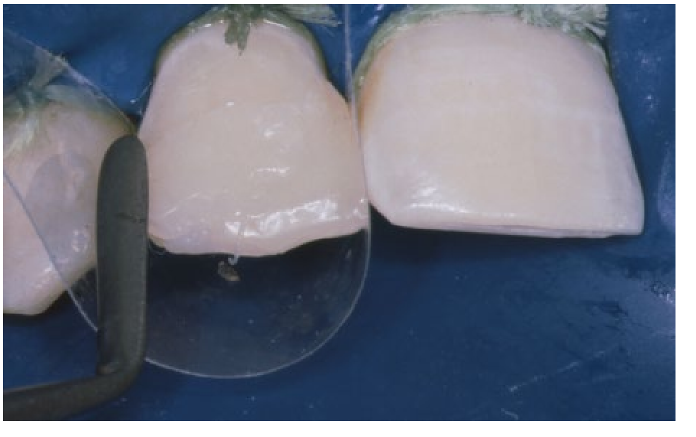

Figure 14.8 **(G)** Initial increments of the darker shade are placed, followed by an incisal overlay. The #3 Extra-Flex (TNCIGFT3, Hu-Friedy) is used in a patting, sweeping motion.

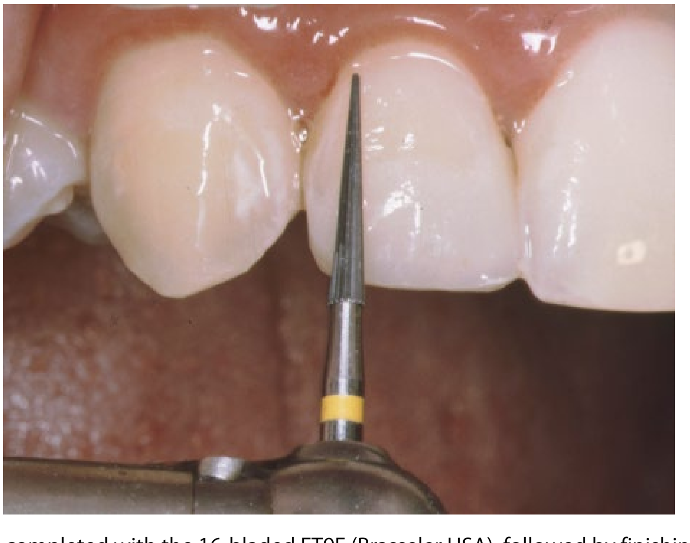

Figure 14.8 **(H)** Final contouring was completed with the 16-bladed ET9F (Brasseler USA), followed by finishing and texturing with the ET9UF 30-bladed carbide (Brasseler USA).

Figure 14.9 (A) This lady fractured her right central incisor while eating.

Figure 14.9 (B) A microfilled composite resin was used to restore the tooth to its original contours.

Figure 14.10 (A) These Class V abfraction lesions were a result of occlusal trauma.

Figure 14.10 (B) A medium-to-long bevel is cut from the eroded surface into fresh enamel. The labioincisal or labio-occlusal margin extends to the point where there is a slight lingual inclination which will help match the tooth color.

Figure 14.10 (C) A long bevel is added with an extra-coarse diamond (AC2, Brasseler USA).

Figure 14.10 (D) The entire facial surface is etched.

Figure 14.10 (E) After bonding agent is applied and polymerized, composite resin is applied in increments (TNCIGFT4, Hu-Friedy).

Figure 14.10 (F) An extra-thin composite instrument (TNCIGFT4, Hu-Friedy) is used to finalize subgingival margins without causing bleeding.

Figure 14.10 (G) An 8-bladed finishing carbide (ET4, Brasseler, USA) is used to help contour the gingival aspect of the Class V.

Figure 14.10 (H) A 30-bladed carbide (ET4UF, Brasseler USA) provides a final finish to the restoration.

Figure 14.10 (I) Polishing is done with silicone rubber polishing cup (Illustra, Brasseler USA).

Figure 14.10 (J) Final restoration.

Figure 14.11 **(A)** This beauty contestant wanted a brighter, but more prominent smile.

Figure 14.11 **(B)** The final result was achieved utilizing a minimally invasive technique of direct composite bonding. Her newly confident smile may have helped her win the pageant, but more importantly she won a successful career.

Figure 14.11 **(C)** Multiple layers of a bleaching shade of microfill composite resin was used.

Figure 14.11 **(D)** Final surface texture was achieved using a 30-blade carbide finishing bur (ET6UF, Brasseler USA).

Figure 14.11 **(E)** This 46-year-old businesswoman was concerned about the wear and the loss of interdental tissue between the central incisors. Composite resin bonding was chosen as a conservative, reversible, one-appointment restoration.

Figure 14.11 **(F)** After building up the preselected body shade, the incisal portion was serrated with a GCI 3 (Hu-Friedy). Next, medium blue stain was placed and polymerized in the serrated areas to help simulate incisal translucency.

Figure 14.11 **(G)** The completed restorations provided a younger-looking smile line as well as closing the previously open gingival embrasure. Although there is the appearance of a small amount of incisal translucency, it can be enhanced by additional labial finishing.

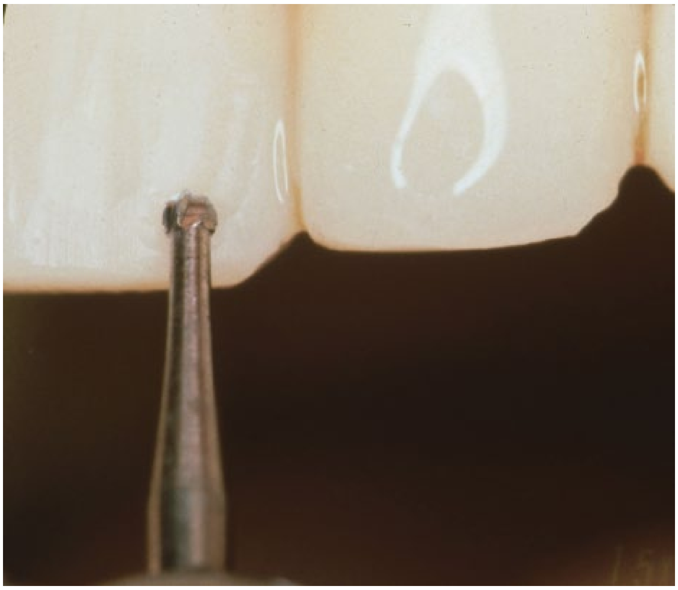

Figure 14.11 **(H)** A more precise method of achieving spot staining can be obtained by slightly cutting back the finished composite restoration.

Figure 14.11 **(I)** A mild gray stain is placed and polymerized to help simulate a subtle translucency. Either body- or incisal-colored composite resin is applied and polymerized over the stained area.

Figure 14.11 **(J)** The polished restorations achieve the feeling of slight translucency. If a more intense translucency is desired, use a darker gray or blue stain.

porcelain veneers on the anterior teeth for maximum longevity and esthetics, while using direct resin veneers on the bicuspids, and even on the first molars if necessary (Figure 14.12A–C).

Repairs of existing restorations

Chipped or fractured porcelain can be repaired quickly and esthetically with composite resin, using direct intraoral porcelain etching procedures. The esthetic life of this type of repair may be considerably shorter than for a normal bonded restoration, however, ranging anywhere from 6 months to several years. And as with most composite restorations, there will be marginal staining, especially in an anterior porcelain repair, necessitating more frequent maintenance and earlier repeat repairs. To improve the bond to porcelain, use one of the air-abrasive systems with medium pressure and a fine abrasive. See Chapter 38.

Provisional treatment

Creation of anterior guidance or posterior rehabilitation during occlusal therapy for patients with bruxism-associated myofascial pain can be achieved using bonding.[20] A hybrid composite is usually the material of choice.

Bonding is an excellent treatment selection for young persons who will have continued facial growth since it is likely that passive eruption will leave unsightly lines or the gingival margins of any veneer. But with direct-bonded veneers, the veneer can be replaced or repaired when growth is finished with either composite resin bonding or porcelain laminate veneering.[29]

Figure 14.12 **(A)** This young woman wanted to improve the color and shape of her teeth.

Figure 14.12 **(B)** For reasons of tooth preservation and economics, a treatment plan was developed that included a combination of ceramic restorations as well as direct composite resin bonding.

Figure 14.12 **(C)** Final result shows how the all-ceramic crowns, porcelain veneers, and composite resin bonding blend together.

Direct and indirect inlays

There are several methods of constructing the posterior inlay. Direct resin inlays can be cured initially in the mouth for shaping, then cured again in the laboratory, and only then bonded into the tooth preparations with resin cements. As Christiansen[30] outlines clearly, this restoration solved some of the problems seen with resin restorations cured directly in the tooth. The shrinkage during polymerization takes place in the oven, and there is less shrinkage in the marginal areas. These restorations are time consuming, but they have excellent appearance and lasting power. They also have the advantage of being "custom made," signifying quality and personalization to many patients.[31] One trade-off that must be respected is that indirect curing causes resins to become more brittle and less forgiving under occlusal loads.[32] Indirect inlays that are constructed in the laboratory have been slowly gaining acceptance. They have the same strength and wear characteristics as the direct resin inlays and onlays, but do require laboratory technicians and, thereby, greater cost. The best method of constructing posterior inlays or onlays is with a computer-assisted manufacturing apparatus, which is covered in Chapter 15 (Figure 14.13A–C).

Materials

The technique of bonding is heavily material-dependent. Bonding materials were the first esthetically substantial products used in dental restorations that were simultaneously free of mercury, resistant to corrosion, thermally nonconductive, and without galvanic reactions.[33] The availability of new materials for use in bonding has been the major player in the balancing act between esthetics and strength. Excessive rate of wear was the most serious physical limitation of early dental composite resins, limiting their use, for example, in Class I and II cavities where they are subjected to greater occlusal loads and abrasive actions.[34] However, the wear rate of posterior composites sealed with a surface-penetrating modified bisphenol A-glycidyl methacrylate (BIS-GMA) resin was reduced 50%, as reported by Dickinson et al.[35] Recently, new materials have shown improved wear resistance very similar to that of amalgam.[36,37]

The continuing improvement in bonding technology has created materials that are lasting and can be polished to a porcelain, tooth-like appearance. Earlier bonding materials had a tendency to stain, especially at the edges, and to wear. This is less true of the newer materials, especially when close attention is paid to preparation, application, and finishing.

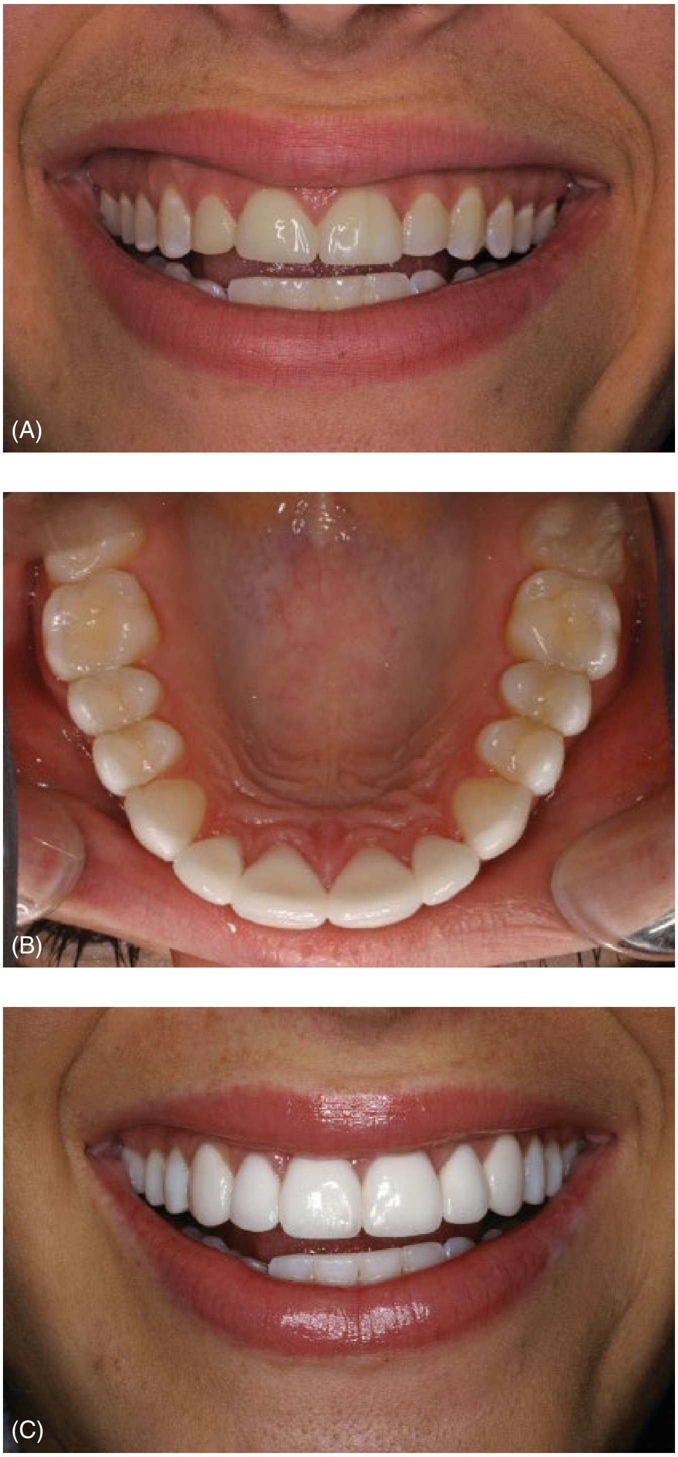

Figure 14.13 **(A)** This young woman was unhappy with her smile due to extra-large central incisor crowns, plus her discolored teeth. Since she could not afford a treatment plan based on full crowns and porcelain veneers, a compromised plan was created which included all-ceramic crowns, porcelain veneers, and direct composite resin bonding. **(B)** The occlusal view shows all-ceramic crowns on centrals and laterals, porcelain veneers on the cuspids, and direct composite resin bonding on the bicuspid and first molars. **(C)** The final smile is the whitest shade possible to please the patient.

As Jordan and Gwinnett[38] pointed out, composite materials consist primarily of resin-binding matrix and inorganic filler phases. The resin-bonding matrix is fairly consistent, with Bowen's BIS-GMA resin constituting the resin matrix of most composite materials (although urethane dimethacrylate is occasionally used in some). Composite materials differ primarily in the inorganic filler type and size of particles, and it is these differences that will determine the strength of the bonding—and, inversely, the degree to which the materials can be polished for esthetic appeal, and resistance to discoloration. The ideal composite material is highly polishable, so that the finished restoration would have the smoothness and reflective quality of enamel. It also needs to be highly resistant to chipping or fracture, with maximum durability in stress-bearing areas. Newer microhybrid and nanofilled materials have shown excellent qualities and durability. These new materials are very strong, have nice optical properties, and are able to maintain their luster.

In general, the different composites have different roles to play. When restorations are in high-stress areas, the greater filler loading of microhybrids gives them an advantage. When an enamel-like polished surface is required, microfilled composites are the material of choice.[39] However, the introduction of microhybrids, nanohybrids, and nanofilled composites have shown a great potential to be universal materials. They can be used in the posterior and anterior parts of the mouth.

Concise and extremely detailed comparative summaries of available resins and their recommended uses can be found in newsletters like *The Dental Advisor* (published by Dental Consultants, Ann Arbor, MI, USA), *Reality* (Houston, TX, USA), or *CRA Newsletter* (Provo, UT, USA), and in current journal literature. Although a few commercially available products have various degrees of shades with ranges of opacity, you will find that certain manufacturers tend to place more opacity in their composites than others. Since most BIS-GMA composites are compatible, you may choose to purchase a composite kit with the broadest possible shade range and then add additional individual shades of another brand that may have more or less opacity as you need to have the full range of shades.

Microfilled composites

The inorganic filler in most microfilled composite materials is colloidal silica, a fine white powder with a particle size of 0.04 µm. When the inorganic filler particle is this small in diameter, it is highly polishable. With proper finishing, the surface is smooth and highly reflective, much as natural enamel. However, the particle size means that the composite will not hold a large amount of inorganic filler. The maximum inorganic loading with a microfilled material may be half that of other composite materials.[11,38,40] The microfilled materials, therefore, do best in protected clinical situations such as Class III and Class V labial veneer restorations and small Class IV situations in which the occlusion can be carefully adjusted and controlled.[11] However, full labial bonded direct resin veneers are perfect for microfill composites due to their high polishability (Figure 14.14A–D).

Figure 14.14 **(A)** This 14-year-old student was unhappy with her previous bonding which attempted to mask her tetracycline stain. Note how inflamed the right central, lateral, and cuspid gingival tissue was due to overhanging margins.

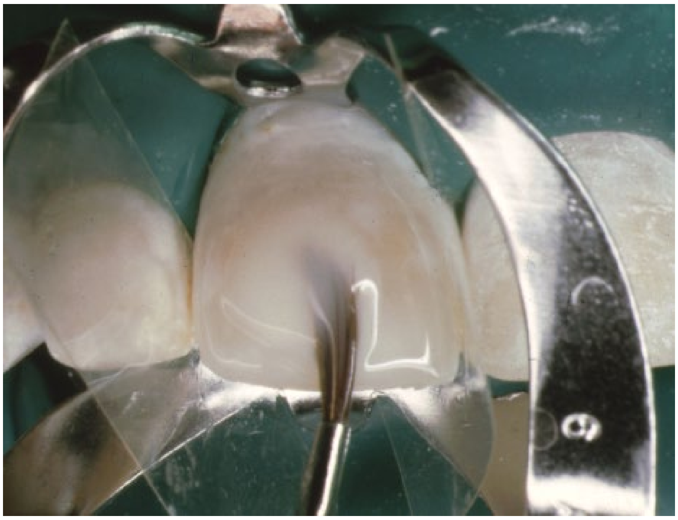

Figure 14.14 **(B)** Due to tissue inflammation, a rubber dam was placed and each tooth was individually clamped before it was bonded. Here the first of multiple layers of opaquer are applied and then polymerized.

Figure 14.14 **(C)** After multiple layers of the lighter shade of microfill composite resin are applied, polymerized, and finished on the right central, the right lateral is treated.

Figure 14.14 **(D)** After 2 weeks, note the final result shows a more favorable color and an improved tissue response to properly finished margins.

Small-particle macrofilled composites

Composite materials in which the size of the inorganic filler particles is between 1 and 8 μm are only semipolishable, with a duller, less reflective surface after finishing. They are more resistant to fracture, however. This makes them highly appropriate in Class IV situations exposed to heavy occlusal loads. These types of materials are obsolete for use in modern bonding where strength and polishability are essential, especially in the anterior region.

Hybrid, microhybrids, and nanohybrid composites

These composite materials address the trade-off between esthetics and strength, combining reasonable polishability with increased resistance to fracture. Average particle size for these materials is about 1 μm. Clinical trials have provided data on the long-term effectiveness of these composites, so they were widely used. In fact, the trend in composite resin technology has been toward smaller average particle size and higher filler loadings.[6] The dental industry has improved the processing of materials which permit high loading and finer particle texture to be achieved together.[41] Advances in technology have allowed a reduction of the particle size used in the fabrication of composites. Thus the average particle size has decreased to a submicron size (about 0.4 μm). Because of the submicron size the new generation of hybrid materials received the name "microhybrids." These materials with enhanced properties and improved appearance have been the workhorse of the profession for the last 15 years. In more recent years the incorporation of even smaller fillers with the purpose of changing handling properties has resulted in naming some of these materials "nanohybrids." These "microhybrids" and "nanohybrids" have good physical properties, polish well, and are esthetic and strong enough to be used universally.

Nanofilled composites

This category of material indicates a new development in resin composites technology. These materials incorporate silanated silica and very small zirconia particles as well as agglomerates or clusters of zirconia and silica. The particle size for these materials varies between 80 and 20 nm. The cluster or agglomeration behaves as a large particle filler, providing strength. Because of the small particle of the agglomerate they can be polished to a high luster.

Bonding techniques

The underlying aim of bonding techniques, just as for the selection of materials, is to achieve an esthetic effect while creating a strong retention of the composite material to the surface and especially the margins of the area to which it has been applied. Not only must the bonded material hold up under stress, but it must eliminate marginal leakage which can destroy your esthetic results.

As with any clinical esthetic procedure, the first step is to make photographic records prior to even cleaning the teeth. This provides the "before" for your restorative "after" photos, and it also provides information about the patient's oral hygiene and stain-forming habits that may threaten the esthetic effect you are about to create. This photographic documentation can prove invaluable if later a question arises about what you did and why you did it. Remember, even the best of patients can have a short memory. Only after the photographs are made should you pumice the area thoroughly and take all steps to provide a thoroughly clean surface. As noted by Paquette,[42] failure to remove all debris from every surface of the tooth to be restored may result in a "peeling" of the composite, especially interproximally. It is probably not a good idea to appoint a patient for resin placement on the same day as a recall prophylaxis because crevicular weeping/hemorrhage can undermine every step of the bonding technique. Instead, allow soft tissue to heal and be certain that your patient is maintaining good home care. Miura et al. have demonstrated that a prophylactic cleaning of enamel raised bond strength by approximately 50%. No wonder Gwinnett called the interface between resin and tissue the potentially weakest link between restorative resin and enamel. He advocated a thorough dental prophylaxis to remove deposits (including calculus) from the enamel to allow the acidic conditioning agent, namely phosphoric acid, to exert its optimal effect.[18,43] Gwinnett also reported that the use of ethanol to remove any residual water from the etched enamel enhances the ability of resin monomers to penetrate the surface irregularities.[18]

An optimal working field can be achieved through careful isolation of the teeth, usually with a rubber dam, after pumicing and rinsing. Do not use prophylactic pastes which contain glycerin and fluoride, however, since these will act as barriers to etching solutions.[10] Brockmann[44] has demonstrated that air abrasion prior to etching a tooth for occlusal sealants creates an enhanced retentive surface. Air abrasion increases the number of enamel "tags," thereby permitting more saturation of the resin.

Possible limitations of routinely using an air-abrasion instrument may be that the force of the spray can cause gingival hemorrhage or crevicular weeping when close to the gingival sulcus. Goldstein has also advocated using an extra-course diamond bur on enamel surface prior to etching (AC2 diamond, Brasseler USA), especially if the surface may have been previously bonded. Then follow up with air abrasion.

Shade selection

This step of the procedure merits a significant amount of time to test and consider a complex mix of factors. Recognize that there can be a marked difference, one noticeable to the naked eye, between color shades and resin samples, especially for the incisal colors and the deep and dark colors.[45] Compounding the difficulty of shade selection are, according to Makinson, color changes that develop during curing. He found that, in general, all become lighter, with some becoming more opaque and some transparent. It therefore follows that a cured try-in of the shade(s) that you have selected offers a good idea of the color of the final restoration.[46] These factors include color of the dentin and enamel and, as discussed previously, the color of the liner. Custom composite shade guides may somewhat improve shade matching.[47]

Prior to shade selection the operator needs to consider several factors as follows:

1. **Teeth need to be clean.** Use a rubber cup and pumice to clean the tooth to be restored and adjacent teeth. It is quite often that a shade needs to be selected from the adjacent tooth, such is the case of a discolored restoration in a central incisor to be restored. In this case the shade needs to be selected from the contralateral incisor to achieve shade match and symmetry between the central incisors.
2. **Avoid dehydration.** Dehydration has proven to make teeth whiter and more opaque. It is a good idea to ask the patient to keep the teeth wet during shade selection.
3. **Use good light.** It is recommended that the operatory environment is properly illuminated in amount of light and type. Color-corrected fluorescent lights with a temperature of 5500 K and a color rendering index (CRI) of at least 90 is the best suited for shade determination. It is recommended that operatory light unit light be turned off because most units use incandescent light which emits orange-red hues.
4. **Remove any surrounding strong color** like lipstick and cover colorful clothing with the patient napkin.
5. **Be brief when selecting shades.** The response time of the rods and cones to differentiate color is short. A determination between shades should be limited to 4–5 s.
6. **If possible, use a shade guide made of the resin composite to be utilized.** It is beneficial to have a shade guide made from the brand of resin composite of choice by the clinician. Most manufacturers of resin composite use nomenclatures based on the Vitapan Classical shade guide. Unfortunately, resin composite shades do not always match those of the Vitapan shade and furthermore the shades among manufacturers do not match each other.

Regardless of whether you have operatory lights that are color-corrected, getting the right amount of color-corrected light into the oral cavity can be challenging. One of the most efficient ways to clearly delineate between tooth and resin shade is by using a specially designed light source that allows you to evaluate your intended shade with different color-corrected light (Figure 14.15).

Clinical procedure for shade selection

Organize the custom shade guide, from lightest to darkest. Position the patient in the chair at eye level, retract the lips, and run the whole shade guide parallel to the incisal edges of the teeth to be restored. Select three or four of the closest shades. Repeat the process with these fewer shades until the closest shade is selected. This process of elimination is usually very reliable for shade selection (Figure 14.16A–G).

Figure 14.15 An accurate, close-up source of color-corrected light is important in shade selection (Rite-Lite, AdDent).

Figure 14.16 **(A)** This 37-year-old prima ballerina was dissatisfied with her discolored, protruding, and spaced teeth. Although orthodontics was the strongly suggested treatment of choice, composite resin bonding was chosen instead as an economic and quick compromise solution to her esthetic problem.

Figure 14.16 **(B)** Multiple shades of composite resin from different manufacturers were applied and polymerized to help determine which shade to use.

Figure 14.16 **(C)** Composite resin is applied in incremental layers on the central incisors first. During polymerization, a protective eye shield is used.

Figure 14.16 **(D)** Composite resin is finished with an ET9 8-blade carbide (Brasseler USA).

In choosing the color, obviously the choice will be the closest shade possible to the tooth that is available with your brand of composite resin. It may be necessary to use a combination of two or even more shades to arrive at the proper depth of color. If so, always use the darker shade first to achieve a depth of color that will look more natural in the mouth. However, for a Class III restoration in a tooth with multiple shades, the lighter (matching the incisal value) composite should be inserted first, and then layered with the shades that match the gingival portion. You may also perform a cutback and then use stains or darker shades, like the repair technique, to provide the most esthetic result.

Once you have chosen a shade, or better yet, a combination of shades or tints/opaques cotton dry the tooth, and place a small amount of composite resin on the tooth. Using a mylar strip to hold the material in place, polymerize with your curing light. Isolation tends to desiccate the tooth, making it appear lighter than it actually will be under normal circumstances, and there is danger in assuming the shade will match if the tooth has been kept dry too long. Therefore, do this step of the shade selection phase of treatment as rapidly as possible. Avoid using cotton rolls and save the tooth drying until the last moment; even then, complete the polymerizing as rapidly as possible. If you anticipate difficulty in matching your patient's tooth color, consider making a separate appointment to spend the necessary time to properly complete this important step. This extra appointment should definitely be considered if your patient's shade is not going to be an easy one to match.

Figure 14.16 **(E)** Use dental floss to help discover any previously undetected overhangs.

Tooth preparation

Most dentists have been taught standard preparation designs intended to conserve tooth structure and preserve natural tooth contacts whenever possible. A 90° angle of exit is often used when maximum conservation of tooth structure is desired.[10] A chamfer in enamel also allows for a 90° angle of exit, which provides a more durable margin, but it is the least conservative design and most dentists turn to it only when maximum retention is necessary. Modern concepts of cavity preparation for resin composite calls for caries removal followed by a bevel if necessary for esthetics or to increase bonding surface area. The most commonly used finish line for resin composites is a 45° bevel on the enamel. This bevel conserves much of the tooth structure and provides more exposure to the ends of the enamel rods while providing a superior seal to enamel, particularly at the gingival margins.[48,49]

Myers and Butts believe that a bevel of the cavosurface enamel provides increased surface area for resin bonding, reduces microleakage, and improves esthetics in restorations of permanent teeth with acid-etch composite resin.[50] Moore and Vann found that beveling the margin of posterior composite resins reduces microleakage.[51]

The overlay method

For the past 30 years, Goldstein has used a preparation design, which he called the overlay technique: it is a procedure that greatly enhances the esthetic appeal of the bonding without sacrificing stability. A 4–5 mm long finish line is placed past the bevel of the cavosurface margin of a Class III, IV, or V restoration. Although in normal circumstances undercutting will not be necessary, some roughening of the enamel can enhance the

(F)

(G)

Figure 14.16 **(F and G)** Before and after treatment demonstrate the patient's greatly enhanced smile with improved proportions and lighter tooth shade.

color blend as well as surface retention. It is helpful to round the ending of the enamel bevel to produce a so-called "infinite bevel" to improve blending of the resin composite over enamel. Scalloping of the bevel could prove beneficial in several instances where the preparation is in a straight line, like in a fracture of the incisal edge due to trauma. The scalloping allows for a nonlinear bevel which enhances blending (Figure 14.17A–H).

This overlay technique means that the actual margin of the new restoration overlays the beveled and roughened tooth surface. Remember to etch the enamel involved in the overlay technique and take it even further to ensure adequate enamel preparation and seal. This has several advantages. Esthetic restorations often are trade-offs between beauty and strength—or perhaps more accurately between esthetic appeal the day the patient leaves the office and esthetic appearance some months or years later. The overlay technique provides the best esthetic result today and yet also greatly enhances the durability and esthetic life of the restoration for the future.

First, the overlay technique enhances the color blend from the gingival to the incisal or occlusal part of the labial or lingual surface. With a variable margin, there is a natural transition to and through the different colors of your patient's enamel.

Second, the overlay technique has an extremely important function as a method for tooth lengthening. Figure 14.18A–I illustrate the technique of beveling the labioincisal surfaces of mandibular anterior incisors or shortening the entire incisal surface to allow for the lengthening of the maxillary anterior teeth. The decision of whether to bevel or shorten is dependent largely

Figure 14.17 **(A)** The fractured right central incisor requires repair with composite resin. Two major repair options are chamfer-shoulder and overlay techniques.

Figure 14.17 **(B)** This illustrates the chamfer-shoulder preparation. Note the margin is situated just above the fracture site.

Figure 14.17 **(C)** The overlay technique requires a long bevel and an overlaid margin that extends into the cervical portion of the labial surface and in many instances, subgingivally.

Figure 14.17 **(D)** If performed correctly, both techniques can produce an esthetic result with invisible margins.

Figure 14.17 **(E)** When inevitable staining occurs, it appears at the marginal junction between the tooth and composite resin. Here stain is seen at the labial margin of the chamfer-shoulder technique. A repair procedure is required to remove the stain.

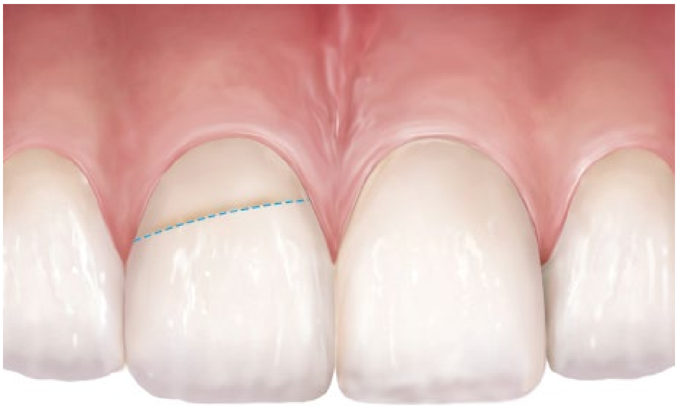

Figure 14.17 **(F)** With the overlay technique, stain usually appears closer to the cervical margin and is much easier to eliminate using a simple polishing procedure.

Figure 14.17 **(G)** Since simple polishing would result in a concavity, the chamfer-shoulder technique requires a cut-and-patch repair to eliminate stain.

Figure 14.17 **(H)** In the overlay technique, stain can be removed simply by finishing with a 30-blade carbide bur and repolishing, thus achieving a more conservative and economic solution. These advantages, plus ability to achieve a good color blend, make the overlay method the technique of choice.

upon the incisal plane and the arc of the mandibular anterior teeth. Although orthodontic therapy is generally the treatment of choice, many patients elect the restorative compromise. Further, composite resin overlay can extend the longevity of the restoration by providing resiliency as a measure of protection against possible future fracture.

Third, depending on the patient's lip line, staining is less likely to be objectionable because margins are usually placed out of sight either subgingivally or high enough to be concealed by the lip line. A major esthetic problem with any composite restoration is the staining that almost invariably occurs at the margin of tooth and composite. The overlay technique provides the restoration a longer esthetic life without having to pursue a repair technique; staining can usually be corrected by merely polishing the stain away to a new margin further up or down the enamel surface. Figure 14.17 illustrates how much easier it is to freshen a tooth with an overlay technique versus the chamfer-shoulder method, thus avoiding replacing or even repairing the restoration.

Fourth, it also is a more forgiving preparation. With its gentle lines and lack of precise margins, it becomes an easier restoration to complete.

Figure 14.18 **(A and B)** This 23-year-old dancer was concerned about her smile. In addition to facial enamel erosion, she had worn her maxillary anterior teeth so much from bruxism that it made her smile appear deformed.

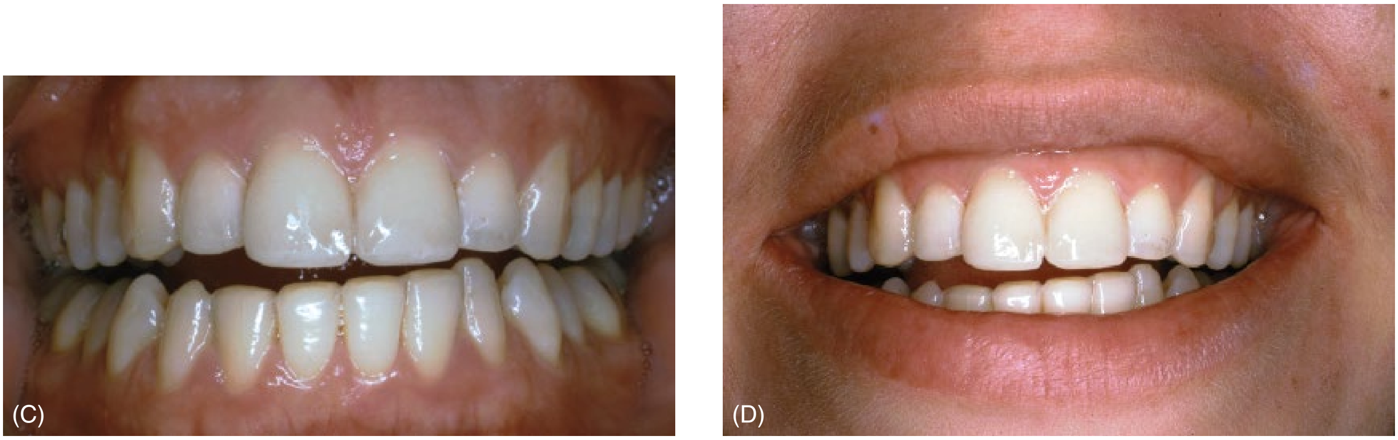

Figure 14.18 **(C and D)** The patient chose an economical and immediate result using composite resin bonding to restore the normal length of her anterior teeth. The incisal edges of the mandibular incisors were cosmetically contoured to compensate for the new length of the maxillary anterior incisors.

Enamel bonding and acid etch

As Phillips pointed out,[4] there are two basic mechanisms for bonding. The purely mechanical can be illustrated by acid-etching of enamel to provide resin tag formation into the surface roughnesses. Adhesive bonding implies molecular attraction between the adhesive and the substrata and is the basis of dentin-bonding agents and polyacrylic acid cements.

The significance of bonding materials to tooth structure is not, of course, purely esthetic. They also serve to protect enamel rods and dentinal tubules, which are inherently opened during preparation, from the effects of bacterial contamination by saliva. In fact, they must protect in order to obtain a satisfactory long-term esthetic and functional result. If microleakage occurs because of lack of a true seal of the restoration, then acids and microorganisms may penetrate from the margins down along the interface, which can lead to stain or even secondary caries.[52] If leakage progresses down and across the floor of the preparation, it also can produce pulpal irritation.[4] However, studies would indicate that restorative materials produce pulpal reactions only when there is bacterial leakage and little or no irritation if bacterial influences are effectively controlled.[53] Cariostatic fluoride-releasing composites or planning a resin-modified glass ionomer base may serve to limit recurrent caries, as proposed by Temin et al.[54] Resin-bonded inlay restorations can provide superb marginal seal, especially at the cervical restoration–dentin interface.[32]

If both enamel and dentin are involved, it is best to etch the enamel with a gel since the gel causes localized penetration that is deeper and wider.[55] It is also self-limiting. It remains exactly where you place it, instead of "running all over the place" on tissue or adjacent teeth or even on unwanted same tooth surface. A 15–30 s gel application should be sufficient to etch the enamel. Although it is not necessary to etch glass ionomer, some clinicians feel a 5 s final etch on just this portion will condition any remaining tooth structure as well as the base itself. However, it is important to consider the individual tooth. Young teeth generally etch more quickly than older teeth. The fluoride content of the teeth also affects etching time, as does whether or not the enamel has been freshly cut. Freshly cut enamel etches faster than unprepared enamel.[10]

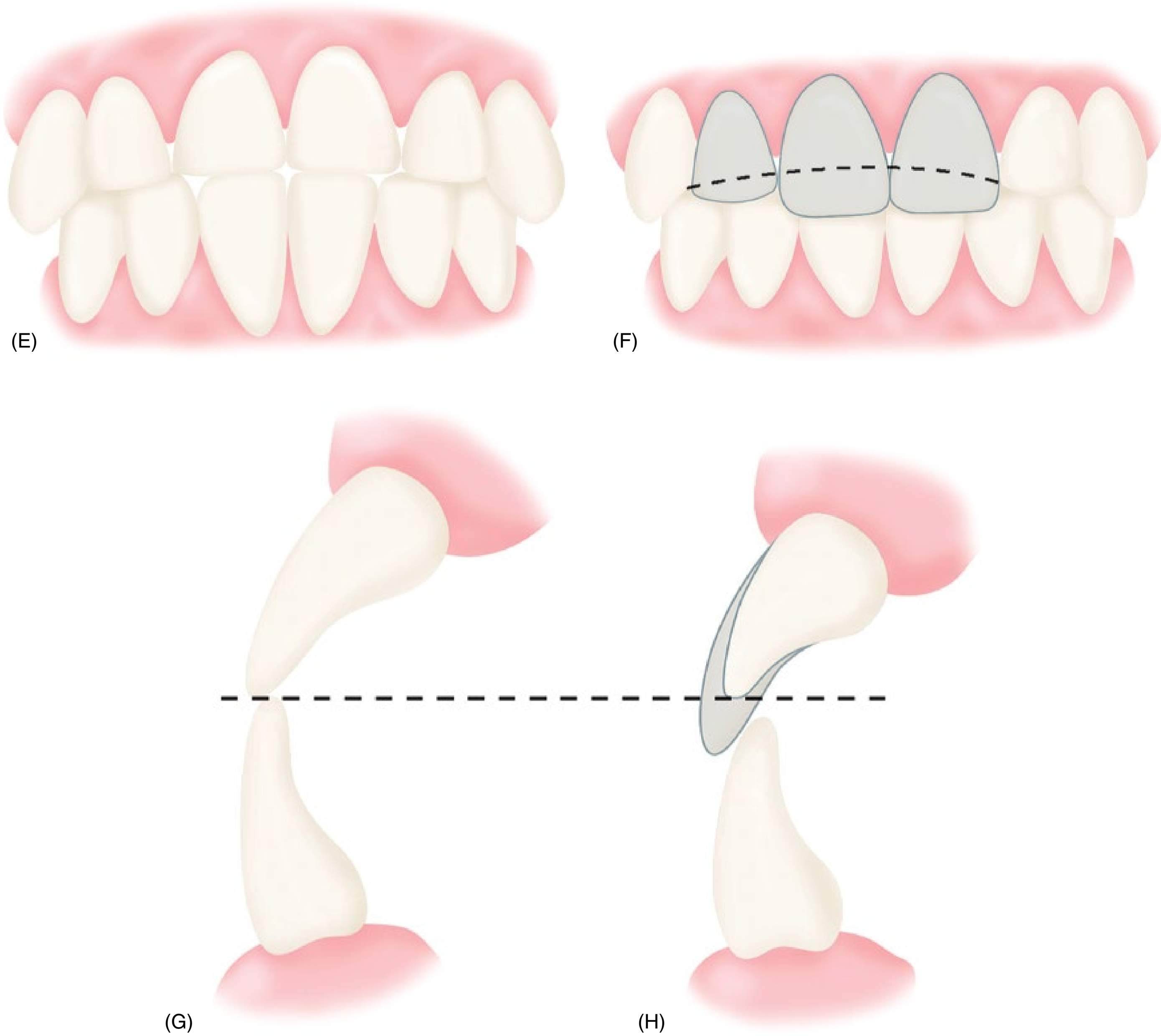

Figure 14.18 **(E–H)** The technique of beveling and shortening the mandibular anterior incisors demonstrates how the occlusion is compensated for, which allows the bonded maxillary teeth to function virtually parallel to the original lateral and protrusive pathways.

Figure 14.18 **(I)** Five years after treatment was completed, the patient fell down a concrete stairway, fracturing the bonding of one tooth, but not the enamel. Note that the composite resin seemed to act as a "shock absorber" to the natural enamel, which remained intact and required only a 1 h repair technique.

Dentin bonding

An important consideration when bonding to dentin should be to carefully follow the manufacturer's directions. A myriad of bonding systems are available in the market today. Bonding systems can be classified as "total-etch" or "self-etch." "Total-etch" are the bonding agents that use phosphoric acid to create micromechanical retention in enamel and dentin. Self-etch systems do not require the use of an etchant because the primer is acidic. Furthermore, these two categories can be divided by the number of steps involved in their use. "Total-etch" can be used in a three-step approach, with etching, priming, and adhesive application; or a two-step approach where the primer has been combined with the adhesive into one component. Self-etch can be used in a two-step or a one-step approach. The two-step method applies a self-etching primer followed by an adhesive. The one-step approach incorporates all steps into one. Recently, the concept "selective etching" has been suggested for self-etching adhesives. With this technique, the enamel margins are etched with a phosphoric acid and rinsed, while the dentin remains untreated.[56]

Another consideration should be based on the individual's sensitivity after dental procedures, especially if there is an abundance of freshly cut deep dentin or a large pulp. Attaining reliable adhesion to deep dentin is difficult due to the large size and number of dentinal tubules. The use of glass ionomer liners is thus recommended to cover these deep dentin areas before adhesive procedures.

Lastly, self-etch bonding agents are being used to decrease sensitivity (cervical abrasion, for example) and usually do not call for the removal of the smear layer.

McLean and others[57] described what is called the "sandwich technique" using composite resin on the glass ionomer-coated dentinal surface of a cavity preparation (Figure 14.19A–E). The newer glass ionomer liners are presently highly suited materials to use as liners and bases under almost any restorative materials. They provide an adequate amount of opacity and have the added advantages of bonding to dentin or resin, releasing fluoride, and not causing harm to the pulp,[10] and even reducing sensitivity.[58,59] Most recently they have been used in preventive restorations such as small occlusal cavities where carious lesions have extended into dentin.[60] Hembree[61] found that less microleakage occurred at gingival margins of Class II restorations when a glass ionomer cement was used as a liner. The liner should be close to the color of the dentin (not opaque white, which is difficult to mask). The exception is when replacing an amalgam that has left a stain; in this case, the liner may need to be somewhat lighter to cover the dark stain.

If a "total-etch" approach is selected the enamel should be etched for at least 15–30 s, and the dentin no longer than 10 s; this differential timing suggests the application of etchant to the enamel first followed by a brief application to dentin. Immediately rinse thoroughly with an air/water spray, for 10–15 s, and remove excess water to leave a moist surface. It should be noted that Gwinnett advocated an extra 10 s of air/water rinsing if a gel etch is used to prevent its cellulose vehicle from becoming a contaminant which may reduce bond strength.[62] It is also essential to have an oil-free air and air/water spray to prevent contamination that diminishes bond strength. If overdrying occurs, dab the preparation with a moistened cotton pledget to create a uniform amount of "wetness." Alternatively, a specialized rewetting agent can be applied (Aqua-Prep F, Bisco). Next, apply multiple coats of primer or a combination primer/adhesive. Different products require different drying and solvent evaporation protocol, so a careful reading of the manufacturer's instructions is essential.

The overlay technique described earlier provides a broader surface for the bonding process to achieve its primary function: to eliminate the gap that often results at the enamel boundary when the enamel interface contracts from polymerization shrinkage. The phosphoric acid etching before the resin materials are placed helps to eliminate this gap at the enamel boundary, thus enhancing the marginal seal.

Polymerization

All bonding materials are produced to be polymerized either chemically—known as self-curing—or by light. Other composite resins are dual-cure, that is, when the base and catalyst pastes are mixed together, they can be light cured, allowed to self-cure, or both light- and self-cured together. For most dentists today, light curing has become the method of choice because a higher degree of polymerization is possible.[23,63,64] Phillips summarizes these advantages succinctly: the single paste formulations do not require mixing, so there is less porosity in the restoration, making it more resistant to wear. The surface should be perfectly smooth, enamel-like, and free of irregularities. Photocuring provides sufficient working time for more precise and esthetic insertion of the materials. This works especially well with resins used incrementally for color match and improved margin adaptation. The cure is faster and more complete; margins can be feather-edged without concern that the thin, frail marginal areas will be insufficiently cured.[65]

Complete polymerization of composite resin in deep preparations, such as the proximal box of Class II restorations, has long been a concern. Rueggeberg found that for most modern curing systems and composite systems a depth of cure could not be reached beyond 2 mm.[66] Different clinical techniques have been developed to address this issue. The most common is the incremental layering technique.[67] With this technique, a thin layer of composite resin is placed and cured. For stress reasons, these layers are most often placed obliquely rather than horizontally.[17] Lutz introduced the "three-sited light-curing technique," which utilizes translucent matrices and light-reflecting wedges to improve the light's access to the interproximal box.[68]

Other clinicians utilize a flowable composite (Sure-Fil SDR flow Dentsply) as a base or liner to cover the floor of the preparation, including the floor of the proximal box. It has been suggested that this may improve the issues of microleakage and stress resulting from polymerization.[69,70]

While esthetics may be the primary reason for bonding, the trade-off is usually between superb esthetic restoration the day the patient leaves the office and a sometimes less than excellent result that endures and is likely to be esthetically appealing for more years. Good polymerization does not involve such a

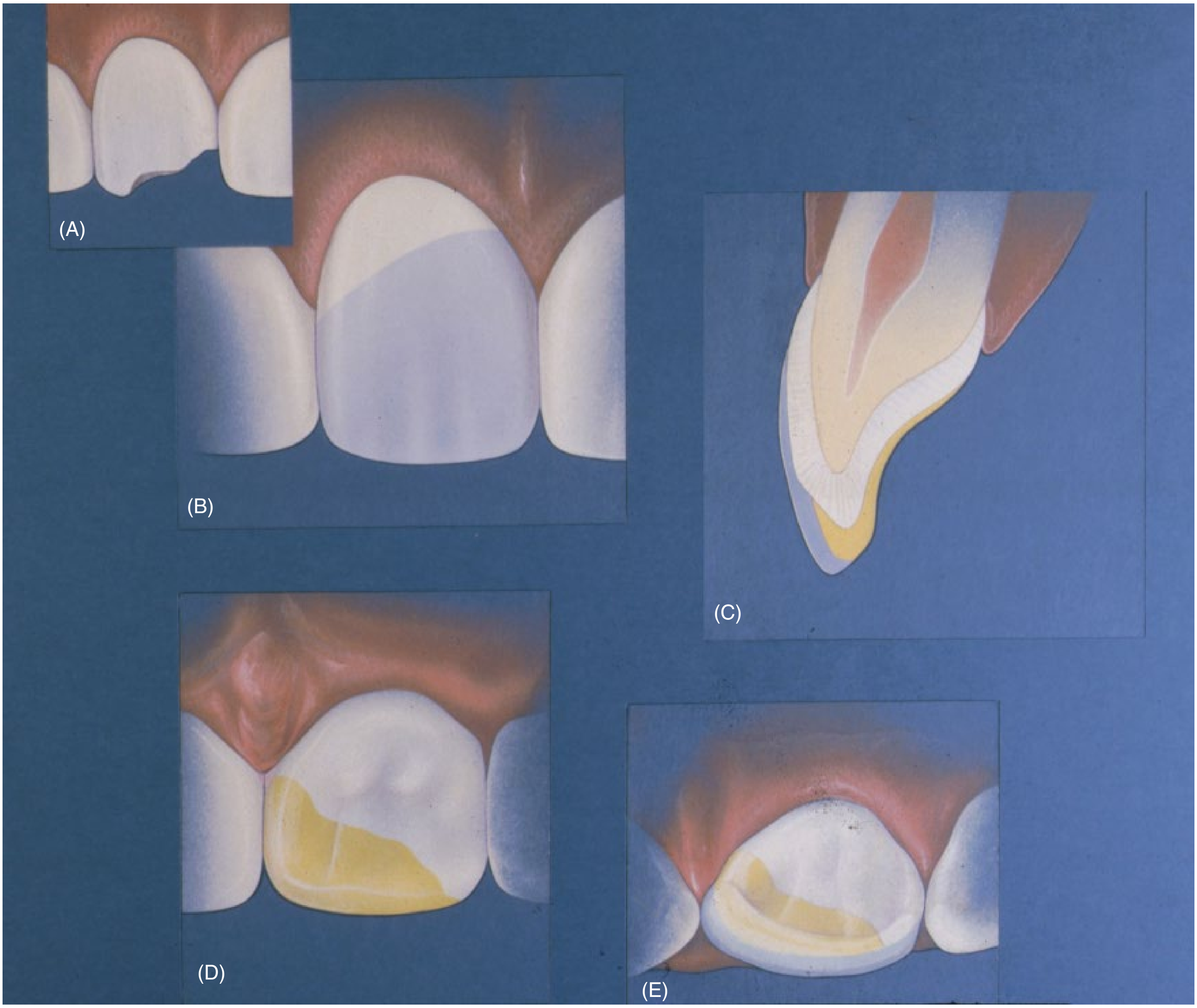

Figure 14.19 **(A)** Fractured right central incisor. **(B)** A highly polishable microfill labial veneer has been placed by using the overlay technique with margins extended to the cervical third of the labial surface. **(C)** The lingual view shows the restoration with a stronger and more durable hybrid composite. **(D)** A sagittal view that shows the "sandwich" outline of both composites in their relative positions. **(E)** The blend of the two composites from the incisal view.

trade-off. Maximum polymerization is important to the clinical as well as the esthetic success of the restoration, and in fact a 20 s repolymerization of the restoration following final finish can provide an *even stronger and long-lasting finish*. After final etching and conditioning, thoroughly dry the preparation and apply the bonding agent on both dentin and enamel.[62] Some agents will require more than one coat, as will be described in the manufacturer's directions. The bonding agent should not be allowed to pool because it may be mistaken for recurrent caries on a radiograph, as demonstrated by Hardison et al.[71] He advocates gently blowing the bonding resin after its application to a thin, even coat. Thinning the bonding agent, however, is best determined by following the manufacturer's instructions. Some are not to be thinned as shown in the research of Hilton et al., who found lowered bond strengths in three agents that were tested with air-thinning.[72] However, Schvaneveldt et al. reported significantly higher bond strengths when an agent was polymerized in a nitrogen environment.[73] Heymann feels that while the issue of air-thinning is material-specific because, for example, some adhesives are filled, the degree of air-thinning is a factor where excessiveness can lower bond strengths (HO Heymann, personal communication, 1998).

Polymerize with the light of your choice for the specified time (Figure 14.20). Both exposure time and light-tip composite distance are important variables, and Jordan[11,38,40] has recommended that the time be a minimum of 40 s and the distance from the light tip to the composite surface should be as close as possible to zero. Be sure to *periodically test your light* to make

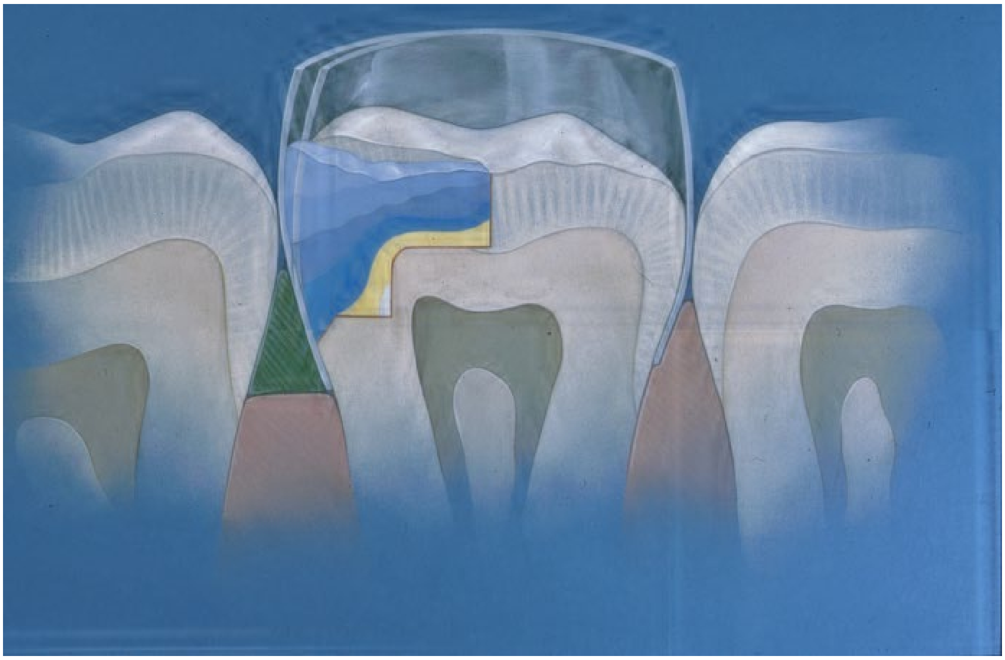

Figure 14.20 This schematic drawing illustrates the layering technique used to construct a properly contacting Class II restoration. After optional pulp protection (white) a glass ionomer liner/base protective layer (yellow) is used to offer the benefits of fluoride (Vitrebond, 3 M). The deep-to-light layers of blue indicate the layering technique by polymerizing the layers one at a time. Note also the tight seal offered by wedging that initially aids in gingival margin closure. After sealing the gingival margin, relax the ultrathin dead-soft matrix band to obtain maximum contact with the adjacent tooth.

certain it is still strong enough to accomplish deep polymerization. Apply no more than 2 mm increments of your chosen shade and polymerize again with your visible light. The extent of polymerization will depend on several factors including the depth reached by the light, catalyst concentration, and composition of the material. The darker shades usually require differing illumination times.[74] Color modifiers also may be mixed with composite restoratives, although this has the disadvantage of weakening the materials and making the curing process somewhat longer and less predictable.[10]

Antonson and Benedetro, Friedman, and others have studied the variability of the longitudinal intensity of visible light-curing units, stating that these findings may have an overlooked impact on complete polymerization of critical margin areas or even the polymerization of dentin-bonding materials.[75,76]

There are two main types of curing lights on the market today: quartz-tungsten-halogen (QTH) bulbs with a broad light spectrum of 400–500 nm, and light-emitting diode (LED) bulbs with a spectrum of 450–490 nm.[77] Plasma arc curing (PAC) lights are also available, but have fallen out of favor in recent years. While studies show QTH and LED units to be similar in their effectiveness,[78–80] LED units tend to be more user-friendly than QTH units. LED units do not require a filter or ventilating fan, so they tend to be smaller and less cumbersome than QTH units. QTH units suffer a decrease in output over time, which may be attributed to lamp filament burnout, bulb blackening or frosting, and reflector degradation, all of which, says Friedman, mandate lamp replacement at least every 6 months.[76] Additionally, LED units tend to maintain their power output for longer periods, consume less energy, and are often cordless, powered by rechargeable batteries. Because of this, LED units are growing in popularity.

If your light does not have a built-in light meter, then purchase one (Figure 14.21), such as L.E.D. Radiometer, Demetron (Ker), or Bluephase Meter (Ivocalr Vivadent), to monitor each curing unit periodically for the manufacturer's recommended output. Other simple measures call for cleaning the end of the curing tip and/or replacing it, inspecting and cleaning the filter/reflector, inspecting the bulb and replacing it, and doubling the curing time if using an older curing light.

All composite resins contract, causing dimensional changes, during polymerization, and this shrinkage can cause separation between the composite resin mass and adjacent tooth structure. The average shrinkage is about 2–3%.[81] This can create defects that welcome bacteria and may cause stress on cusps, resulting in sensitivity, occlusal disharmony, or even delayed fracture.[9]

Polymerization shrinkage coupled with technique sensitivity can lead to a risk of an open margin, especially in situations where the enamel is thin. These open margins then lend themselves to stain. Since too much polymerization shrinkage can reduce the restoration life expectancy, it is much better to take additional time in curing the composite by adding three to five layers of material, making sure the final layer is over the entire restoration, to avoid microscopic composite margins that may attract additional stain. Another advantage in building the restoration in this fashion is that you will be able to vary the shade as you add each layer of composite from gingival to the incisal or occlusal margin. Incremental placement, or layering,

Figure 14.21 Light tips must be kept clean and your light source periodically checked with one of several diagnostic testing devices Bluephase Meter (Ivocalr Vivadent).

of light-activated composites also produces a bond strength that compares with, even exceeds, the cohesive strength of the material used.[82] For these reasons, incremental placement of composite resins, especially in Class V cervical restorations, is the most desirable mode of placement, followed by margin seal procedures.[83,84]

Finishing the restoration

Proper finishing of a restoration *cannot* make up for inadequate preparation or any other step necessary for successful esthetic and functional restorations. It *can*, however, make the difference between an ordinary and an extraordinary esthetic appearance. The objectives of a thorough, well-planned finishing are to improve and finalize restoration margins and contours to help make the restoration biocompatible with both tooth and tissue, and to develop maximum surface luster to enhance esthetics, reduce stain and plaque retention, and minimize wear and fracture potential. You will know you have achieved these objectives if the finished restoration has the following qualities:

- well-finished margins, with no overhang, void, or extension of restorative material that could interfere with tissue health
- a sufficiently smooth surface that will not attract bacterial plaque or food stains
- suitable surface texture that blends in or matches adjacent or opposing natural teeth
- color matching that of the existing adjacent, opposing, or preselected tooth shade
- a surface finish devoid of too obvious contour, finishing bur, or diamond scratches.

As with etching, numerous articles provide detailed instructions on finishing. But the following provides a brief outline of steps of special significance to an esthetic finish. Roulet and his colleagues recommend using a diamond bur with an abrasive particle size of 15–40 µm to contour the facial surface of the restoration.[16,25] Goldstein suggests you begin with either an ET 6 or 9 30 µm diamond or 8-blade carbide (Brasseler USA) for gross contouring (Figure 14.22). Although Greiff, Burgess, Davis, and Theobald[85] report no difference between wet and dry polishing, Goldstein has not found this to be the case. All instruments should be used wet to contain the inevitable dust which can produce an extremely bitter taste for the patient.[84] In addition, Collard, Ladd, and Vogel fear that dental personnel are at a high risk for developing respiratory silicosis if the dust is not minimized, and they recommend the use of face masks during composite finishing.[86] The wet finish also avoids frictional heat that may tend to pull up the margin.[38] Continuing to polish dry after the margin is opened sweeps the composite dust under the margin, producing a "white line." Also, Mazer feels that the initial cracking of a posterior composite is probably caused by the surface and finishing process.[35] If diamonds are used, finish with the ET fine (15 µm diamond) in the same size as above. As reported in a comparison of finishing instruments by Pratten and Johnson,[87] an extra-fine diamond with 15 µm particles (ET yellow band) produces a surface smoothness superior to white stone and similar to that produced with a carbide bur and rubber point. Diamond finishing with a slow speed produces a somewhat smoother finish than with a high speed. For ultrafine diamond finishing, use an 8 µm diamond (DETUF) or a 30-blade carbide (UF Brasseler USA).

If carbides are being used, final contouring should be done with the 16-bladed carbides in the same number (ET fine). Once the final labial contour is completed, make sure the gingival margins also are contoured correctly with the 3 or 4 mm DET in the same sequence. The final instrument subgingivally should be the 30-blade carbide or 8 µm diamond (DETUF; Figure 14.23), usually the 3 or 4 mm. It is important to use the safe-ended ET so the cementum is protected while finishing in this area.

The necessity for careful choice of instrumentation, and the care in finishing, is well illustrated in a clinical study conducted by Ratanapridakul, Leinfelder, and Thomas.[88] The authors found that after the first 30 days, resistance to wear was significantly higher for an unfinished group of teeth as compared to those that received a conventional finish. The authors attributed this to possible microcracks generated by the rapidly rotating blades of the finishing instrument. Similar concerns have been expressed by Watson.[89] This is why it is best to use either an 8-bladed carbide or a 30 µm diamond only for bulk reduction. As soon as possible, switch to a 16-bladed carbide or 15 µm diamond for final contouring and initial finishing. The final finishing will be

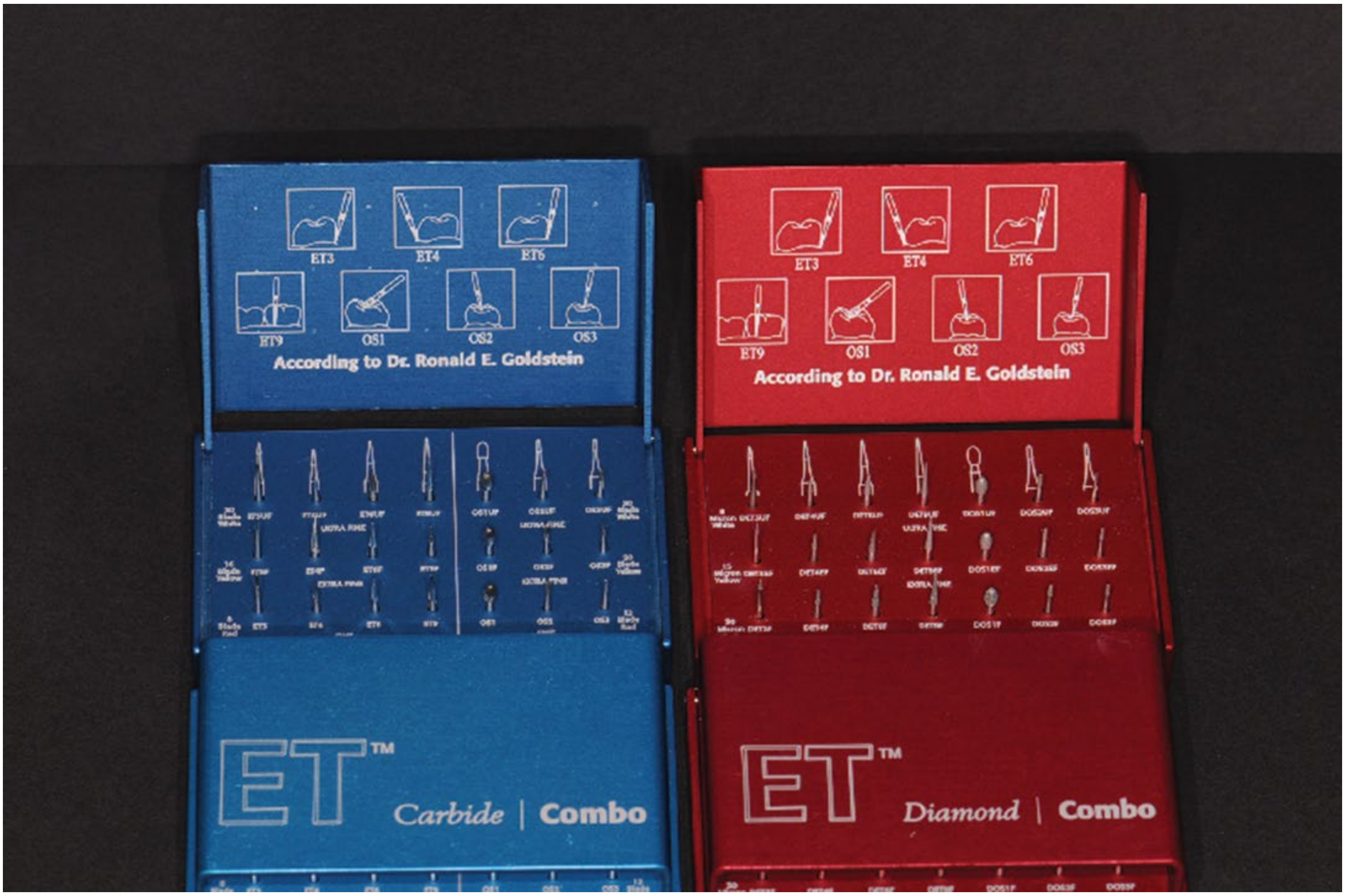

Figure 14.22 The ET kits for both diamonds and carbides (Brasseler USA) are divided into three sections for easy entry-level contouring and finishing. Each kit contains both anterior and posterior finishing burs for specific blade or grit size.

Figure 14.23 Since there is a straight emergence profile as the tooth erupts from the sulcus, the design of the ET3 or ET4 (Brasseler USA) makes them excellent choices for subgingival finishing. Here, a DET4UF (Brasseler USA) diamond bur puts the final finish of the cervical margin on the maxillary right cuspid. This 8 μm diamond is especially helpful to reduce gingival irritation (see Figure 14.27A).

accomplished with either a 30-blade carbide or an 8 μm diamond. Figure 14.24A–C shows the type of surface achieved by using 8-, 16-, and 30-bladed carbides. There are times when an endcutting ET bur is useful. For instance, opening or restoring incisal embrasures can be easily accomplished using the ET3A "cutting" bur (H132A Brasseler) (Figure 14.25).

Polishing will be done by one of the disc systems (3 M, Brasseler USA, Cosmedent, Shofu,) for maximum luster. These discs can produce the smoothest polished surfaces.[22,90] Final polishing can also be accomplished with silicon- or diamond-impregnated rubber cups and points or DiaComp composite Feather Lite polishers (Brasseler USA). These should also be used wet and copiously rinsed between grits (Figure 14.26A–H).

Texturing your bonded restoration

If you desire to either mimic adjacent tooth texture or create your own pattern or texture, you will need to alter the finishing procedure slightly. First, perform your labial and gingival contours using the previously described system. Second, begin disc finishing with the first two coarse discs if using a four-disc finishing system. Third, choose either an ET6UF or ET9UF 30-bladed carbide or DET6UF or DET9UF 8 μm diamond to place your desired texture. Be careful to not "ditch" the composite cuts too deep. Make both vertical and horizontal cuts in an asymmetrical pattern. Fourth, following your placement of the textured surface you are now ready to polish with the DiaComp Feather Lites (Brasseler USA) in sequence. Be sure to polish wet

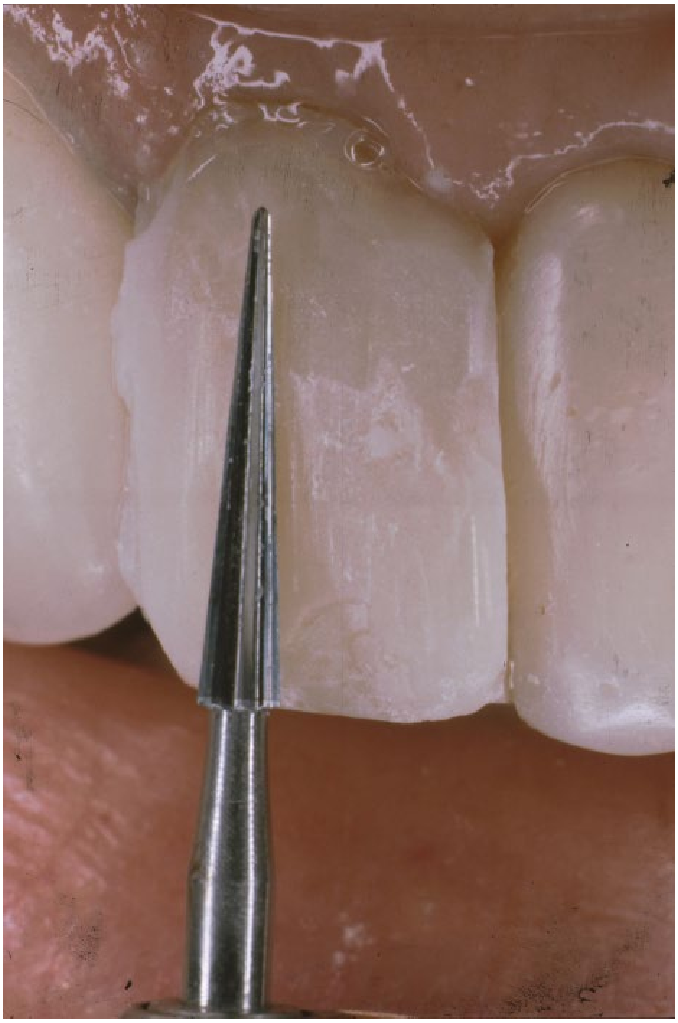

Figure 14.24 **(A)** The ET9 8-bladed carbide (Brasseler USA) should be used on the labial surface when there is considerable bulk present (see Figure 14.27B).

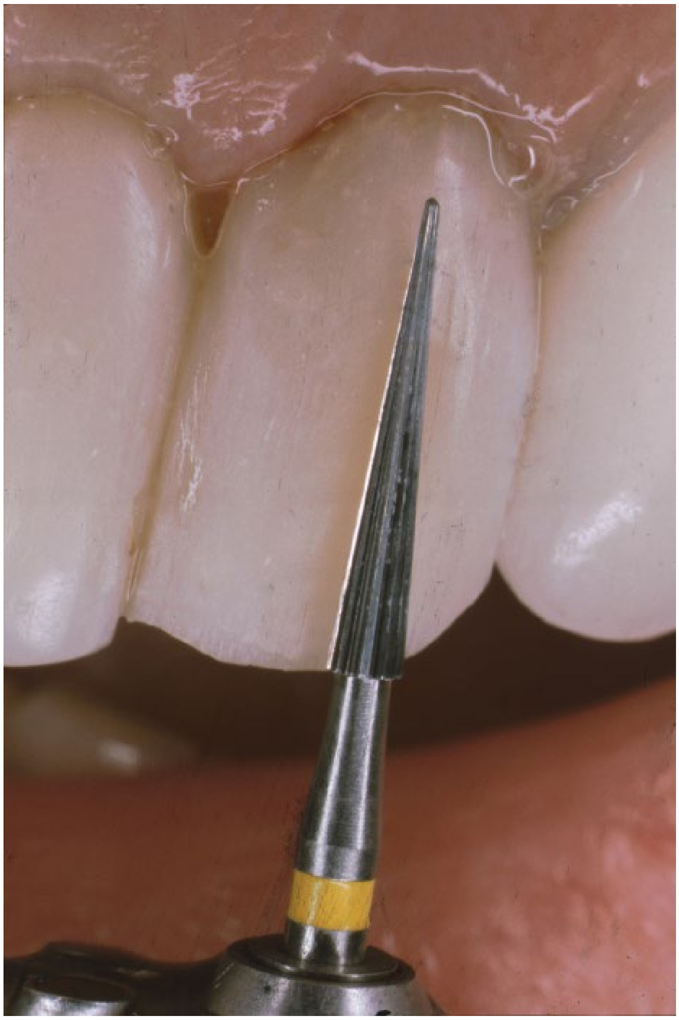

Figure 14.24 **(B)** The ET9F 16-bladed carbide (Brasseler USA) allows you to do more detailed carving while producing a smoother surface.

and vary your polishing angles. The final result should give your bonded restoration a natural-appearing light-reflective surface.

Problems in finishing

Beware of using an inappropriate-sized finishing instrument. For instance, using an ET9 is appropriate for the labial surface of a central incisor. However, it may not be suitable to finish the gingival margin because of the angle of finish and the necessary amount of torque required. Figure 14.27A shows how finishing should utilize most of the finishing instruments' blades. Figure 14.27B shows how maximum utilization of the longer burs is in the body of the anterior teeth whereas just using the tip would result in lack of support, possibly making a bur fracture more likely (Figure 14.27C).

A microfill composite resin is the ideal restorative material to use in restoring Class V tooth defects. Use the overlay technique to restore facial surfaces because it will provide longer esthetic life to the restoration. One not uncommon defect in certain patients is shown in Figure 14.28A–E.

The Class V overlay restoration should be overfilled to allow for two-plane finishing. Use an ET3 or 4 to define the gingival emergence contour. An ET6 or ET9 held parallel to the long facial axis establishes the facial height of the contour.

If there has been a significant amount of gingival recession, you may opt to duplicate the existing anatomy, or reestablish the facial height of contour at a level closer to the receded gingival margin. This is especially true for the patient who has a high lip line, and whose smile displays the roots of the anterior teeth. Using a darker shade on the roots of these teeth minimizes their "long" appearance.

After the final polish, allow the patient to rinse, then dry the teeth and inspect from different views with the dental light reflecting at varied angles. The surface should have enamel reflectivity and the veneer should have depth of color that closely mimics teeth. You are looking for small areas that may be insufficiently polished and thus will show scratches. These should be refinished until the restoration is free from surface scratches and other defects. The finished composite restorations should have margins that are not detectable to floss or a sharp explorer.

Figure 14.24 **(C)** The ET9UF 30-bladed carbide (Brasseler USA) accomplishes final texturing and an extra-smooth surface. This will be followed by either a 3 or 4 mm ETUF 30-blade carbide (Brasseler USA) as a final step in contouring and finishing.

Posterior finishing requires a special technique because of the occlusal anatomy. As mentioned previously, using a composite carving instrument (TNCIGFT 8 Instrument Series, Hu Friedy) makes final finishing much easier (Figure 14.29A–K).

Interproximal finishing

The last phase of finishing involves interproximal polishing with abrasive strips. Depending on how much is necessary, your choice to begin may be an extremely thin diamond abrasive strip. In certain circumstances a #12 scalpel blade is useful to remove any excess material by scraping or shaping the excess. Following the sequence of a more- to a less-abrasive strip results in a smooth transition when flossing. When interproximal finishing is complete there should be no fraying of the floss.

Note the different width strips. A wide one will reduce the contact area between the teeth whereas the narrow ones can be slipped between the teeth using the nonabrasive center part of the strip and placed exactly where stripping is needed. This will prevent unwanted removal of the contact area which could conceivably leave an unsightly space between the newly bonded teeth.

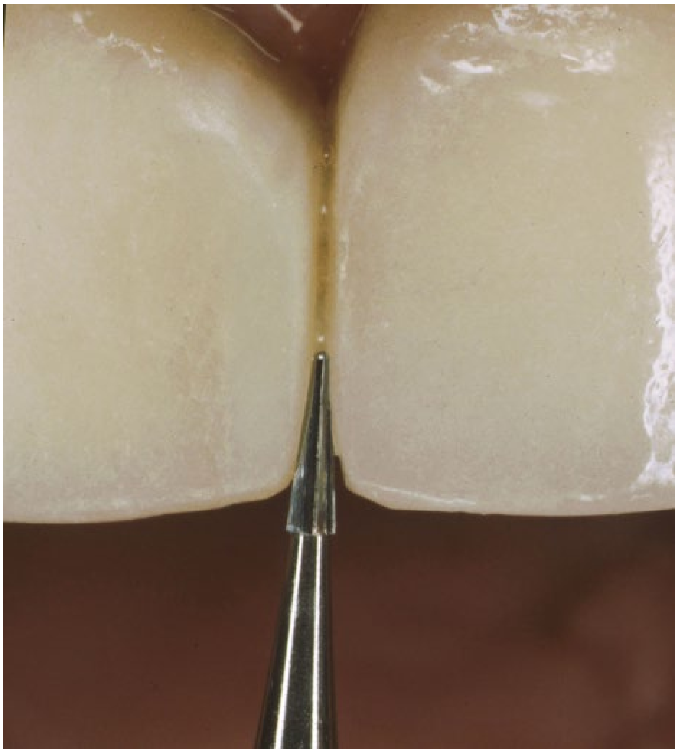

Figure 14.25 The non-safe-ended ET3A "cutting" bur (H132A, Brasseler USA) is a 3 mm carbide that is an excellent design for opening and shaping incisal embrasures as well as removing excess interproximal resin cement.

Maintaining the restoration

The most often overlooked means of extending the life and attractiveness of bonding frequently occurs at this point, when you hand the patient the mirror to admire the new look. This is when you or your assistant should provide instructions to the patient, preferably written, on what to do and what to avoid to insure that the bonding surface is less likely to stain or fracture. Some dentists[91] believe that use of less-forgiving restorative materials should be limited to patients who are "well motivated to high standards of oral hygiene." To clean the bonded surface, patients should pay extra attention to oral hygiene—with brushing and careful flossing, with the floss being pulled through the teeth horizontally, not vertically. Also warn your patients about the potential damage of "guillotining" the papilla (refer to Chapter 25, on oral habits). This occurs when patients, anxious to clean both sides of the proximal surface, do it so fast that they clean one side then forget to return to the height of contour before cleaning the other tooth. Instead they clean one side and rush the floss to the adjacent tooth surface without realizing they are injuring the interdental papilla.

Mouthwashes with high alcohol content should be avoided because they can soften composites. Coffee, tea, and cola drinks

Figure 14.26 **(A)** This man chipped his front tooth from grinding and was advised to have the tooth bonded rather than contour to maintain the tooth's length and width proportion.

Figure 14.26 **(B)** A microhybrid composite resin was placed to restore the incisal length (Venus Diamond, Heraeus).

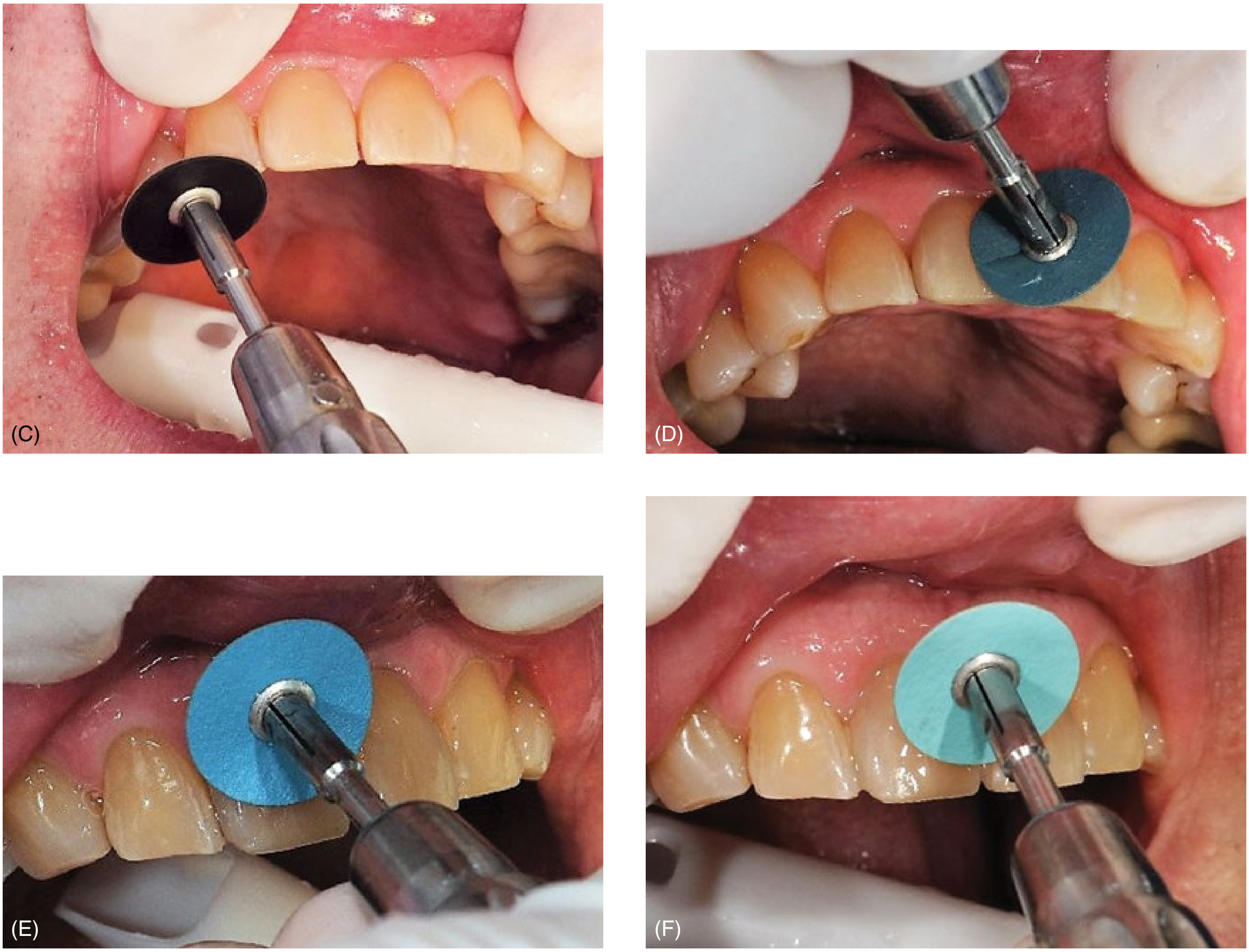

Figure 14.26 **(C–F)** A sandpaper disc series (Sof-Lex, 3 M) was used from coarsest to finest, rinsing well between each disc.

Figure 14.26 **(G)** The finished restoration, with shine and luster matching the adjacent teeth.

Figure 14.26 **(H)** Final polish is accomplished with DiaComp Feather Lite intra-oral composite polishers (Brasseler USA)

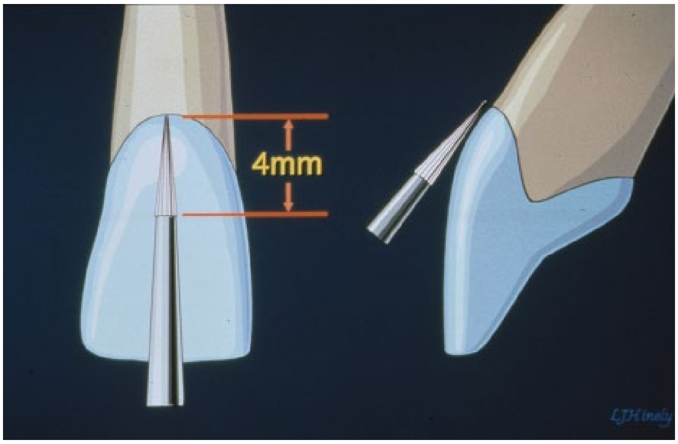

Figure 14.27 **(A)** This drawing illustrates the correct-length bur for trimming the gingival margin.

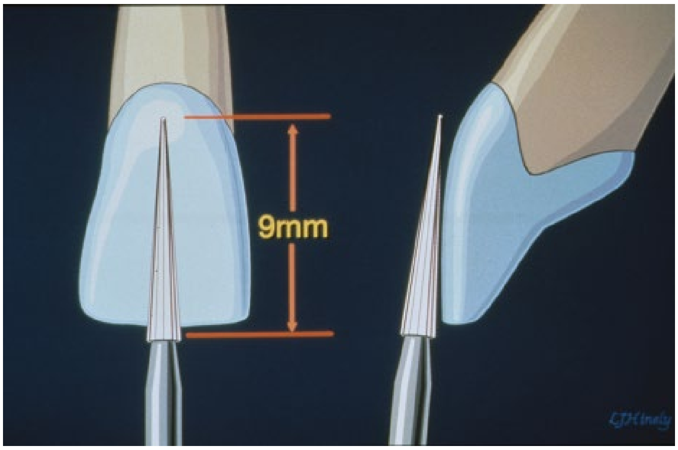

Figure 14.27 **(B)** The long facial surface is best served by a 6 or 9 mm finishing bur to make a consistent, smooth, and precise cut.

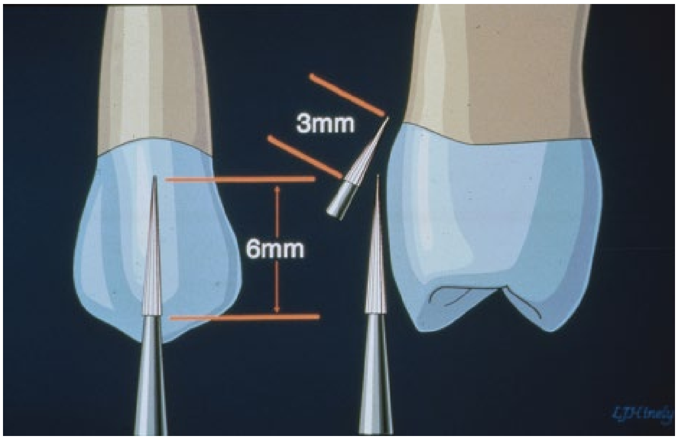

Figure 14.27 **(C)** This drawing shows the proper length and shape burs to use for contouring and finishing of posterior restorations.

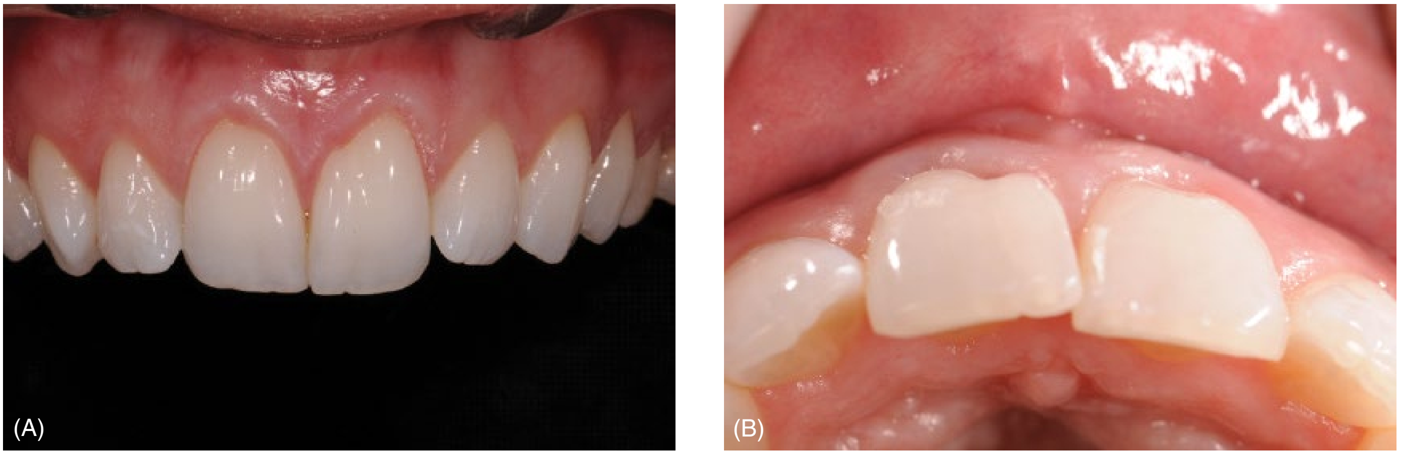

Figure 14.28 **(A and B)** This beauty contestant wanted to make her smile as attractive as possible. Note the tooth defects in the cervical third of her teeth, which also affected the shape of her gingival contours.

Figure 14.28 **(C)** Gingival displacement with cotton cord was used to allow access for the subgingival repair.

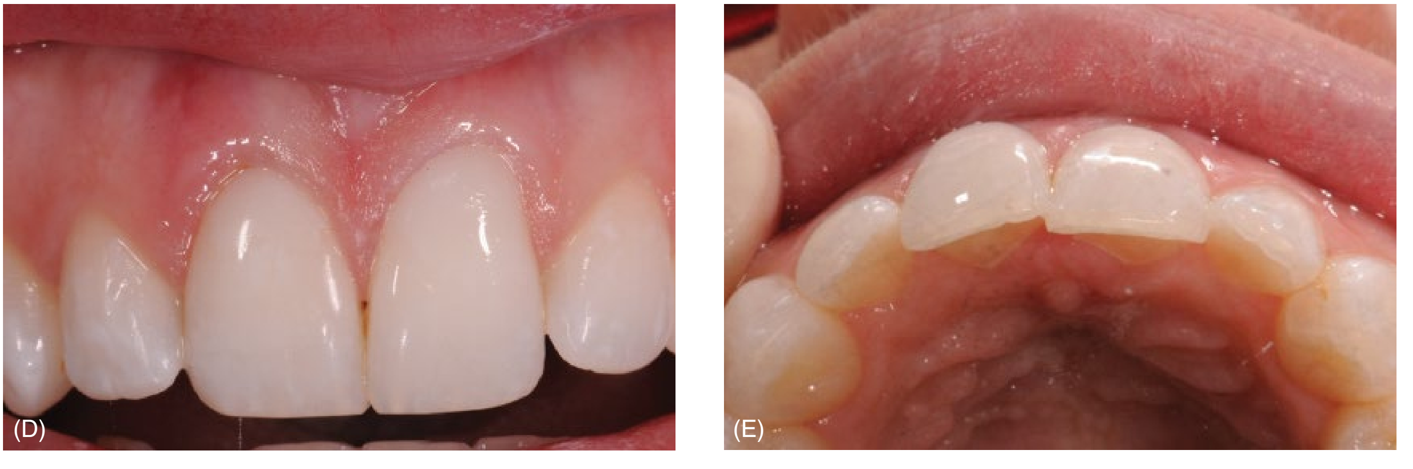

Figure 14.28 **(D and E)** Final restorations show how restoring the tooth defect helped achieve normal gingival architecture.

can stain the bonded areas even more quickly than original enamel. Should your patients smoke, this is also an excellent time for you to reinforce what the patient's physician doubtless has been telling him or her about cigarette smoking or other tobacco use. Its deleterious effect on the appearance of the teeth, as well as the health of the oral cavity, is yet another reason to quit. The patient should avoid foods that are likely to stain the teeth. Much of the advice is pure common sense, although Chapter 25 outlines in detail some of the ways patients sabotage their restorations by chewing, biting, grinding their teeth, holding objects in the mouth, or even just using hard toothbrushes and abrasive toothpaste.[68,92] Make the patient aware of these harmful habits by asking which habits they have that might cause damage to their restorations. Ask your patients to review the last chapter in *Change Your Smile*,[93] which includes a patient habit questionnaire dealing with these problems.

Bonding protection

Unless your patient has an open bite or a protective occlusion that would prevent unfavorable stress on his/her anterior restorations, consider constructing a special mouthguard to be worn during sleeping or other times of patient need. The most comfortable appliance is one with a hard acrylic outside and soft acrylic inside to provide a "cushion" seat. This appliance is generally made for the maxillary arch (Figure 14.30). Make certain the appliance is occlusally well balanced so that there are no interferences and all teeth have occlusal stops to prevent eruption.

Figure 14.29 **(A)** This 50-year-old man required replacement of his aging amalgam restorations due to defective margins and stained fracture lines, which were the causing facial surface discoloration.

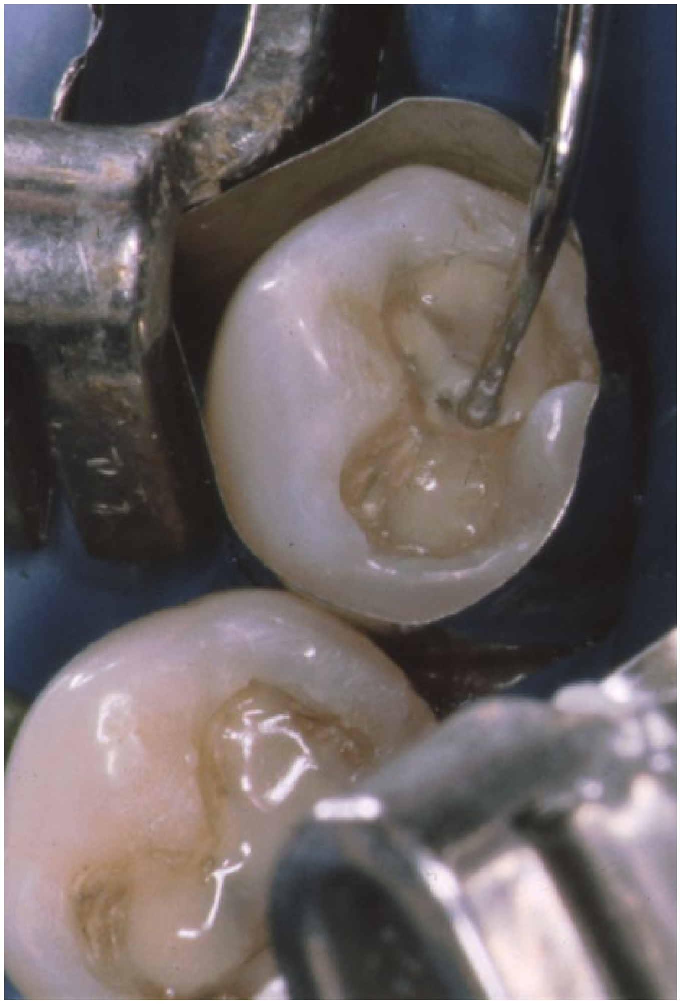

Figure 14.29 **(B)** A glass ionomer layer is applied using a Novatech PINT 11 instrument (Hu-Friedy), then polymerized.

Figure 14.29 **(C)** A semisoft gel etch is used to etch the enamel areas for 15–20 s, and is then washed with a simultaneous combination water/air spray for approximately 5–10 s.

Figure 14.29 **(D)** Each layer of composite resin is placed using the appropriate-sized round-end anodized aluminum or stainless steel instrument TNCIGFTI (Hu-Friedy).

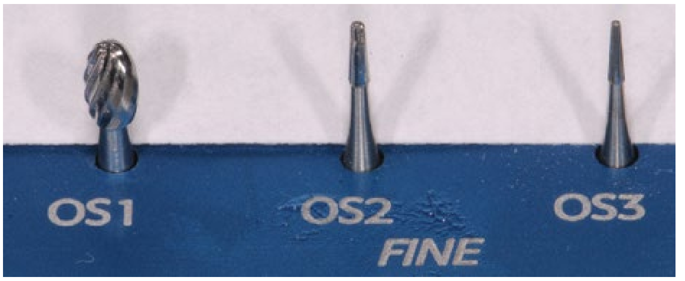

Figure 14.29 **(E)** Initial trimming and finishing cuts are done with the OS 1-, 2-, or 3-carbide burs (Brasseler USA).

Figure 14.29 **(F)** Initial occlusal anatomy is placed using an ET OSIF 16-bladed carbide (Brasseler USA).

Figure 14.29 **(G)** Initial grooves and fissures are carved with an OS2F (Brasseler USA) 16-bladed instrument.

Figure 14.29 **(H)** Final occlusal finishing is done with a 30-bladed OSIUF (Brasseler USA) carbide.

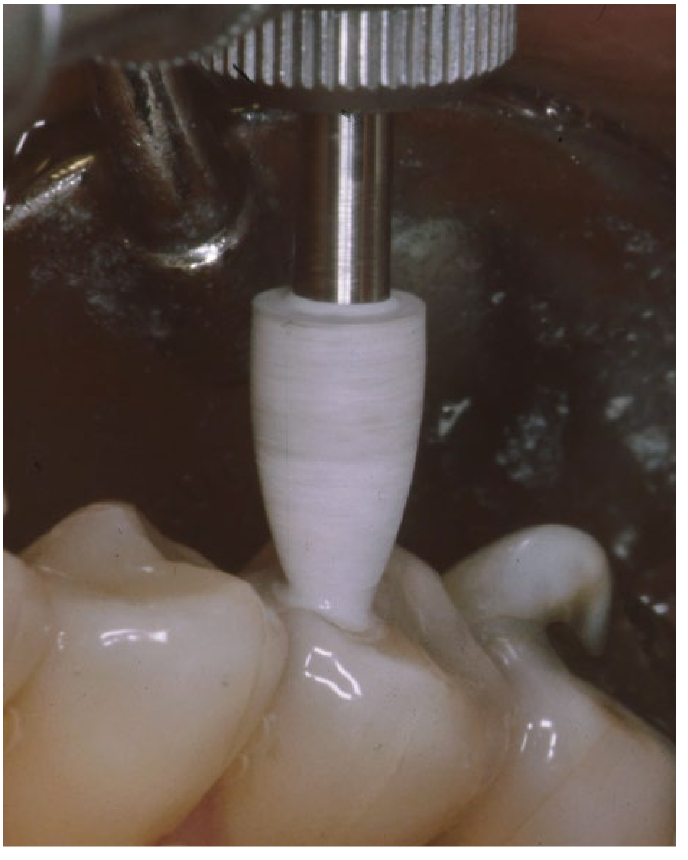

Figure 14.29 **(I)** The tapered point abrasive impregnated polisher (Brasseler USA) can be used to polish the occlusal anatomy.

Figure 14.29 **(J)** The before occlusal view of the defective amalgam restorations.

Figure 14.29 **(K)** Occlusal view of the final restorations.

Figure 14.30 After bonding, this patient was fitted for a protective night appliance with hard acrylic outside and soft acrylic inside which she could wear during sleeping and times of possible stress.

An alternative to the full occlusal mouthguard is the nociceptive trigeminal inhibition tensions suppression system (NTI-TSS) appliance. However, a possible limitation to this type of appliance is the necessary torque that may be required to both seat and unseat the appliance. If your anterior bonding consists of tooth lengthening this could be a problem. An alternative would be an anterior guard that covers only the six maxillary anterior teeth (such as the Bite Soft from TriDent Dental Laboratories). This can be made, as previously described, with a soft interior and hard exterior surface.

Beware of the patient who emphatically states "I don't clench or grind." Instead, look for craze lines and wear facets on the teeth and remember that almost everyone can have stressful sleep at times. It only takes one instance of clenching in eccentric positions to damage your patient's bonded restorations. A good way for you and your patient to visualize potential wear patterns is through the use of an intraoral camera. However, the very best way for you to see exactly what is taking place and to communicate it to your patient is through the use of a surgical or operative microscope (Global Surgical). The stereoscopic view as seen by the dentist is outstanding. When connected to a video recorder and monitor both you and your patient can discover exact habit patterns, making it so much easier for you to suggest preventive measures. Consider imposing limitations on your office warranty if your patient does not accept your recommendations for wearing a protective appliance (Figure 14.30).

Homecare

The immediate homecare of the patient should emphasize the most gentle, but thorough, cleaning. During this time, a chemotherapeutic agent, such as Peridex (3M) or Listerine (Johnson & Johnson), can help control plaque. Dipping a Rotadent (Den-Mat) brush tip in the mouthwash before using is an excellent way to apply the solution and obviates some of the staining problems associated with the mouthwash.[94]

Although a sizeable portion of the population is capable of adopting good hand brushing habits, using a rotary cleaning device (ProDentec) can make a dramatic difference for most people. Otherwise, patients may miss important areas where plaque can build up, resulting at the very least in unattractive stain. It is essential for the patient to receive proper instructions on how to use the device. For instance, a close grip to the actual tooth surface will result in better and easier control (Figure 14.31A and B).

Recall visits

In this mobile society where your patient may be receiving follow-up care on the other side of the country next year, he or she also needs to be sure that the new dentist or hygienist knows about the proper professional care of bonded teeth. Hygienists should avoid scaling against the margin of bonded teeth; instead, do hand scaling with a lateral movement to remove any calculus without a counterforce that could dislodge the restoration. Use of a Cavi-jet (Dentsply) or air powder abrasive instruments also pose potential damage to composite restorations,[95,96] as can ultrasonic and sonic instrumentation.[97] Certain polishing pastes can also be harmful.[98] Acidulated fluoride pastes are to be avoided; Miller advocates aluminum oxide polishing paste applied with a wet rotating rubber cup.[99] Remind patients to always make any dentist or dental hygienist (or for that matter, any physician or anesthesiologist who will be working around the mouth) aware that esthetic dental restorations have been done that could be damaged.

Figure 14.31 **(A)** An individual rotary cleaning device (Rotadent, Den-Mat) provides the patient with an excellent means for maintaining the subgingival margin of this bonded veneer.

Ideally, the patient should return for a postoperative visit within 1–2 weeks to make certain that soft tissue is healing properly. Some additional finishing may need to be done at that time to conform to the patient's emergence profile in order to achieve the highest esthetic and functional gingival margin possible. Until you have evidence of excellent tissue response, continue to have the patient return for periodic postoperative visits.

Most patients with esthetic restorations should be asked to return for inspection and hygiene recall within 3 months, in order for you to detect any problems, to make certain that the patient is caring for his or her mouth properly, and to ensure that there are no habits that could esthetically or functionally shorten the normal life span of a restored tooth. Use this recall to look especially at the margins of Class V composite resin restoration since water absorption in restorations without perfect margin seals may begin to cause a cervical overhang within 3 months.[84] If this happens, refinishing at that time may be required to avoid plaque retention and gingival irritation.

The life expectancy of most bonding may be more than 10 years now, as suggested by Drake et al.[5] However, *Change Your Smile*[93] gives a more conservative forecast of 5–8 years, depending upon the type of restoration and the patient's cooperation in maintaining it. The following point should be made: dentists or treatment coordinators should always remember that patients have a right to expect indefinite life of the bonding *unless* the dental professional enlightens them as to a definite range of life expectancy. Dentists may overestimate the patient's awareness of this. In a study by Goldstein and Lancaster,[100] almost one in three persons said they believed bonding to be permanent. More recently, Davis et al. found a similar lack of information in the general public concerning the strength of composite resins for posterior restorations.[101]

Pit and fissure stain

"It's just stain" is a typical comment made to patients by dentists when patients inquire about a darkly pitted or stained tooth. No longer is it necessary or even wise to allow these types of stained areas to exist in teeth. As Goldstein and Parkins suggest in their article in the *Journal of the American Dental Association*, changing patterns of dental caries suggest the need for a new emphasis on diagnosing and treating pit and fissure caries.[102] Although occlusal surfaces represent only 12% of the total permanent dentition surface area, occlusal surfaces account for more than 50% of reported caries in school-age children. This would suggest a need to focus on pit and fissure stain. In a National Institute of Dental Research (NIDR) study from 1980 to 1987 it was found that decay in pits and fissures had reduced by only 31% while caries in other surfaces dropped by 51–59%. Pit and fissure caries accounted for 80% of total caries in nonfluoridated water areas and 90% in fluoridated water areas.

Figure 14.31 **(B)** It is essential to properly instruct your patient on the use of this cleaning device. Note that the closer the patient's forefinger is to the brush tip, the more control and thus cleaning efficiency he or she will have.

Our clinical experience has shown 70–75% of these stained areas are involved into the dentin and, in fact, the great majority of them are actually carious lesions. Re-evaluation of the methods used to detect pit and fissure lesions has led to questioning

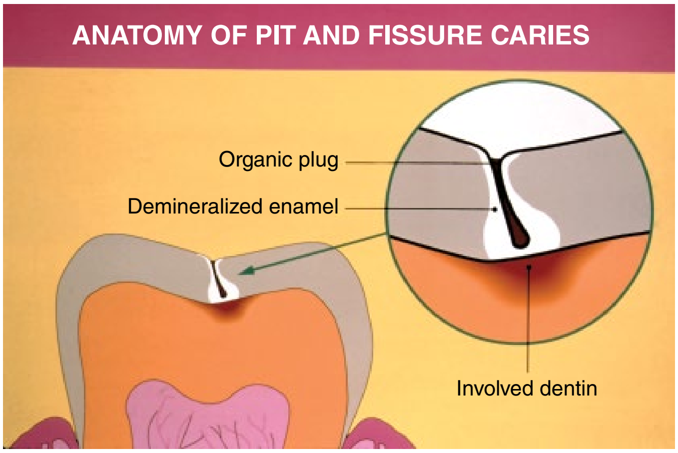

Figure 14.32 **(A)** Anatomy of pit and fissure caries.

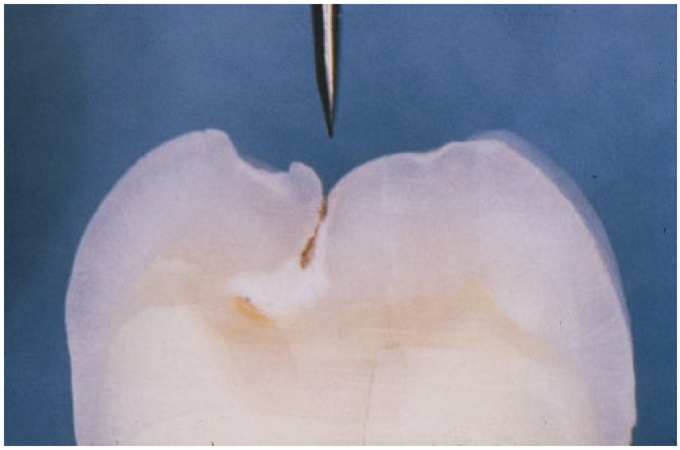

Figure 14.32 **(B)** The explorer is often of limited use in the diagnosis of pit and fissure caries since fissures are frequently narrower than the explore tip. This tool would not have aided in the diagnosis of this lesion. Therefore, the only sure way of knowing if a stained pit or fissure is carious is to "spray" it out with air-abrasive technology. Reproduced from Paterson et al.[103] courtesy of Quintessence Publishing Co, Inc.

the traditional use of the explorer to probe for caries. Enamel that is undermined with caries but strengthened by fluoride makes decay difficult to detect. A sticky fissure detected by the wedging of an explorer tip is no longer considered the only method for detecting pit and fissure caries (Figure 14.32A and B). In fact, probing of pits and fissures also has been deemphasized because of its potential for damaging enamel. It is also interesting to note that few of these lesions are actually seen on radiographs as decay, although intraoral video cameras can facilitate the viewing of caries in grooves that are too narrow for the penetration of an explorer tip. However, difficulty in distinguishing a stain on the surface from a darker-colored organic plug within the pit or fissure that can promote caries also contributes to the diagnostic dilemma (Figure 14.32A). Instead, use either a laser detection device or AC impedance spectroscopy technique which can be quite helpful in determining if a pit or fissure is carious or just stain (Diagnodent, Kavo, Cariescan pro) (Figure 3.5B and C).

The traditional placement of sealants in pits and fissures without removing the stain or organic plug, and possible underlying caries, is *seriously questioned*. Shrinkage and marginal wear often lead to undetected marginal leakage. Paterson et al. report that if such leakage occurs over active dentinal caries, it may not be detected before pulpal involvement or extensive undermining of enamel and/or cuspal fracture occurs.[103]

Use of air-abrasive technology

According to Goldstein and Parkins,[102] air-abrasive technology (PrepStart by Danville) (MicroPrep, Lares; Mach 5, Kreativ) offers options in caries diagnosis and treatment. The air-abrasive system uses a narrowly focused particle stream that abrades tooth structure in proportion to the particle size, air pressure, and nozzle distance employed. The key issue for this newly revived technology is that it provides a more conservative approach to both diagnosis and treatment of pit and fissure caries than conventional methods. After observing suspiciously stained pits or fissures, one or more short bursts of alpha alumina powder from the air-abrasive system can be used to remove both the stain and organic plug for a more accurate evaluation of the presence of caries. If this is simply stain or the organic plug, the abrasive action will eliminate it while leaving all but a few micrometers of healthy tooth structure intact. This examination is especially facilitated by the use of an intraoral camera or operative microscope. Several intraoral cameras also have caries detection ability (Figure 3.9A–F featuring Kodak CS1600, CareStream, Soprolife, Acteon). If there is no decay, the air-abrasively prepared pit or fissure can then be sealed or restored with resin materials.

If underlying caries is detected, further bursts of the abrasive powder stream may be used to completely eradicate the lesion, preserving the maximum amount of healthy tooth structure. (Hand or rotary instruments may be used as well if the area of decay is large.) The air-abrasive technique roughens the tooth surface, leaving it ready for direct bonding techniques with or without acid etching.[104–109] The preparation can be restored immediately with either filled or unfilled composite resin. A combined sealant and bonding technique may be considered: if tooth structure has been removed or the anatomy is irregular, restore those areas with a bonded filled resin. The smaller, secondary grooves may then be covered with a sealant, creating a preventive resin restoration (Figure 14.33A–E). With the introduction of flowable composite resins, this procedure can be accomplished in a single step.

Patients like the fact that abrasive technology does not usually require an anesthetic, and therefore an "uncomfortable" injection and associated numbness are often eliminated.[3] This also saves time for the dentist because he or she can begin immediately with a happier patient, not waiting for an anesthetic to take effect. The unpleasant heat, pressure, and bone-conducted noise and vibration associated with most "drilling" is minimized. This gentleness is confirmed by histologic studies demonstrating that this technology is much kinder to the pulp.[84]

The esthetic advantage of using air-abrasive technology is the ability to easily eliminate stained and/or carious areas without

Figure 14.33 **(A)** This lower bicuspid reveals a stain.

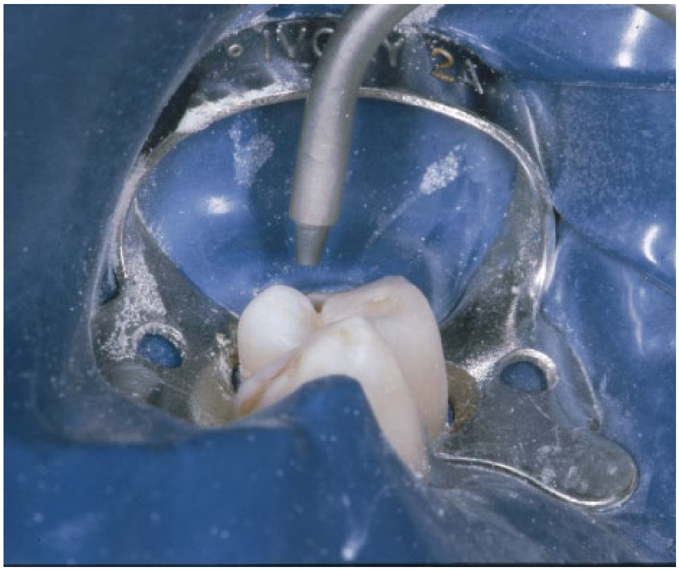

Figure 14.33 **(B)** A 3 s burst by an air-abrasive system (PrepStart, Danville) helps determine if the problem is caries or just stain.

Figure 14.33 **(C)** Using the intraoral camera with caries detection ability helps to ensure that all caries is removed.

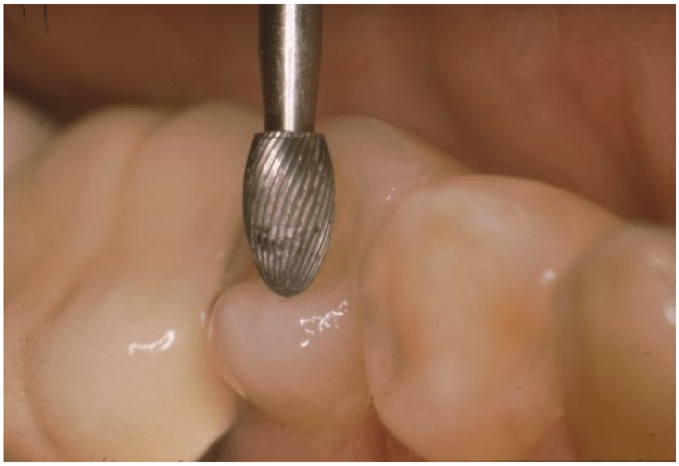

Figure 14.33 **(D)** Once all caries are removed, the tooth is restored with a hybrid composite. The final finish is achieved with a 30-bladed carbide finishing bur (OSIUF, Brasseler USA).

Figure 14.33 **(E)** The final bonded restoration can be further enhanced with a composite surface sealant (Fortify, Biscover).

cutting into the tooth with a rotary handpiece. Patient acceptance is so high that it is a definite practice builder. Psychologically, patients also may feel better about maintaining teeth that have been restored to a natural, healthy appearance, rather than restored teeth that retain unsightly stains around the restoration. Further, patients appreciate the concept of maximizing the conservation of healthy tooth structure by attacking decay at the earliest possible moment. Preliminary studies of shear bond strength also suggest that the roughened surface created by air-abrasive technology may enhance bonding, especially bonding to dentin.[109]

Other techniques of eliminating pit and fissure caries are use of special ultrathin diamonds or bursor hard tissue lasers. Goldstein has also used the ET3 30 μm to enter previously diagnosed carious pit and fissures. However, use of a diamond bur makes it necessary to use a restorative technique to keep out the lesion, whereas the use of air abrasion may eliminate the stain and no further treatment may be necessary.

A major advantage in using the hard tissue laser is the ability to perform most procedures without injectable anesthesia (Solea CO_2) (Figure 14.34A–I). This means children and young adults may never have to have injections for restorative dental treatment. Specifically, defective or carious pits and fissures plus interproximal decay can easily be done with the hard tissue laser that also anesthetizes the tooth being treated.

Another major use of air-abrasive technology is the repair of composite resin and porcelain restorations. Until now, no satisfactory method had been devised to etch the existing composite resin when new composite resin was to be added as in a repair or even esthetic enhancement of a discolored composite. By first preparing the surface of the composite with the air-abrasive

Figure 14.34 **(A)** The second bicuspid revealed a 2.5 LED reading (Kavo, USA). It was decided to follow out the stain to verify that caries were present.

Figure 14.34 **(B)** A CO_2 laser (Solea, Convergent) hard tissue laser was selected so no local anesthesia would be necessary.

Figure 14.34 **(C)** The probe showed almost 2 mm depth to the carious lesion after it opened up in the dentin.

Figure 14.34 **(D)** One advantage of the laser is to keep the opening as narrow as possible. Therefore, a very thin placement instrument is used to place the inner base (Vitrebond), plus light-curing glass ionomer, (3 M).

Figure 14.34 **(E)** Note how the special end of the Goldstein micro placement instrument (Hu-Friedy TMGPI) can carry and place a very small amount of liner/base into the preparation without even touching the walls of the cavity.

Figure 14.34 **(F)** The final layer of micro-hybrid composite is condensed by an aluminum titanium nitride-coated double-ended condenser (TNCIGFT 2, Hu-Friedy).

Figure 14.34 **(G)** Before polymerizing, the restorative is carved using a satin steel XTS composite carver (#5-TNCIGFT 5, Hu-Friedy).

Figure 14.34 **(H)** After polymerization, the occlusal anatomy is smoothed using either a 15 μm diamond (DOS3, Brasseler USA) or a 30-blade carbide (OS3UF, Brasseler USA).

Figure 14.34 **(I)** The final restoration after polishing with the Feather Lite polisher (Brasseler USA), and a 10 s polymerization to reinforce surface hardness.

system, an excellent etched surface exists to help gain greater retention of the newly bonded composite resin. A study by Chen et al. also showed that a 120 s air abrasion provided the highest bond strength of composite resin to porcelain.[110]

The future

McLean doubted that the ideal restorative material will be achieved until well into the 21st century,[111] but it is clear that bonding will continue to improve through both materials and technique. The use of erbium:YAG lasers for tooth preparation and etching as well as argon and other lasers, some of which feature subsecond polymerization, may result in shorter procedural time and increased restoration strength.[57] New strength, new direct and indirect materials, and perhaps even decreasing costs will bring bonding to larger numbers of people. Furthermore, if current findings continue to hold true, composites will not only become more valuable for esthetics but also for reducing caries,[4] in combination with glass ionomers and other similar compounds.

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Chapter 15 Ceramic Veneers and Partial-Coverage Restorations

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History

In the early part of the 20th century, movie actors frequently had dingy but otherwise healthy anterior teeth reduced for full crowns. Then, in the 1930s, California dentist Charles Pincus developed thin facings of air-fired porcelain that could be fastened in place with adhesive denture powder.[1] While these smiles live on in the film archives and in late-night movies, the veneers themselves were peeled away when the camera was turned off. Nonetheless, with this technique, Pincus had laid the groundwork for a new kind of dentistry, one that considered esthetics, not just articulation and function.

Veneering remained merely another form of cosmetics until the techniques and materials evolved to produce strong veneers that could be mechanically bonded to teeth. In 1955, Buonocore's research into the acid etch technique provided a simple method of increasing the adhesion to enamel surfaces for acrylic filling materials.[2] His discovery was quickly followed by Bowen's work with filled resins.[3,4] Only in the 1970s, however, with the introduction of visible-light-cured composites, did the dentist have the necessary working time to properly shape direct composite veneers.[5,6] Even so, these veneers were difficult to do: they were highly technique-sensitive, required extensive clinical chair time, and were frequently subject to in situ polymerization problems.

In the 1970s, Faunce described a one-piece acrylic resin prefabricated veneer as an improved alternative to direct composite resin bonding.[7,8] The veneer was attached both chemically, with a chemical primer applied to the veneer, and mechanically, with a composite resin to lute the veneer onto the etched tooth. These early indirect veneers and their successors had certain advantages over the direct veneers. Because they were fabricated by a manufacturer or trained technician, the indirect veneers typically displayed greater anatomical accuracy and almost always required less chair time for the patient and the dentist. More completely cured through laboratory processing, they were less likely to shrink during polymerization, and they provided superior shading capabilities and control of facial contours.[9] The indirect veneers had the additional advantage of being more stain-resistant than direct veneers.

Both acrylic resin and microfill resin veneers offer a smooth surface and good masking ability, with very little need for finishing. However, both exhibit poor resistance to abrasion[10] and are restricted to teeth not involving heavy functional contacts.[9] Presently, modern direct composite restorations can offer an alternative midterm solution, if the need of dental correction is limited, and the patient wants to avoid tooth structure preparation or has financial limitations (Figure 15.1A–T).

It was inevitable that the pioneers in veneers would turn to porcelain, one of the most popular and attractive materials in the dental armamentarium. The concept of acid etching porcelain and bonding to a tooth with an acid etch technique was first cited in the dental literature in 1975 with Rochette's description of an innovative restoration of a fractured incisor.[11] Since then, there have been key advances in the development of ceramic veneers and their fabrication and placement.[6,12–21]

The introduction of glass-ceramic and oxide-ceramic materials with enhanced flexural strength offered an alternative to feldspathic porcelain to fabricate dental veneers.[22–25] The new ceramic materials allowed for extension of classic facial veneer preparation designs[16,26] to more defect-oriented partial coverage and full veneer preparations introduced by Stappert et al. in 1999.[21,27] The new flexibility in preparation design based on enhanced ceramic material strength established ceramic veneers as valid alternative to full crown restorations in the anterior

Figure 15.1 **(A)** This 24-year-old patient was concerned by her compromised anterior esthetics. Aged composite restorations showed discoloration at the four maxillary incisors.

Figure 15.1 **(B)** The lateral incisors showed malformation and were built up by extended composite restorations. The incisal edge of tooth #8 had been replaced.

Figure 15.1 **(C)** Facial interocclusal dental overview demonstrates multiple shades, ranging from A3.5 to A1.

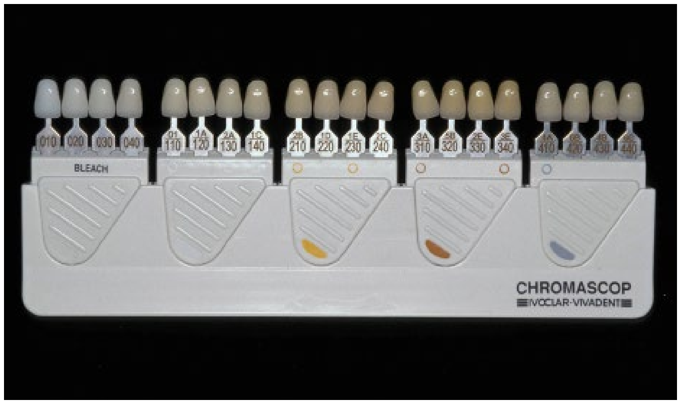

Figure 15.1 **(D)** To anticipate the bleaching outcome better, a bleaching shade guide was used.

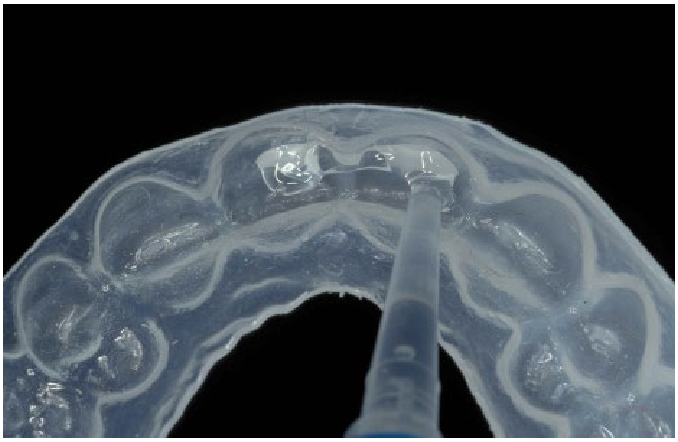

Figure 15.1 **(E)** Home bleaching was used to allow for customized bleaching periods of individual teeth.

dentition.[28] Anterior veneer restorations require on average only 17–30% coronal tooth structure removal when compared to 60–70% of full coverage restorations.[29]

The further development of physical and biomechanical characteristic of dental ceramics resulted in ceramic material classes, showing significant differences in esthetics, strength, and reliability.[30]

Glass-ceramics and oxide ceramics exceed the fracture toughness and durability of silicate ceramics[31] and can be used even under higher masticatory loads of the posterior dentition.[32,33]

As the demand for esthetic dental services continues to grow, the introduction of stronger indirect ceramic restorations offers new minimal invasive options for both anterior and posterior restorations.

This chapter describes in detail the advantages and disadvantages, the indications and contraindications, and the techniques for using ceramic partial coverage restorations for anterior and posterior teeth, ranging from veneers to partial crowns (Figure 15.2).

Figure 15.1 **(F)** A bleaching level of 020 or 030, according to the bleaching guide, was anticipated.

Figure 15.1 **(G)** Bleaching progress was monitored and dental hygiene treatments performed. The previous composite restorations became more visible.

Figure 15.1 **(H)** Following the bleaching shade guide, composite material was used in a multilayer fashion.

Figure 15.1 **(I)** Rubber dam was applied and composite build-ups in dentin and enamel were performed.

Figure 15.1 **(J)** Final outcome of the composite build-ups on teeth #7, #8 and #9 under dry condition.

Figure 15.1 **(K)** Facial interocclusal view of the upper and lower dentition. The upper dentition shows a lighter shade than the lower dentition (A1 vs. A2). The patient didn't want to perform further bleaching in the lower dentition due to sensitivity concerns.

Figure 15.1 **(L)** Close-up view of the upper four restored anterior teeth #7–#10 in relation to the upper and lower lip position.

Figure 15.1 **(M)** Facial display of the patient's smile in area #5–#12 in relation to the lower and upper lip line.

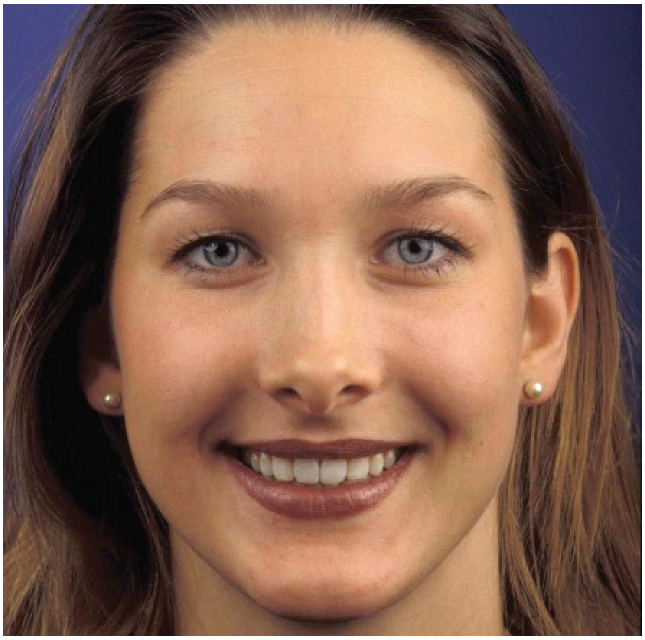

Figure 15.1 **(N)** Patient facial appearance after completion of the composite restorations in the anterior dentition. The patient was very satisfied with the final outcome.

Figure 15.1 **(O)** Patient recall 9 years after the initial composite restorations on teeth #7–#10. The right lateral view demonstrates intact composite restorations with minor discoloration.

Figure 15.1 **(P)** Facial view of interocclusal relationship demonstrates discoloration of the mesiofacial restoration # 8 and recognition of the filling margins at tooth # 10.

Figure 15.1 **(Q)** The left lateral view does not demonstrate significant discoloration areas.

Figure 15.1 **(R)** Pre-op facial view (before) of the upper anterior dentition.

Figure 15.1 **(S)** Post-op facial view (after) of the composite restored upper anterior dentition 9 years later.

Traditional porcelain veneers

Porcelain is generally considered the most esthetic and biocompatible material available for dental restorations.

Advantages of porcelain veneers

1. Natural and stable color. The smooth surface texture and natural color of porcelain are exceptional, and the crystalline structure of porcelain gives it optical refractive properties similar to those of translucent enamel.[34,35] Furthermore, porcelain can be internally stained and the ability to adjust the final color of the veneers during placement allows considerable flexibility in final shade adjustments. Texture also is easily developed on the veneer surface to simulate that of adjacent teeth, and this texture can be maintained indefinitely,[16] as opposed to veneers of

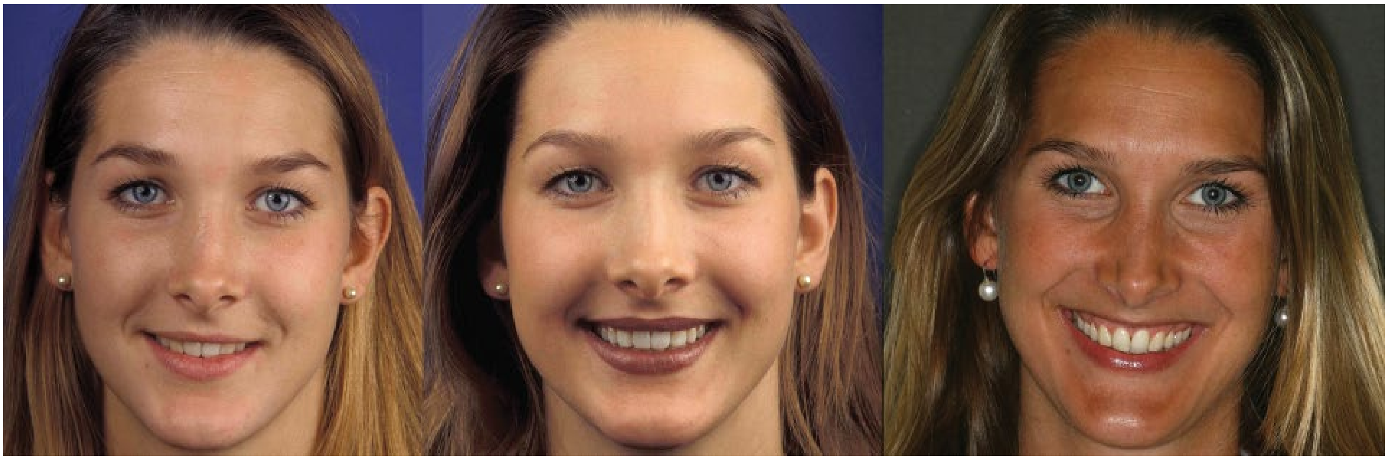

Figure 15.1 **(T)** The patient presents excellent dental hygiene and continues to appreciate her anterior composite restorations.

Figure 15.2 **(A)** This patient had a gummy smile and disliked the appearance of her two anterior front teeth. The teeth #8 and #9 appeared darker than the lateral incisors.

Figure 15.2 **(B)** Strong facial cervical enamel attritions at teeth #8 and #9 on this 30-year-old patient. Gingival conditions of the patient are very favorable. The cervical defects end below the cementoenamel junction close to the gingival margin.

Figure 15.2 **(C)** Facial smile analysis resulted in a wax-up of the anterior two front teeth. A preparation guide was fabricated, showing the potential new incisal lengths.

Figure 15.2 **(D)** Master model shows two very thin 0.4 mm press-ceramic e.max Press veneers for teeth #8 and #9.

Figure 15.2 **(E)** Occlusal view of the adhesively bonded two anterior restorations.

Figure 15.2 **(F)** Patient smile 6 months after placement of the anterior veneers. The new incisal length implies a more positive smile line.

monolithic pressed glass or computer-aided design/computer-aided manufacture (CAD/CAM) ceramics.[36,37]

2. Highly acceptable tensile bond strength. The bond of etched porcelain veneers to enamel is considerably stronger than that of any other material or veneering system. The resin to silane-treated etched porcelain veneer has bond strengths ranging from 17.9 to 22.1 MPa as compared to composite resin veneer to enamel bond strengths of only 6.2–9.7 MPa.[38,39]
3. Inherent porcelain strength that permits reshaping teeth.[40] Although porcelain veneers are themselves rather fragile once bonded to enamel, the restoration develops high tensile and shear strengths.[38,41,42] Porcelain therefore can be used to increase the length of a given tooth by extending it over the incisal edge. In certain instances, porcelain veneers can also be used to repair ceramometal restorations.[43,44]
4. Extremely good biocompatibility with gingival tissues. The highly glazed porcelain surface is less of a depository area for plaque accumulation as compared to any other veneer system, and it appears that some types of porcelain veneers actually deter plaque accumulation.[45]
5. Long lasting. Once bonded, porcelain veneers develop high tensile and shear strengths and remain in place.[46] For example, a 5 year clinical study of 186 porcelain veneers placed in 61 patients showed a survival rate of 98.4%.[47] Fradeani et al. reported a probability of survival of 182 porcelain veneers of 94.4% at 12 years, with a low clinical failure rate of approximately 5.6%.[48]
6. Exceptional resistance to wear and abrasion.[49,50] Porcelain veneers still look good after many years (Figure 15.3A and B).
7. Resistance to stain. The microscopic porcelein structure reveals only very few voids and irregularities that could accumulate stain. Therefore, the highly glazed porcelain surface is very resistant to stain accumulation.
8. More resistant to deleterious effects of solvents, including alcohol, medications, and cosmetics than any composite resin veneer.[49]
9. Much less absorption of fluids than any other veneering materials.[50] Water absorption of resin veneers leads to a decrease in physical properties and increasing wear and surface changes over time.[51]

Figure 15.3 **(A)** The patient improved his upper smile by replacing discolorated fillings and dental defects with six veneers and four partial coverage ceramic restorations one year ago.

Figure 15.3 **(B)** Ten years after placement, the ceramic veneers and partial coverage restorations still look good despite the presence of some tissue recessions.

10. Surface luster retention. Composite resin tends to lose the initial luster, requiring frequent repolishing. Porcelain retains its glazed luster over the entire life of the restoration.
11. Lack of radiopacity. On radiographs porcelain resembles natural tooth structure, allowing radiographic access to areas that would be shielded by radiopaque restorations.

Disadvantages of porcelain veneers

1. Porcelain veneers can be easily repaired with composite once bonded to the enamel, but the repairs are not long lasting due to staining which tends to occur at the margin of composite resin and porcelain.
2. The color cannot be easily modified once bonded in position.
3. Irreversibility of preparation versus little or no preparation for direct composite resin bonding.
4. Level of difficulty of fabrication and placement, time involved, and expense. The extremely fragile veneers are difficult for the dental laboratory to make and manipulate, and the process requires at least two appointments, plus laboratory fees.
5. Technical difficulties in avoiding overcontours and obtaining closely fitted porcelain/enamel margins. The margins can be especially brittle and difficult to finish.[16]
6. Lower reparability compared to composite veneers. Yet, Kimmich and Stappert point out that porcelain can be repaired using hydrofluoric acid for 1 min or Co-Jet to create surface roughness to bond to porcelain intraorally.[44] The veneers are then silanated and coated with a layer of unfilled resin, followed by a color-matched composite repair. But the disadvantage still remains in terms of time and complexity, and unknown durability of the repair.
7. Susceptibility to pitting by certain topical fluoride treatments. Stannous fluoride paste should not be used with porcelain restorations. Also it is best to avoid air-polishing prophylaxis systems (Prophy Jet, Dentsply, Air Flow S1, Hu-Freidy Prophy Jet, or NSK Prophy Mate L, Hu-Friedy) on the porcelain surface. Finally, hygienists must avoid ultrasound in prophylaxis treatment, especially around gingival margins. Goldstein, Lamba, Lawson, Beck, Oster, and Burgess demonstrated in a clinical study at the University of Alabama at Birmingham that ultrasonic scaling around margins of Class V composite restorations could result in microleakage.

Indications for porcelain veneers

Classic veneer indications are listed here.[40]

Type I: moderate tooth discolorations/color corrections:

Tetracycline
Fluorides
Amelogenesis imperfecta

Type II: anatomical malformations/corrections of position:

Type IIa	Conoid teeth
Type IIb	Diastemata
Type IIc	Incisal edge lengthening

Type III: extensive damage/changes in form:

Type IIIa	Extensive coronal fractures
Type IIIb	Congenital and acquired malformations

The covering power of porcelain veneers and their ability to reshape teeth make this procedure almost ideal for many clinical situations including those outlined below.

1. Moderate discolorations, such as tetracycline staining, fluorosis, devitalized teeth, and teeth darkened by age which are not conducive to vital bleaching.[8] Porcelain veneers can be especially useful for single discolored teeth.
2. Teeth with generalized moderate facial discoloration from amalgam shine-through.[52]
3. Surface defects. Small cracks in the enamel caused by aging, trauma, or ice chewing can weaken the enamel and stain darkly. In these situations, porcelain veneers can mask the stains, seal, and strengthen the teeth. Also, teeth with numerous shallow, esthetically compromising restorations on the labial surfaces can be dramatically improved (Figure 15.2A–F).
4. Replacement of missing or fractured parts of the teeth.[19,40] Nixon[52] and Kimmich and Stappert[44] report the use of veneers on porcelain crowns to repair porcelain fractures.

5. Closing of diastemas, single or multiple spaces between the teeth, and improving the appearance of rotated or malpositioned teeth. Persons who have relatively sound teeth but who do not want to undergo orthodontics may be helped with veneers that create the esthetic illusion of straight teeth.
6. Short teeth.[52] These teeth can be lengthened to a more esthetic, appropriate size.
7. Malocclusions or periodontally compromised teeth. Porcelain veneers can restore or change the configuration of the lingual surfaces of anterior teeth to develop increased guidance or centric holding areas. Porcelain veneers can also be used to reshape interproximal embrasure spaces when the gingival tissues have receded.
8. Agenesis of the lateral incisor. When the cuspid erupts adjacent to the central incisor in situations in which there is a missing lateral incisor, porcelain veneers can be used to develop a different coronal form of the cuspid, simulating a lateral incisor. This treatment may have to be combined with veneers on the central incisors to obtain a more ideal ratio in the relative proportion of the teeth, because the cuspid is invariably too wide.
9. Progressive wear pattern. If sufficient enamel remains and the desired increase in length is not excessive, porcelain veneers can be bonded to the remaining tooth structure to restore the shape, color, or function of the teeth. Assuming the parafunctional behavior itself is under control, porcelain veneers even can be used to repair dentitions damaged by the effects of anorexia nervosa or bulimia.
10. Functionally sound ceramometal or all-ceramic crowns with unsatisfactory color.[52] The labial surface of the old porcelain is prepared as you would for a conventional veneer. After an impression, a veneer is constructed in the new shade. The existing crown surface is roughened with air abrasion, and then etched with a buffered intraoral use hydrofluoric acid and silanated.[44] The veneer is then bonded to place with resin cement. However, the cost of this procedure is basically the same as making a new crown, so its use should be limited to those patients not wanting their entire crown or extended fixed dental prosthesis remade.

Contraindications for porcelain veneers

In comparison to other forms of bonding, porcelain veneers have fewer and more forgiving contraindications. Nonetheless, such contraindications do exist.

1. Patients with certain tooth-to-tooth habits such as bruxism or parafunctional habits such as pencil chewing or ice crushing may place undue stress on the porcelain veneers.
2. Ideally, enamel should be around the whole periphery of the veneer, not only for adhesion, but more importantly to seal the veneer to the tooth surface.[25] In addition, there should be sufficient enamel available for bonding, since bonds to dentin are generally less retentive and predictable than bonds to enamel. If the tooth or teeth are composed predominantly of dentin and cementum, extended veneer restorations or crowning with high-strength ceramics may well be the preferable treatment.[26,28] A strict adhesive bonding protocol for dentin bonding should be applied to achieve predictable long-term reliability of the bonding interface.
3. Certain types of occlusion may have problems. These include Class III and end-to-end bites. However, there may still be the possibility of cosmetic treatment by contouring the lower incisors and building out the maxillary incisors. An alternative can be a protective bite appliance for the patient to wear after treatment is completed to protect the veneers from clenching or grinding forces. This appliance would be worn at night or when sleeping, driving, playing sports, etc., as necessary. Still, day clenching or grinding could be a problem.
4. Deciduous teeth and teeth that have been excessively fluoridated may not etch effectively. In order for porcelain veneers to be successful in these cases, special measures such as aggressive roughening of the enamel/dentin surface with an extra-coarse diamond plus air abrasion may be required in combination with last-generation bonding agents. Extreme bleaching-resistant discolorations, such as deep tetracycline or amalgam staining, or discolored devitalized roots and coronal tooth structure, are very difficult to cover with porcelain ceramic restorations. In these cases, the use of more opaque high-strength ceramics such as lithium disilicate,[53,54] aluminum oxide,[55–57] or zirconium oxide[58,59] is indicated.

Shade selection

Shade determination begins at the consultation and examination appointment. This is when an understanding of what exactly the patient wants is needed. How light does the patient envision his or her teeth will be? If the patient is looking for “white” teeth, does that mean opaque white or translucent white? The clinician must determine how much leeway he or she has in arriving at what seems to be appropriate and agreeable color. The easiest way of accomplishing this is to image the patient on a computer so that the clinician and the patient can see how the different colors will look. However, if the patient is a perfectionist, the best method is to have the ceramist construct several trial veneers made from an impression of your patient’s teeth. Thus, several samples of different shade choices can be offered and applied directly to the teeth.

If all teeth that show are going to be veneered, then proceed with shade selection as any other ceramic restoration. If, however, some teeth are to be covered with porcelain veneers and others are to be bonded or restored with full crowns, the porcelain veneers should be placed first because of the difficulty in modifying the color of the veneers once they are bonded in place. The adjacent teeth can then be easily matched to the final, bonded porcelain veneer color. If the procedure involves matching one discolored tooth (especially a central incisor) to another, provide the ceramist with extra room with additional depth of tooth preparation to add sufficient opacity to the veneer to mask the darkness before exact matching of the required tooth shade.

One of the most important steps in the entire procedure is deciding when, where, and how to record color or shade. This should be done before beginning treatment, at a session when the teeth have not been dried out for any period of time. It should be done inside the operatory using color-corrected light, outside in daylight, and inside using incandescent light. A good external device to be able to see all three light values is the Rite-Lite 2 shade-matching light (AdDent). Finally, reconsider the shade after the enamel has been prepared. If the prepared tooth has turned much darker than previously anticipated, consider a lighter shade or a shade with more opaquer, or even re-prepare the tooth to gain more porcelain thickness and thereby additional room for both color and opaquer. If this is the situation, the clinician should have a consultation with the ceramist if possible. In the event the technician is not available, a photographic consultation may suffice to record exactly what the color problems are for the ceramist. However, the final impression may be delayed pending a joint decision on which approaches to take.

The available shade guides, such as the VITA porcelain shade guide, may not be ideal for veneers because they are too thick and are composed of several different layers including opaques. It is better for the ceramist to make an individualized shade guide of porcelain veneers exactly as he or she would fabricate them and use this to select a shade. And always, take photos with the shade guides on the same plane as the teeth to be restored.

Classification of tooth preparation for anterior veneers

The following is based on the present evidence-based literature.[20,21,25,26,40,60–63]

Class 0: no preparation (Figure 15.4A–C).

Class 1: window preparation (window) (Figure 15.5A and B). Veneer ends below the incisal edge.

Class 2: feather-edged preparation technique (feather) (Figure 15.6A and B). Veneer extends to the incisal edge; there is no reduction of the incisal edge.

Class 3: bevel preparation (bevel/small butt joint) (Figure 15.7A and B). Buccopalatal bevel; there is reduction of the incisal edge.

Class 4: overlapping preparation of incisal edges (incisal overlap) (Figure 15.8A and B). Reduction of the incisal edge and palatal extension of the preparation.

Class 5: butt joint preparation (Figure 15.9A and B). Incisal reduction of ≥2 mm, 90° lingual marginal finish. Interproximal preparation includes the contact areas.

Class 6: full veneer preparation (complete veneer, ¾ veneer) (Figure 15.10A and B). Interproximal and palatal preparation extension, including palatal deep chamfer or rounded shoulder preparation. Variable defect-oriented preparation; hybrid between veneer and all-ceramic crown.[21,27]

Classic preparation classes

The veneer preparation Classes 0–4 can be considered 'classic.' The preparation guidelines have the following philosophies in common:

1. The main veneer indication groups for these veneer preparation classes are Type I (discoloration), and to a moderate extent Type IIa, b, and c (conoid teeth, diastemata, incisal edge lengthening) indications.

Figure 15.4 **(A)** No-preparation veneer from sagittal view. **(B)** No-preparation veneer viewed from facial-distal angle. **(C)** No-preparation veneer illustrated with future restoration.

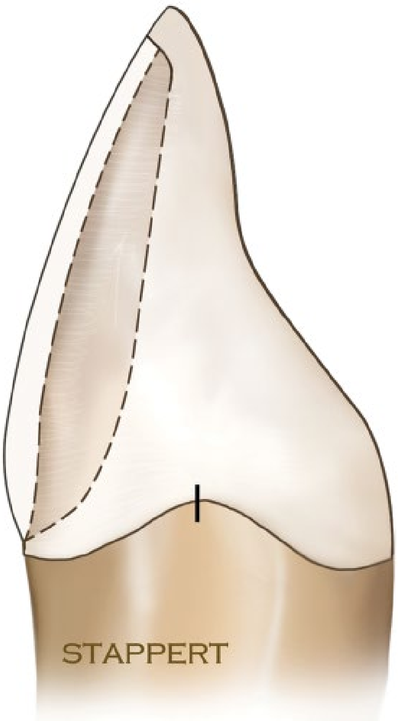

Figure 15.5 **(A)** Window veneer preparation from sagittal view.

Figure 15.5 **(B)** Window veneer preparation viewed from facial-distal angle. Notice the veneer ends below the incisal edge.

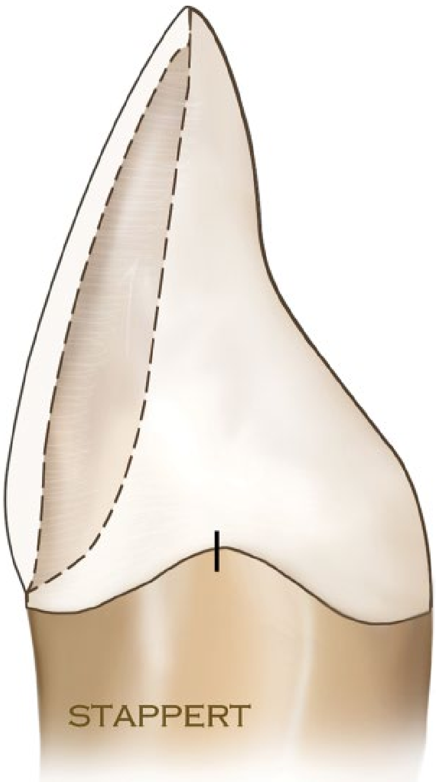

Figure 15.6 **(A)** Feather-edged veneer preparation from sagittal view.

Figure 15.6 **(B)** Feather-edged veneer preparation viewed from facial-distal angle. Notice the veneer extends to the incisal edge with no reduction of the incisal edge.

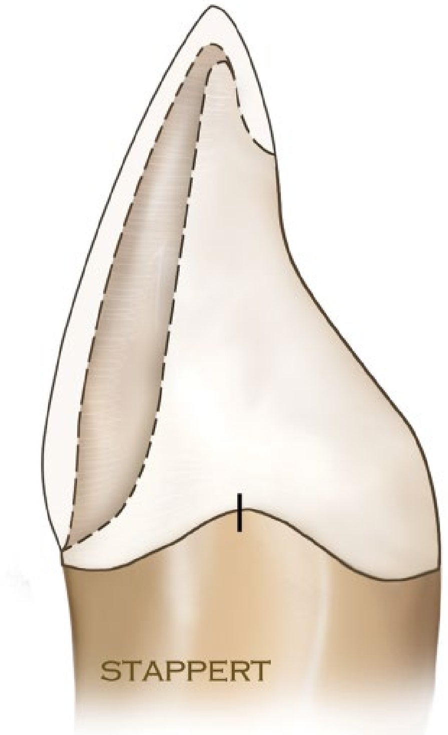

Figure 15.7 **(A)** Bevel veneer preparation from sagittal view.

Figure 15.7 **(B)** Bevel veneer preparation viewed from facial-distal angle. Notice buccopalatal bevel/small butt joint reduction of the incisal edge.

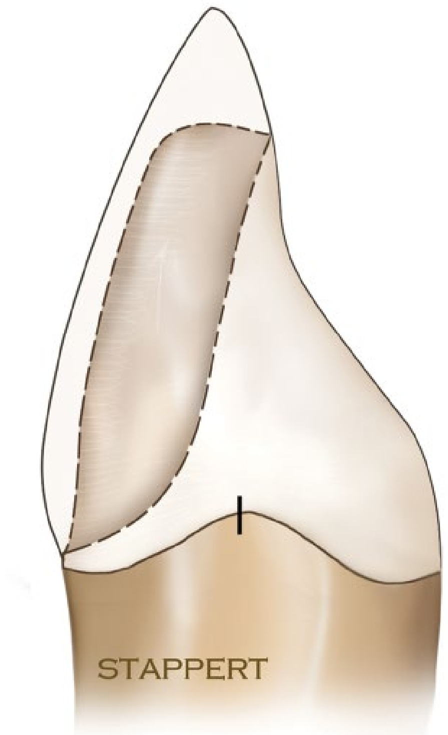

Figure 15.8 **(A)** Overlapping of incisal edges veneer preparation from sagittal view.

Figure 15.8 **(B)** Overlapping of incisal edges veneer preparation viewed from facial-distal angle. Notice incisal overlap and palatal wraparound extended preparation.

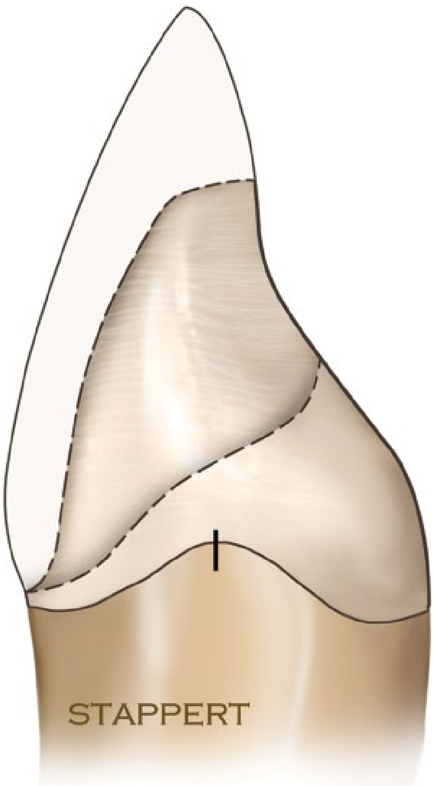

Figure 15.9 **(A)** Butt joint veneer preparation from sagittal view.

Figure 15.9 **(B)** Butt joint veneer preparation viewed from facial-distal angle. Notice incisal reduction of ≥2 mm with 90° lingual marginal finish.

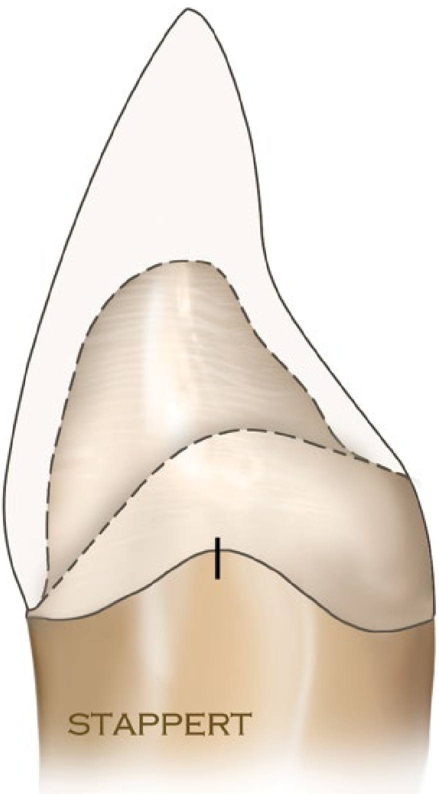

Figure 15.10 **(A)** Full veneer preparation from sagittal view.

Figure 15.10 **(B)** Full veneer preparation viewed from facial-distal angle. Notice extension of the preparation that resembles hybrid between veneer and all-ceramic crown.

Figure 15.11 **(A)** This 32-year-old male patient presented after a bicycle accident with incisal tooth fracture of tooth #8. Dental evaluation did not demonstrate increased mobility or hypersensitivity. The rehabilitation of tooth #8 was planned with an IPS Empress veneer.

Figure 15.11 **(B)** Facial preparation of tooth #8 with estimated 0.4 mm preparation depth, ending epigingival in a light chamfer. Incisal butt joint preparation provided a 90° finish line at the palatal surfaces.

Figure 15.11 **(C)** Fabrication of direct composite veneer as provisional. First the tooth was isolated with glycerin gel to allow later removal of the composite veneer. For fixation, point etching was performed facially and HelioBond was used to bond the restoration temporarily.

2. All of these preparation classes primarily restore the facial aspect of a tooth.
3. The preparation approach is minimally invasive, ideally by maintaining the incisal edge of the restored tooth.
4. Preparation extension into the interproximal contact area or beyond is mostly avoided.
5. Preparation is enamel-sparing and bonding of the veneer restoration relies predominantly on enamel bonding.
6. The most common used material in these classes is feldspathic porcelain.

An example Class 4 preparation is shown in Figure 15.11A–L.

Figure 15.11 **(D)** Final IPS Empress veneer restoration, using the cut-back technique to customize the esthetic outcome.

Figure 15.11 **(E)** Adhesively bonded ceramic veneer at tooth #8. Epigingival placed veneer by using triple-zero retraction cord to catch excess cement.

Figure 15.11 **(F)** Facial view of the bonded ceramic veneer in relation to the smile line. The incisal defect at tooth #7 was treated with a layered composite filling to achieve an enhanced symetrical outcome.

Novel preparation classes

The veneer preparation Classes 5 and 6 can be considered 'novel.' The preparation guidelines aim for the following goals:

1. The main veneer indication groups for these veneer preparation classes are severe Type IIa, b, and c (conoid teeth, diastemata, incisal edge lengthening) and Type IIIa and b (extensive coronal fractures, and congenital and acquired malformation) indications.
2. Preparation includes facial, proximal and palatal dental deficiencies or defects.
3. The preparation is defect-oriented. Enamel preservation and marginal enamel integrity are preferred, yet areas of dentin exposure due to extended dental hard tissue loss are expected, and, due to the path of insertion of the final restoration, unavoidable.

Figure 15.11 **(G)** Full facial view of the full smile of the patient.

Figure 15.11 **(H)** Recall of the patient, 1 year after insertion of the ceramic veneer at tooth #8.

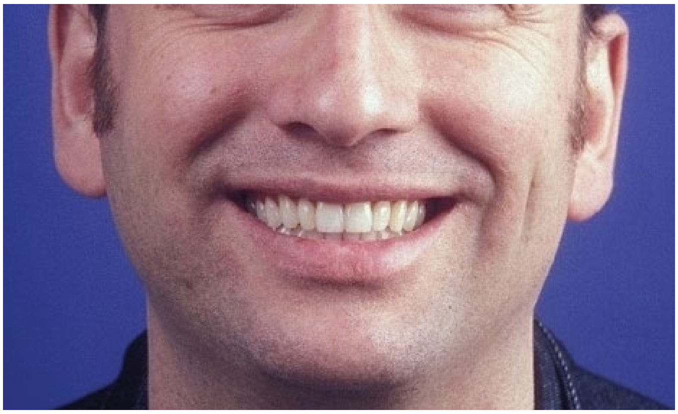

Figure 15.11 **(I)** Facial view of the patient's smile 1 year after insertion of the ceramic restoration.

Figure 15.11 **(J)** Recall shows anterior view of veneer tooth #8 14 years after placement.

Figure 15.11 **(K)** The smile line of the patient does not expose the light marginal discoloration at the extended veneer restoration.

Figure 15.11 **(L)** Patient is still satisfied about his treatment choice to have his tooth restored with an all ceramic veneer (facial view).

4. The preparation includes the interproximal contact areas and extends proximally to the lingual aspect.
5. Incisal reduction or extension depends on the final restorative goals, and preparation depth can vary from 0.4 to 1.0 mm according to diagnostic wax-up and mock-up.
6. Bond strength relies on a combination of enamel and dentin bonding.
7. High-strength ceramics, presently largely lithium-disilicate glass-ceramic, compensates for extended tooth structure loss.

Mandibular veneers: special considerations

From an esthetic standpoint, the mandibular veneer can provide an excellent result in most situations. However, its life expectancy can be drastically compromised unless the patient's occlusion is favorable. The usual problem with preparations for lower veneers is leaving enough tooth structure remaining after the horizontal and vertical reduction. A potentially weak point is at the incisolabial junction, which must always be sufficiently reduced and rounded to allow the veneer to be thick enough in that area to have the strength to resist fracturing when placed under an occlusal load (Figure 15.12A). The possibility of fracturing or cracking means greater maintenance for mandibular veneers in patients with heavy occlusal demands, which includes patients with habits such as severe bruxism or clenching. If this is the situation and if discoloration is the reason for wanting to do mandibular porcelain veneers, it is advised to try bleaching first to see if the teeth will become light enough to satisfy the patient.

Also, the incisal edge of mandibular anteriors is usually the most visible part of the veneer so consider this fact when preparing the tooth. Simply reducing from the labial surface will almost always be insufficient to mask the tell-tale signs of color differences that the veneer has been placed. Sufficient incisal reduction is needed to ensure a normal incisal edge appearance for that patient.

One advantage of the mandibular veneer is that it is seldom necessary to go subgingivally, as with the maxillary veneer, because most people do not show the gingival margin of mandibular anteriors. However, the clinician needs to discuss this with the patient, since there are many individuals who do not want to see a margin or be reminded of the previous discoloration regardless of the fact that he or she is the only one who

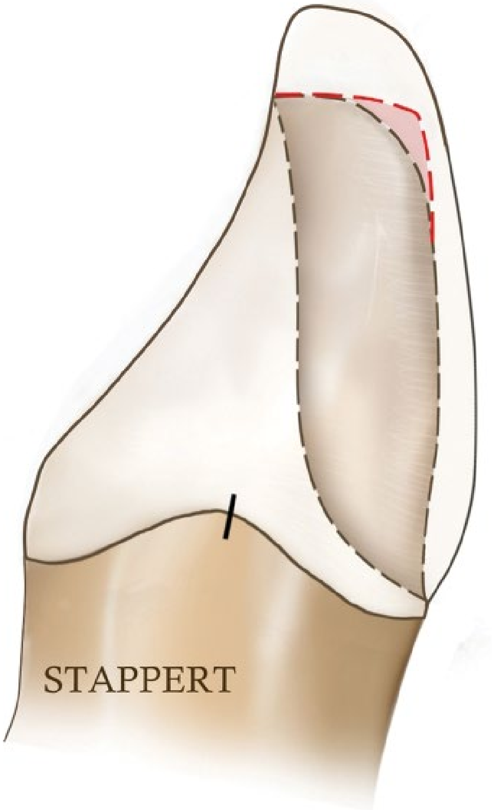

Figure 15.12 **(A)** This illustration shows the proper amount of horizontal and vertical reduction necessary for the average porcelain veneer on a lower incisor. Note that the incisal-facial line angle needs to be rounded to allow for sufficient ceramic thickness of the restoration. A sharp edge preparation (red area marked) will compromise the restoration and can lead to fracture. Interincisal clearance needs to be checked before final impression is performed.

might view the margin (Figure 15.12B–O). Another important consideration is to make sure your patient will agree to wear a nightguard to protect the veneers. This is essential for both maxillary and mandibular veneers. If not, then the patient must understand you will not be responsible for future fractured veneers.

To reduce or not

There are different opinions with regard to how much or how little the teeth need to be prepared—that is, reduced—before the application of porcelain veneers. Some clinicians argue that little or no reduction is required. Teeth that will require building out labially for better appearance are a good example of this. Clinicians at the opposite end of the spectrum argue for a full deep chamfer preparation on the labial aspect of the teeth that extends most or all of the way through the interproximal contact areas. Accordingly, it was reported that high variations in preparations for porcelain veneers exist in general dental practice.[64]

The most practical approach is to evaluate each patient, and indeed each tooth to be veneered, on the basis of (a) the thickness of the veneer needed for covering or reshaping, (b) the degree of anticipated retention of the veneer, considering the receptivity of the tooth to the bonding agent and placement of the veneer, and (c) recognition of how the increased thickness of the veneered tooth will change its appearance, structure, alignment, and function.

Obviously, the ideal would be a technique that requires no preparation and a veneer that is strong, attractive, and functional, with no subsequent adverse periodontal changes. However, that ideal is seldom the case. Most patients need to have about 50% of the labial and some proximal enamel removed in order not to overbuild the teeth being veneered.

Figure 15.12 **(B)** Pre-op smile picture. Patient is not happy with her smile because of the discolored teeth, irregular shape, and defective old restorations.

Figure 15.12 **(C)** Pre-op intraoral picture from frontal view. Notice heavy restorations on #8 and #9, old porcelain fused to metal (PFM) crown #10, and deep overbite.

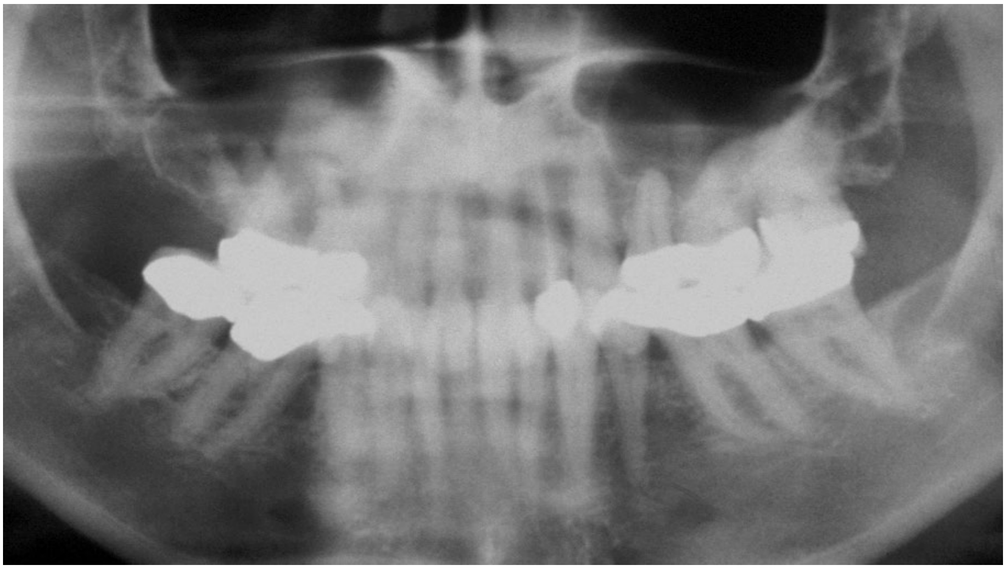

Figure 15.12 **(D)** Pre-op panoramic radiograph. Notice patient has a dental history with multiple restorations and endodontic treatment of tooth #10.

Figure 15.12 **(E)** Teeth #22–#27 show conservative veneer preparations from facial view. Notice #24 and #25 defect-oriented preparation technique due to previous restorations on distal aspects.

Figure 15.12 **(F)** Preparation design of mandibular lower dentition on master cast with dies from occlusal view.

Figure 15.12 **(G)** Wax-up from master casts that can be utilized as a mock-up to evaluate the function and esthetics. **(H)** Mock-up in the mouth utilizing wax-up made from the master casts. Patient has a better appreciation of the final outcome. Wax-up allows for intraoral minor modifications. **(I)** Post-op picture from frontal view: Final leucite reinforced IPS Empress upper and lower restorations after adhesive bonding 4 weeks after insertion.

Figure 15.12 **(J)** Post-op close-up picture of the upper anterior dentition: final restorations #7–#10 4 weeks after adhesive bonding.

Figure 15.12 **(K)** Post-op picture from close-up view: final IPS Empress restorations #22–#27 4 weeks after final insertion.

Figure 15.12 **(L)** Post-op final monolithic IPS Empress restorations in relaxed light smile position from a facial view.

Figure 15.12 **(M)** Post-op final monolithic IPS Empress restorations with wider smile display of upper and lower dentition.

Figure 15.12 **(N)** Facial image of the intermaxillary anterior upper and lower dentition *before* extended ceramic restorations.

Figure 15.12 **(O)** Facial image of the intermaxillary anterior upper and lower dentition *after* extended ceramic restorations were placed. Case courtesy of Study Group: Doris Zimmer and Christian Stappert.

When to consider reduction

Without reduction, the teeth will be larger and more labially positioned. (In lingually inclined teeth, this may be an advantage.) McLean[65] believes failure to remove proximal enamel can result in the finish line placed too far labially and encroachment on the embrasure areas, resulting in exposure of unsightly porcelain margins that may be difficult to finish. Proceeding without preparation will lead to not only distinct overcontouring at cervical and proximal tooth surfaces, but also to higher clinical failure rates as a result of gingival inflammation and secondary caries due to an increase in microbial plaque accumulation.[66]

1. Remove convexities and provide a path for insertion in those situations where either the incisal or the interproximal areas are to be included in the veneer.[67]
2. Provide space for adequate opaquing or heavier coloring. Darkly stained teeth often require more reduction for opaquing purposes. This will allow for a thicker, more opaque veneer.[50] For veneers on tetracycline-stained teeth, for example, the underlying tooth color will modify its shade dramatically. This is because, in most cases, the veneer is only 0.5 mm thick and rather translucent. As a result, the actual shade of the porcelain has only a nominal influence on the final color of the bonded veneer. By reducing the tooth, usually it will be possible to neutralize the underlying color and create the illusion of a normal tooth color by having the opaque incorporated into the veneer itself.[68] Also, by making room for the application of opaquing layers under the veneer, additional opaquing can be obtained at the cementation appointment by using resin opaquers.
3. Provide a definite seat to help position the veneer during placement.
4. Prepare a receptive enamel surface for etching and bonding the veneer.
5. Allow for a smoother transition from the veneer to the tooth surface, enabling the patient to more easily keep it plaque-free.

Contraindications to reduction include consideration of the following points.

1. The size of the pulp. If young individuals or others with large pulps require laminating, consider an alternative to enamel reduction, especially if there is any indication of irreversible sensitivity by reducing the thickness of the enamel. One alternative is building out each of the teeth slightly to avoid preparation. However, this usually requires including at least 8–10 teeth for a natural result.
2. The patient's psychological state and feelings about tooth reduction or veneers. If the patient is apprehensive and unsure, then it is wise to do no reduction. Then if the patient becomes dissatisfied with the veneer or the slightly overbuilt look, the option will be removing the porcelain veneer and repolishing the enamel, thus returning the patient to a semblance of their pre-veneer state.

Tip: make sure you take precaution to record the exact amount of overbuilding you intend to do. This should include a set of pre- and posttreatment study casts and photographs. The photographs should include incisal views as well so you can clearly show just how much you have built out labially. Also, use of a clear vacuform matrix with both cervical and incisal holes placed will allow you to make sure you have adequate reduction (see Figure 15.18H, below).

If reducing, how much?

As a general principle, the enamel should be reduced just as much as necessary to facilitate the placement of an esthetic restoration. Ideally, one would like to remove the same amount of enamel that will eventually be replaced by the veneer and bonding composite resin.

Decisions about reduction need to take into account the relative position of the tooth in the arch. For example, in treating a crowded or rotated tooth or a tooth in labioversion, it may be advantageous to first bring the offending tooth into alignment with the rest of the arch by reducing its labial contour through cosmetic contouring. The use of mock-ups, followed by a wax model, esthetic pre-evaluative temporaries, and silicone index, provides the best esthetic, phonetic, and functional assessment of necessary tooth preparation for veneers.[69]

To facilitate placement of interproximal extensions, the margin of the porcelain veneer should be hidden within the embrasure area. Proper interproximal extension will provide additional stability and retention, due to the wraparound effect. Yet, it should be considered that placing the finish line in the proximal contact area creates a higher risk of interdental decay, especially with patients of compromised dental hygiene.[70]

Another factor to consider in placement of the interproximal margins is the size of the interdental space. If there is an unsightly gap that needs to be closed, the exact placement of the interproximal margin will vary depending upon the size of the space. The larger the space, the further mesiolingually or distolingually the margin will need to be extended. Otherwise, the resultant contact areas will be bulky and potential food traps.

Decisions about reduction need to take into account the need for a good seal. If at all possible, porcelain veneers should be bonded mainly to enamel,[65] so ideally margins of the preparation should have enough enamel left to ensure an adequate seal. The gingival finish line should be epigingival or ≤0.5 mm subgingival to the gingival margin. Unfortunately, esthetics require any tooth discoloration to be masked, may frequent make it necessary to locate the veneer margins subgingivally, terminating on either dentin or cementum. It is important to remember that while it is sometimes necessary to terminate the veneer on dentin, dentin bonding has at least two disadvantages: it provides less bond strength than enamel bonding, and it is a less effective seal. In general, this is not necessarily a problem since the reliability of dentin bonding has significantly improved.[71] Yet, it is very difficult to achieve ideal dry bonding conditions with rubber dam insulation at subgingival veneer margins. In cases where the preparation margins are expected to be positioned deeper than 0.5 mm subgingivally, an initial surgical crown-lengthening procedure may be indicated.

Reduction considerations should also include the color of the teeth to be veneered. Darkly stained teeth often require more reduction for opaquing purposes. Reid[72] proposed neutralization and use of opaquers at cementation. However, it is the easiest and best solution for the ceramist to build opacity into the veneer itself, thereby eliminating the need to experiment on the tooth for maximum opacity. With tetracycline stains, for example, the finish line must be placed subgingivally to hide the dark discoloration that tends to show through marginal tissue. Tetracycline stains are usually darkest in the cervical region where there is thinner enamel covering the stained dentin, making sufficient enamel reduction more difficult. The tooth also appears darker as the enamel is removed because the underlying stained dentin is more exposed. Actually any tooth in which the cervical area is darker than the intended color of the veneer might require a subgingival margin placement to avoid a visible color change between the new veneer and the existing root color. If this outcome is expected, make sure the patient signs an informed consent documenting acceptance of the intended treatment.

The best alternative for deeply stained teeth is the use of more opaque ceramic materials than porcelain. Monolithic lithium-disilicate offers higher opacity for pressable (e.g. IPS e.max Press)[21,25,73] and CAD/CAM fabricated (e.g. Emax CAD)[74,75] veneer restorations. In extreme discoloration cases, highly opaque zirconium oxide veneers might be an alternative to crowning of the tooth (Figure 15.13A–U).

The last, but important, consideration is the ceramist's needs in terms of fabricating an accurately fitting veneer. It is difficult to work with a porcelain thickness much less than 0.4 mm or to create a veneer that will adjust to a feather edge. This means that the ceramist should be allowed to work with veneers no thinner than 0.4, and a preferable clear chamfer margin or butt joint ending for extended veneer preparations. The latter is significant, since new high strength materials for veneers, mainly glass-ceramics are fabricated by pressing or CAD/CAM, which creates either rounded restoration margins (pressed) or higher risk of chipping of too thin margins by cutting tools (CAD/CAM). A good example of a patient who requires average reduction is seen in Figure 15.14A.

Figure 15.13 **(A)** Pre-op smile picture: patient is not happy with her old restorations and the diastema between #8 and #9.

Figure 15.13 **(B)** Pre-op smile picture: profile view.

Figure 15.13 **(C)** Pre-op intraoral picture from frontal view. Notice dark gingival color around the cervical areas #8, #9, and #10 due to old PFM restorations. Multiple insufficient composite fillings are present on adjacent anterior teeth.

Figure 15.13 **(D)** Pre-op intraoral picture from occlusal view.

Figure 15.13 **(E)** Diagnostic and functional wax-up to fabricate all ceramic e.max Press restorations from labial aspect.

Figure 15.13 **(F)** Diagnostic and functional wax-up from palatal aspect. The wax-up was duplicated and a preparation guide produced by the dental technician.

Figure 15.13 **(G)** Teeth #8, 9 and 10 after removing the old PFM crowns. Notice that the dark gingival discoloration around cervical #8 and #9 disappeared immediately.

Figure 15.13 **(H)** Teeth #8, #9 and #10 after removing the old core build-up material while maintaining the old prefabricated posts. Attempt to remove the previous posts failed due to increased risk of root fracture.

Figure 15.13 **(I)** Teeth #6–#11 show final preparation. Notice #8, #9, and #10 have new opaque core build-up material to mask the dark stump shade.

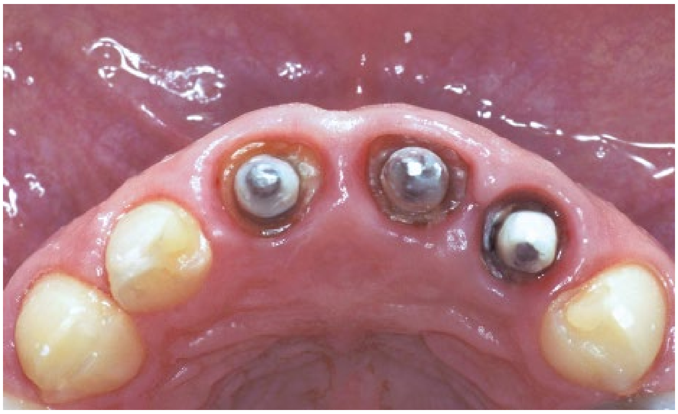

Figure 15.13 **(J)** Teeth #6–#11 demonstrate final preparation from occlusal view.

Figure 15.13 **(K)** Master cast with dies of teeth #6–#11. Notice teeth #7 and #11 defect-oriented preparation design due to position of old restorations. All defects needed to be covered by the new ceramic restorations.

Figure 15.13 **(L)** Teeth #6–#11 show final restorations on master cast from palatal view. Notice tooth #7 and #11 defect-oriented restorations.

Figure 15.13 **(M)** Final e.max Press restorations on master cast for teeth #6–#11 from labial view.

Figure 15.13 **(N)** Teeth #8, #9, and #10 final lithium-disilicate crown restorations. An opaque liner was applied to the intaglio crown surfaces to mask the dark post and core structure and discolored stump shade.

Figure 15.13 **(O)** Final restorations #6, #7, and #11 from labial view. Pay attention to the variation of ceramic thicknesses due to the monolithic application of the press ceramic.

Figure 15.13 **(P)** The restorations #6, #7, and #11 do not require any underlying coping. Therefore, preparation can be minimal invasive and defect-oriented (intaglio surface view).

Figure 15.13 **(Q)** Post-op picture: final ceramic restorations 4 weeks after adhesive bonding from lateral view. **(R)** Six months post-op picture: final press ceramic restorations in relation to smile and lip line from frontal view. **(S)** Six months post-op smile picture from lateral profile view. The female patient was very pleased with the outcome. The patient was restored in 2001, and represents one of the first monolithic lithium-disilicate cases documented.

Figure 15.13 **(T)** Initial retracted view of the patient's upper and lower dentition (before).

Figure 15.13 **(U)** Follow-up photo of the patient's upper and lower dentition 3 years post-op. Based on present recall results, the restorations are still in place and in full function.

Classic veneer preparation technique

The Goldstein veneer preparation kit (LVS; Brasseler USA) (Figure 15.14B) provides a rapid method of measured reduction for porcelain veneers. First the clinician must decide on the required amount of reduction, using the considerations given previously. In most instances the needed reduction will be 0.5 mm, obtained by using the LVS-1. Small teeth such as the mandibular incisors where the thickness of enamel is considerably less may only require 0.3 mm reduction and you would use LVS-2. The appropriate LVS diamond depth cutter is selected and gently drawn across the labial surface of the tooth from mesial to distal. This will develop the depth cuts as horizontal grooves, leaving a raised strip of enamel in between (Figure 15.14C and D). The depth of the cut is limited by the instrument itself. The remaining enamel is then reduced to the depth of these initial cuts, using a coarse diamond (LVS-3 or -4). The resulting rough enamel surface facilitates retention and refraction of the light reflected back out through the veneer. At the marginal areas, however, it is desirable to use a finer-grit diamond which will create a definitive polished finish line to enhance the seal at the periphery. Thus, the special two-grit LVS-3 or -4 is an ideal instrument to accomplish these tasks (Figure 15.14E and F).

The basic preparation should be completed with only the finishing of the final margins remaining. If the margin is planned to be placed subgingivally, it is best to begin by displacing the tissue for 10 min with retraction cord saturated with a hemostatic agent. Once this step is completed it will be much easier to complete the final margin using the LVS-3 (Figure 15.14G–I). If the teeth are extremely dark, consider using a deep chamfer or modified shoulder. This will give the technician extra depth, and thus extra veneer thickness, to mask the grayness that can show through the gingiva, especially if the gingival tissue is thin and transparent. An initial impression and cast will allow for corrections before the final impression is taken (Figure 15.14 J and K).

Novel extended veneer preparation technique

Both, the overlapping incisal edge preparation (modified overlap design; Stappert 1999) and the full veneer preparation design (Stappert 1999) include the proximal tooth surfaces, but differ in palatal extension. The extent of tooth structure defect and the functional and esthetic objectives of the therapy determine the choice of preparation design. The extended veneer preparation kits combine classic crown burs with veneer burs. They are performed initially with rough diamond burs (80 μm)

Figure 15.14 **(A)** Matching the discolored right central incisor to the left central presents one of the most difficult challenges in dentistry.

Figure 15.14 **(B)** This veneer system (Brasseler USA) includes four burs to prepare the tooth and four to finish the veneer.

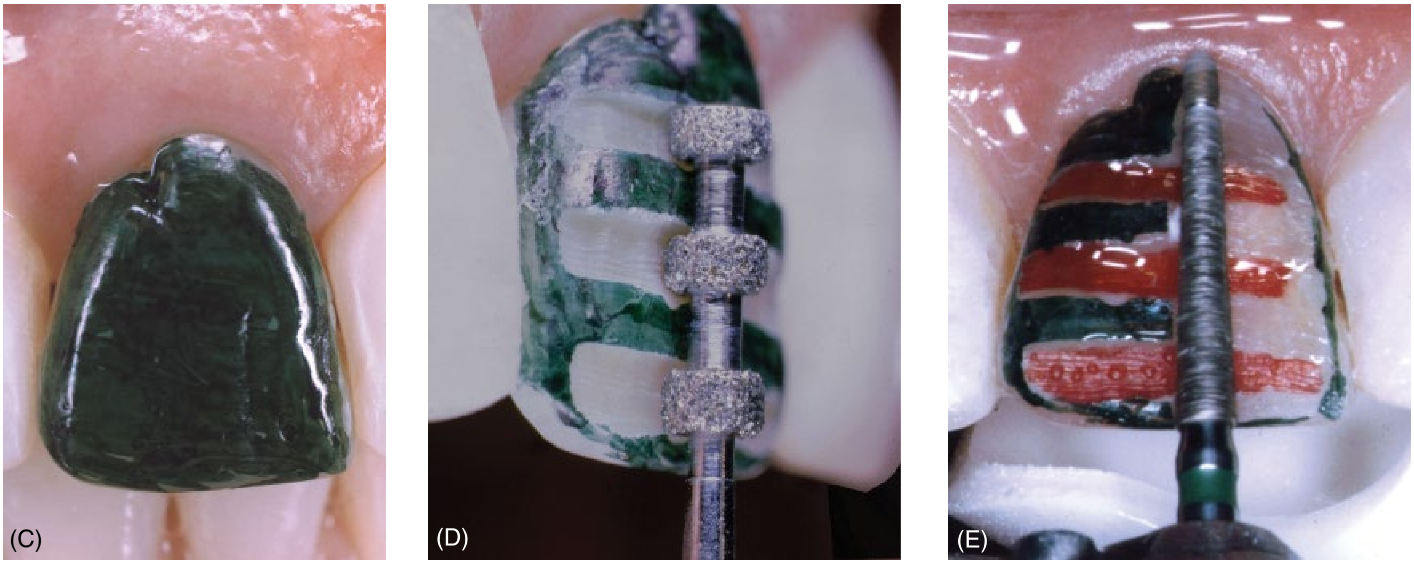

Figure 15.14 **(C)** The discolored incisor is painted green to help guide the depth cuts. **(D)** The special three-tier extra-coarse diamond depth cutter (Brasseler USA) comes in 0.5 mm (LVS-1) and 0.3 mm (LVS-2) thicknesses and is so efficient that usually one sweep across the labial surface completes the depth cut. Since the veneer will be approximately 0.6 mm in thickness (up to 0.8 mm in darkly stained teeth), the 0.5 mm bur will generally be the depth cutter of choice unless overbuilding is desired. **(E)** After completing the depth cut (marked in red for illustrative purposes only), the remainder of the preparation is completed with the two-grit diamond. The body of the diamond contains extra-coarse grit, which leaves a rough finish on the preparation to maximize veneer retention.

(e.g. #837KR.314.012, #878.204.012; Brasseler USA) followed by finer shape-congruent diamond burs (30–40 µm) (e.g. #8837KR.314.012, #8878.204.012; Brasseler USA) for the finishing procedure. The extent of labial and incisal reduction is predetermined for both preparation forms by using a silicone key based on an esthetic functional wax-up. The labial surface is axially reduced by 0.3–0.5 mm. Cervically, a shallow chamfer (0.5 mm) is prepared epigingival. The proximal reduction is 0.5–0.7 mm. The incisal edge is shortened by a minimum of 0.5–1.5 mm for both preparation forms (e.g. #837KR.314.012; Brasseler USA), depending on the defect size. For the overlapping incisal edge preparation (overlap veneer) the incisal edge is extensively shortened and slightly beveled towards the labial aspect. The angle between labial surface and incisal platform is approximately 110°. On the palatal aspect, a right-angled contour between the incisal and the palatal surface is achieved (butt joint). The palatal centric contact point of all overlap veneers remains on the natural tooth structure. Full veneer restorations differ by preparing an extensive 0.5–0.7 mm deep rounded shoulder in the palatal area. Extension of palatal preparation is

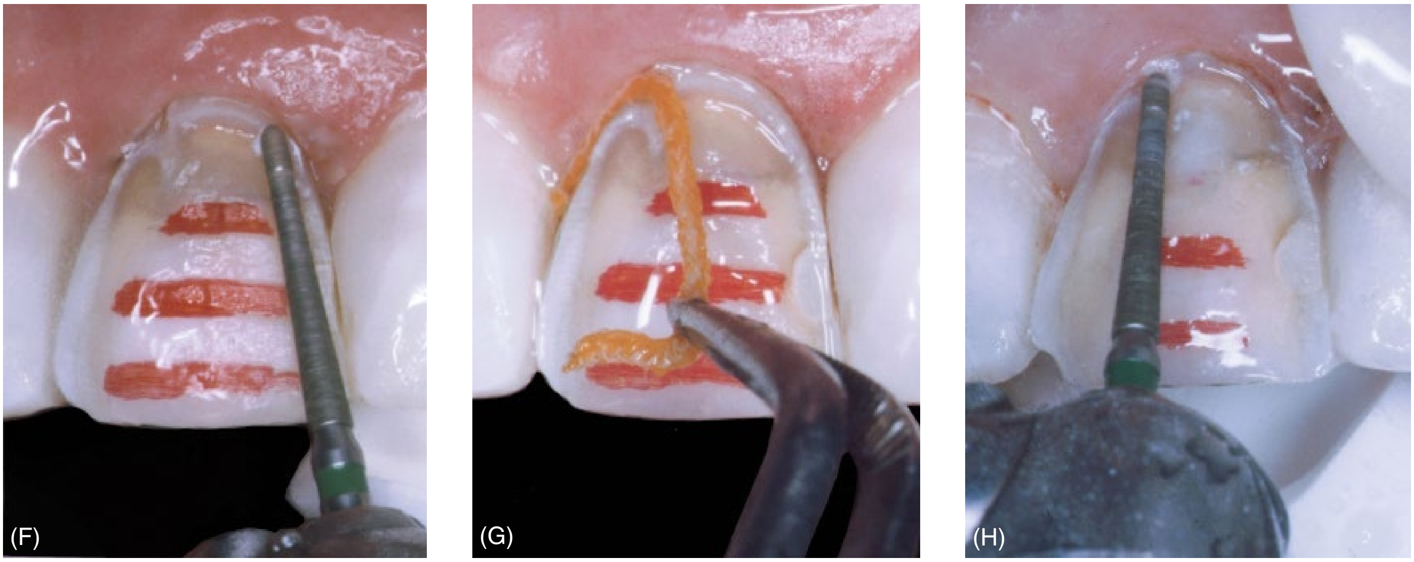

Figure 15.14 **(F)** The tip of the two-grit diamond LVS-3 or -4 (Brasseler USA) has a fine grit for marginal finishing. Note how close the preparation was finished to the base of the depth cut as shown by the remaining illustrative red markings. **(G)** Gingival displacement cord is carefully removed after remaining in the sulcus for approximately 10 min. **(H)** With the tissue displaced, the gingival margin can now be placed just into the gingival sulcus.

Figure 15.14 **(I)** When using the foil technique for veneer construction (see section on Foil versus refractory die), slight separation between the teeth is obtained by using a diamond strips. The proximal surfaces can then be finished with a sandpaper strip.

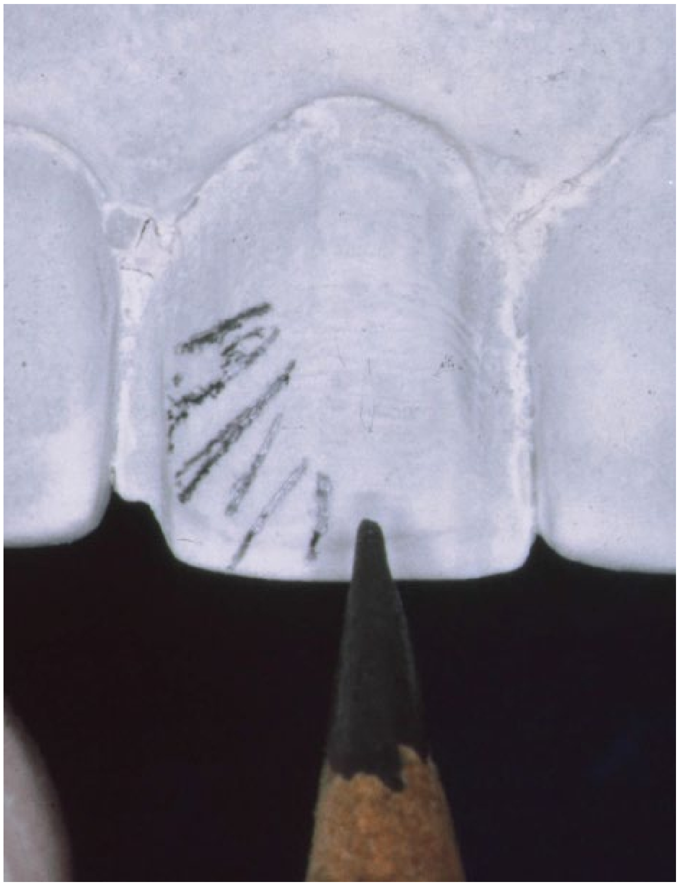

Figure 15.14 **(J)** An initial impression is made of the completed preparations and poured in quick-set plaster or stone to carefully analyze each tooth. Here the distal-labial aspect appears to need slightly more reduction.

Figure 15.14 **(K)** The incisal view is especially helpful in analyzing whether or not more tooth reduction is necessary. Tilting the study cast from buccal to incisal and mesial to distal allows you to verify that you have not left any sharp line angles.

generally limited to the cingulum area; however, an extension is justified with large tooth defects. Palatal centric contact points on the ceramic surface are avoided, when applicable. All preparation margins should be restricted by enamel. Labial epigingival preparation and controlled preparation depth enable adhesive cementation mainly to enamel. All inner line angles should be rounded. Preparation margins are not beveled. Minimum material thickness (axially at least 0.4 mm and incisally 1.5 mm), should be consistently maintained during preparation. Incisal ceramic thickness of 1.5–2.5 mm is ensured for overlap and full veneer restorations. (See Figure 15.13A–U, and Figures 15.18A–R and 19A–P below.)

Impressions

Although it may be possible to take an impression without further tissue displacement, it is preferable to place a new cotton tissue displacement cord to make certain all margins will be properly recorded. Approximately 5 min should be sufficient to gain enough tissue displacement to capture the "lip" or actual margin plus a bit of tooth structure gingival to the margin. Obtaining an impression with this extra amount of uncut tooth structure guarantees that the technician will be better able to identify the margins and follow the correct tooth contour.

Basically, there are two choices regarding impression types: digital or conventional.

No doubt, most convenient for the patient would be digital, since most patients prefer not having impressions trays in their mouth for several minutes. Plus, scanning techniques have become both accurate and time saving, especially in extended patient cases which often require taking backup impressions chair side.

Digital impression

Intraoral chair side scanners (e.g. CEREC-Sirona Dental Systems, Lava COS-3 M Dental ESPE, iTero, TRIOS-3Shape Dental) allow digital impressions to be taken, yet still the basic principles and preparations of conventional impressions must be followed. Dry field and clear margin with sufficient soft tissue retraction are critical. CAD/CAM systems (such as NobelProcera, CEREC, Lava 3 M) utilize the digital scanning data to fabricate the final restorations directly, whereas other systems offer the option to produce a patient master cast based on the digital impression, which allows a dental technichian to generate restorations in a conventional way or to combine both methods.

Conventional impression

Materials can vary from hydrocolloid, polysulfide, polyethers to polyvinyl siloxane (PVS):

- **Hydrocolloid** impression material is highly hydrophilic. Therefore, moderate wetness during the impression does not reduce the impression accuracy. Yet, hydrocolloid impressions tend to tear into unprepared undercut areas below or between the contact areas. If this material is your first choice, sending off two impressions to fabricate two verification models is recommended. In some cases, it might be required to block out undercuts before taking the impression from the lingual aspect.
- **Polysulfide** impression materials are generally low to moderately hydrophilic and can generate an accurate impression. They reproduce excellent details, but their dimensional stability is only fair. The material is not very rigid; therefore the impressions are easier to remove than polyether or PVS impressions.[76–80] They can capture subgingival margins upon impression without tearing during removal, which is an advantage when compared to PVS. However, polyethers and silicones offer better elastic recovery and accuracy.
- **Polyether** impression materials are moderately hydrophilic; thus they can capture accurate impressions in the presence of some localized saliva or blood. In general, a dry field is required to make an acceptable impression. They produce impressions with excellent details and their dimensional stability allows multiple pours of accurate casts for 1–2 weeks, if there is no tearing of the impression. They are rigid and more difficult to remove than PVS, so cases with short teeth are the easiest to impress with polyether.[79,81] They allow clinicians to get good subgingival detail on removal due to their high tear strength. Common commercial examples are Impregum and Permadyne (3 M ESPE).

Figure 15.14 **(L)** The final preparation of this badly discolored central incisor has been completed for the porcelain veneer and an impression will be performed.

- **Polyvinyl siloxane (PVS) or addition silicone** impression materials can be either hydrophobic or hyrophillic. If hydrophobic, moisture presence from saliva or blood can interfere with impression accuracy.[82] This is why the newer hydrophilic impression materials may be easier to use. PVS has the best elastic recovery of all available impression materials.[83,84] It has an excellent ability to reproduce detail and its dimensional stability allows multiple pours of accurate casts for several weeks.[85,86] The material is moderately rigid but less rigid than polyethers. It has good tear strength and it is easier to remove than polyether materials (Figure 15.14 L–N).[83,86]

The choice of impression materials depends mainly on the subjective choice of the operator. It is based on personal preferences, handling, and the impression techniques used. In recent years, dentists have tended to use PVS and polyethers because of their improved physical and mechanical properties. The injection method for PVS is probably the cleanest and easiest conventional impression technique.

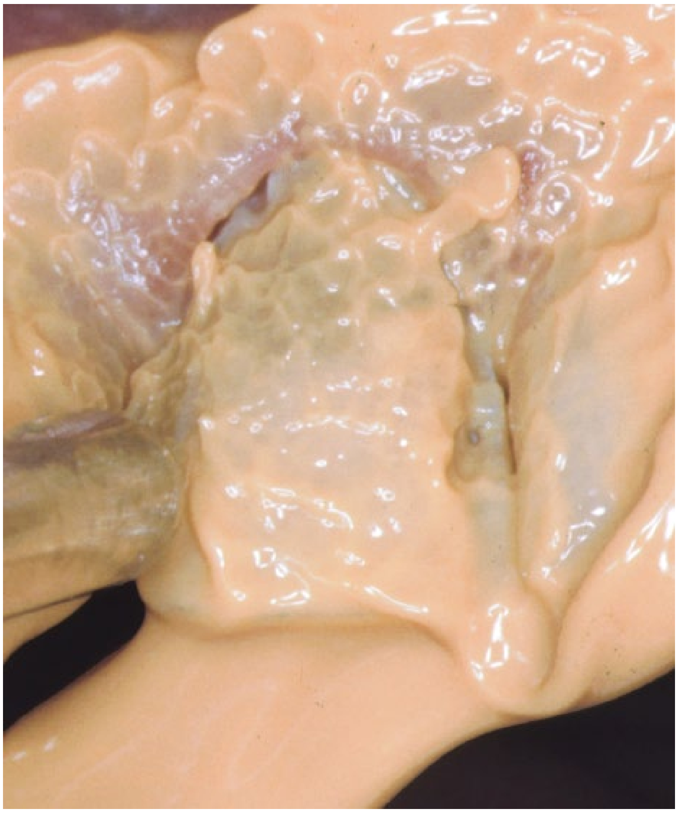

Figure 15.14 **(M)** Polyvinyl siloxane (PVS) is an excellent material for a final impression. Here, the syringe material has been placed and an air stream gently spreads the material so that you can be assured that the entire preparation has been covered and that no air pockets or bubbles exist.

Figure 15.14 **(N)** Occlusal registration is also made with polyvinyl siloxane paste (Regisil PB, Caulk/Dentsply).

Temporaries

Temporaries for classic veneers usually are unnecessary because in many situations only half of the enamel surface is removed, not exposing the dentinal tubules. There should be little or no sensitivity and only minimal esthetic compromise. Temporaries also may cause gingival inflammation unless carefully trimmed and polished.

Situations that require temporaries include those Class 4–6 preparations in which (a) the teeth have been extensively reduced, particularly if dentin is exposed, and/or sensitivity exists, (b) open contacts have been created that could allow movement of the teeth, or (c) the patient finds that the reduced teeth are too esthetically compromised for comfort (see Figure 15.14 L). In these situations, temporaries can be constructed through one of five methods: (1) direct composite veneers, involving the placement of a composite restorative material directly on the non-etched surface of the prepared tooth; (2) direct composite veneers, involving the placement of a composite restorative material directly on a 1–2 mm etched surface of the prepared tooth (Figure 15.14O–S); (3) direct

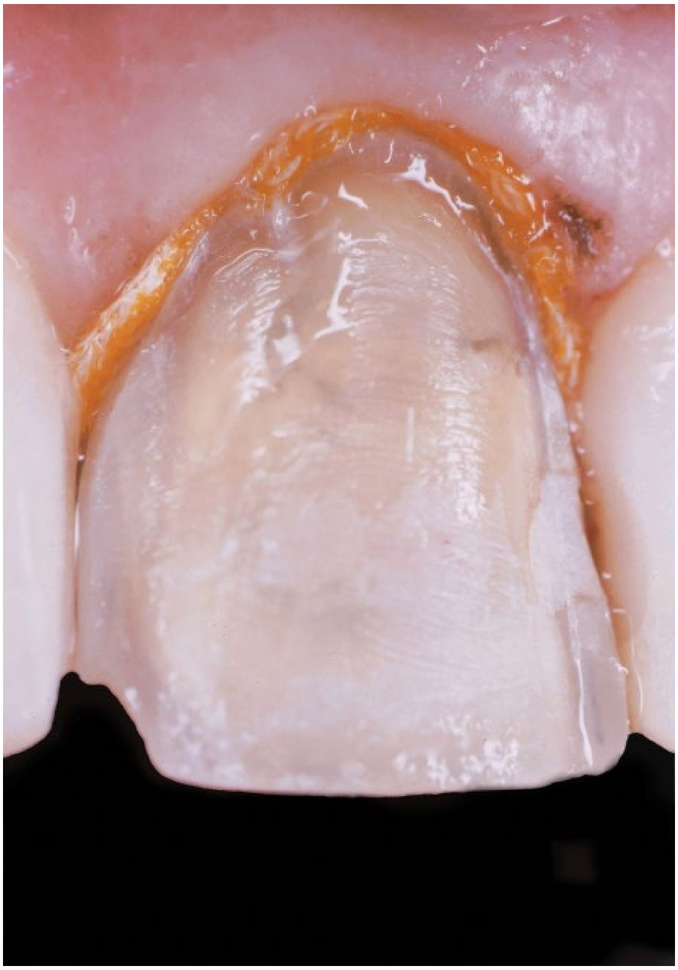

Figure 15.14 **(O)** Tissue displacement with retraction cord for 3–5 min will make it easier to create a more accurate gingival margin for the interim restoration.

Figure 15.14 **(P)** A direct composite veneer can be used as temporary restoration. First the tooth can be isolated with glycerin gel and point etching can be performed facially to bond the restoration temporarily.

composite veneers using a vacuform or silicone matrix made on a preoperative plaster model of the patient's mouth, or on the duplicate wax-up model if changes are to be made before esthetics or functionality; (4) direct acrylic veneers in which methyl methacrylate self-cure acrylic is mixed into a soupy state, flowed into the buccal aspects of a vacuform matrix or silicone matrix and allowed to reach the "doughy" stage of curing, and then manipulated into position over the prepared teeth; and (5) indirect composite/acrylic temporaries, which are fabricated in the laboratory on a model of the prepared teeth (Figure 15.T–Z).

Classic porcelain veneers: laboratory procedures

Making a model

A master cast that accurately reproduces what exists in the mouth is the necessary next step in the fabrication of veneers. The laboratory veneer fabrication technique, die or foil, may determine the type of impression and the type of model.

Foil versus refractory die

There are two basic techniques for fabrication of porcelain veneers, both of which can produce excellent results. In the platinum foil technique (Figure 15.15A–G), the more conventional of the two methods, porcelain is fired over a 0.0254 mm thick platinum foil matrix. This technique uses individual removable dies on a master cast poured in conventional die stone. Good delineation of each tooth is assured if the contact points in the mouth are modified by stripping with an ultrafine diamond strip (Brasseler USA or, Premier Dental Products) (see Figure 15.14 L).

In the refractory die technique, porcelain is fired directly on a refractory die material. This reduces the cost of construction by eliminating the need for platinum foil. It also avoids some of the shrinkage and distortion that can occur with the more technique-sensitive foil method.

It may be prudent in the refractory die technique to block out lingual-interproximal undercut areas with orthodontic wax before taking the impression. Never do this if the foil technique is being used, however, as the technician will not be able to section the model. Porcelain is an excellent material in terms of color because the amount of opaqueness can be controlled, through both mixture of the ceramic powder components and depth of the veneer.[50] In tetracycline-stained teeth, for example, the clinician usually will neutralize the underlying color and then create the illusion of normal tooth color by having the opaque incorporated into the porcelain veneer, using the

Figure 15.14 **(Q)** The temporary composite resin veneer is carefully shaped with a Goldstein #3 anodized aluminum Flexi-Thin instrument (Hu-Friedy).

Figure 15.14 **(R)** Polymerization should be completed from both the labial and lingual aspects.

composite cement for additional help if needed. Despite the attractive teeth that can be achieved this way, it is important to remember that the actual shade of the porcelain has only nominal bearing on the bonded final veneer. This is because in most cases the veneer is only 0.5 mm thick and rather translucent. The underlying tooth color and resin can modify its shade dramatically. Fortunately, several systems for opaquing the dark stain exist, one involving the use of opaque powder, another a complex layering.[68,87]

The porcelain veneers are then constructed in the ceramic laboratory, following the prescription of form, fit, and color. Although most any porcelain can be baked and etched for a veneer, some of the current products have been specifically developed for this procedure. They are especially formulated to have increased amount of opacifiers and metallic oxide pigments so that within the 0.5 mm thickness of a veneer, intricate characterization and color effects can be developed.

Pressable ceramic veneers: laboratory procedures

A master cast that accurately reproduces the preparation margins and contact points in the mouth is necessary in the fabrication of glass-ceramic veneers.

Extended veneer restorations can be made of the leucite-reinforced glass-ceramic IPS Empress or lithium-disilicate reinforced e.max Press (Ivoclar Vivadent). This pressable ceramic is processed according to the IPS Empress layering technique using IPS Empress conventional lost-wax method following the manufacturer's instructions. After an ideal wax-up of the extended veneer restoration, the surface is cut back by 0.2–0.4 mm to allow for a layer of veneering porcelain. The wax-up is then embedded in an investment cylinder. The glass-ceramic ingot is pressed into the pre-heated hollow mold (furnace EP 500, Ivoclar Vivadent) at 910–920 °C. Restorations are removed from the molds and cleaned with a steam jet cleaner (EV1 SJ, Silfradent Sync.). Manufacturing individually layered veneer restorations is enabled by fusing IPS Empress dentin, incisal, and transparent veneering porcelain, as well as the IPS Empress glaze material (Ivoclar Vivadent) onto the ceramic core structure (ceramic furnace Programat P90/P95; Ivoclar Vivadent).

Minor corrections of the glazed restorations during trying-in are made at the chair side. Changes to the incisal and labial surfaces can be repolished to a high gloss using ceramic silicone polishers (Dialite Polishing Set Ceramic, Gebr. Brasseler). Veneers requiring major corrections or needing complete revisions will be sent to the dental laboratory. Those restorations receive entirely new coats of ceramic glaze.

Veneers can be created as full contour monolithic structure as well, without cut back of the wax-up for a layer of veneering porcelain. In this case, the level of esthetic individualization and

Figure 15.14 **(S)** Since the temporary veneer restoration is initially contoured close to the desired final form, only slight finishing with a 30-blade carbide (ET3UF, Brasseler USA) is necessary. Additional polishing can be done with a series of impregnated discs (Soflex [3 M], Cosmedent, or Brasseler USA).

correction is limited to superficial staining and ceramic glazing procedures. Special emphasis must be given to the right choice of ceramic ingot, matching the right shade and level of translucency of the residual dentition. In many cases, monolithic glass-ceramic veneers can offer a respectable esthetic result, especially when the veneer restorations remain fairly thin (≈0.5 mm) and a chameleon effect is achieved. Yet, once the veneer has been permanently adhesively bonded, incisal or occlusal adjustments need to be avoided, since the superficial staining would be removed at these locations.

The most common pressable glass-ceramic material choices are outlined below.

IPS Empress

In 1990, the high-strength glass-ceramic IPS Empress (Ivoclar) was introduced. It is pressed in a hot, ductile state into a hollow mold. Analogous to Dicor, the restoration is fashioned with the lost-wax technique, and the final coloration is achieved using the staining or the layering technique. In a feldspar glass matrix, leucite crystals with an average diameter of 3–5 µm are homogeneously distributed in a high concentration (40–50 %). Due to the higher thermal expansion coefficient of the leucite crystals, the glass matrix is subjected to compressive stress during cooling, which results in an increase of flexural strength.[88] Data published so far on the suitability of IPS Empress for adhesively inserted inlays, onlays, partial crowns, and veneers allow the conclusion that the procedure is clinically safe.[89] Initially good clinical experiences with adhesively fixed crowns in the posterior tooth area were modified by failure rates of up to 12 % after 6 years.[90]

IPS e.max Press

This ceramic belongs, together with Empress 2, to the group of lithium disilicate glass-ceramics ($2SiO_2$-Li_2O). IPS e.max Press consists of a high-strength lithium disilicate framework

Figure 15.14 **(T)** While there are many fine porcelain bonding kits available, this is an example of an all-inclusive kit (Choice 2, Bisco).

Figure 15.14 **(U)** The previously selected cement shade used as try-in paste shows the color is slightly too light. A darker tint or opaquer added to the bonding cement is used to adjust the color appropriately.

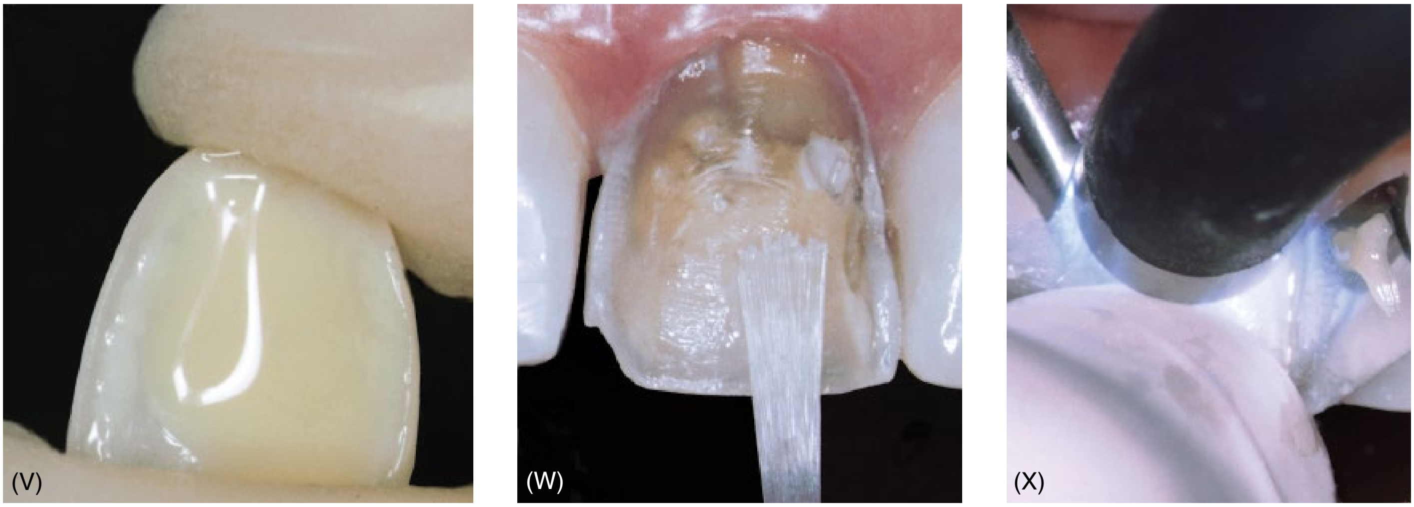

Figure 15.14 **(V)** After etching and silanizing the interior surface of the porcelain veneer, the tinted cement is added. **(W)** The prepared tooth is cleaned with coarse pumice and etched with phosphoric acid, treated with primer and adhesive, before the bonding agent is applied. **(X)** The composite filled veneer is gently pressed to place, and held there with a gloved finger while polymerizing the incisal edge with the light for 5–8 s (stabilizing the veneer in place). Excess cement can be removed with a soft brush or foam pellets before final light curing.

Figure 15.14 **(Y)** Interproximal excess is removed with the sickle end of the Novatech 12 (Hu-Friedy) and the veneer is then completely cured for 40 s labially and 40 s lingually. Note the ultrathin separation strips.

Figure 15.14 **(Z)** All remaining composite resin cement excess is then removed with the LVS-5 30-blade carbide bur. If contouring is required it can easily be accomplished with the LVS-6, -7, or -8 burs.

material, which may, if required, be veneered with a glass-ceramic containing fluoroapatite. IPS e.max Press is composed of SIO_2 (>57 weight percent), Li_2O, K_2O, MgO, ZnO_2, AL_2O_3, P_2O_5, and other oxides. The main crystalline phase of lithium disilicate consists of lengthy crystals of 0.5–4 µm, which are added to the glass in suitable grinding fineness. According to the manufacturer's indications, the microstructure of IPS e.max Press shall prevent crack propagation. IPS e.max Press resembles the Empress 2 ceramic both in its mechanical and its physical properties. The fabrication procedure of IPS e.max Press corresponds to that of the IPS Empress system. For pressing, the specific furnaces EP 500, EP 600 or EP 600 Combi (Ivoclar Vivadent) are used. The ceramic is pressed in viscous form into hollow molds at 915–930 °C using pneumatic pressers.

By a new fabrication process, the homogeneity of the ceramic ingots seems to be optimized, increasing the strength up to 400 MPa. This strength allows the use of single-tooth monolithic lithium disilicate restorations in the anterior and molar tooth areas.

IPS e.max Press comes as glass-ceramic blanks, which are available in different degrees of opacity. Ingots of medium opacity are suitable for fabrication of restorations on vital or slightly discolored stumps. Ingots of high opacity are used for fabrication

Figure 15.14 **(Z1)** Pre-op facial view: comparison of discolored tooth #8 and healthy tooth #9 reveal a substantial esthetic compromise.

Figure 15.14 **(Z2)** Post-op facial view: note the closely matched result and healthy tissue response despite the light subgingival margin.

Figure 15.14 **(Z3)** Smile design and tissue conditions 10 years post veneer treatment of tooth #8.

of crowns on nonvital stumps or for coverage of posts and cores made of metal. The tooth-colored, esthetic lithium disilicate glass-ceramic restorations can be individually veneered with the glass-ceramic IPS e.max Ceram. Individualization is attained by staining and subsequent glaze firing.

Placement of veneers

Try-in

Before the veneers are bonded into place (see Figure 15.14 T–Z3), it is important to go through a try-in stage (see Figure 15.14 T and U), which is a three-phase process:

1. Check the intimate adaptation of each individual porcelain veneer to the prepared tooth surface. The teeth should first be cleaned with a slurry of fine flour of pumice that contains no oils or fluoride. Next, use a fine composite finishing strip to clean the contact areas. Then each of the veneers is tried in individually, beginning with the most distal veneer, with the margins checked carefully. (It may be useful to place a drop of glycerin or water on the etched surface to facilitate temporary adhesion of the veneer to the tooth surface.) If the veneer does not go into place immediately, check for any undercuts and contact point impingements and adjust with a 15 μm diamond bur until it seats easily.

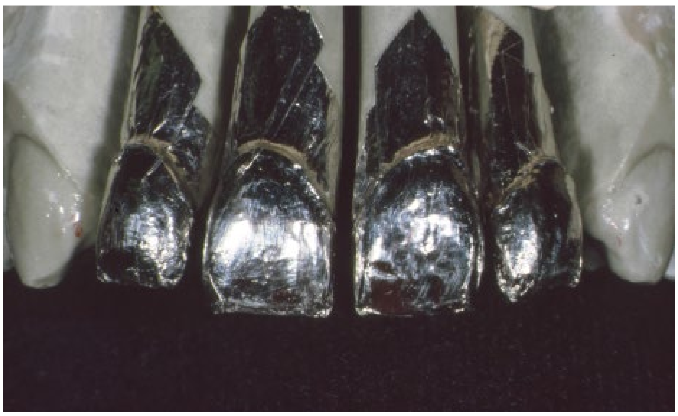

Figure 15.15 **(A)** Four veneers are being constructed to help close multiple diastemas. Here platinum foil is adapted to each individual tooth on the master model.

Figure 15.15 **(B)** The body porcelain is baked and this initial layer is thinned to outline the margins and surfaces on which the ensuing layers of porcelain will be built.

Figure 15.15 **(C)** The yellow build-up represents the cervical color blended with opacious dentin.

Figure 15.15 **(D)** The orange red layer is the body color. After completing the build-up, the incisal area is cut back for incisal porcelain placement.

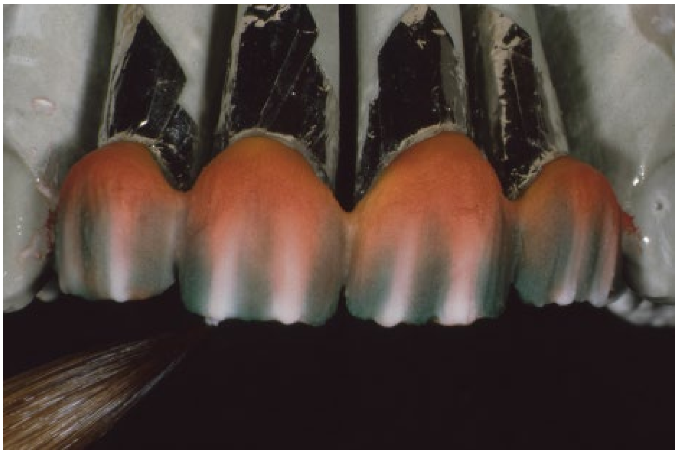

Figure 15.15 **(E)** The white color represents translucent blended porcelain and is placed between the more opaquely colored mamelons.

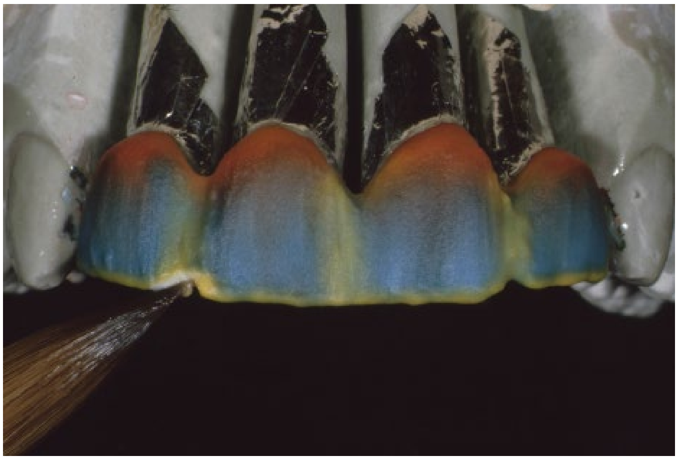

Figure 15.15 **(F)** Finally, the blue represents the outer layer, a blend of 50% translucent and 50% incisal color. The yellow creates the "halo" effect and is a 50% mixture of dentin and incisal porcelains.

Figure 15.15 **(G)** The finished veneers on the master model with no foil. Reproduced with permission of Pinhas Adar.

Figure 15.16 **(A)** These four porcelain veneers have been etched and are ready for try-in.

Figure 15.16 **(B)** Each veneer is individually fitted and checked for marginal accuracy.

Figure 15.16 **(C)** Following individual fitting, pairs, then groups of veneers are checked for proper contact until all were properly related to one another.

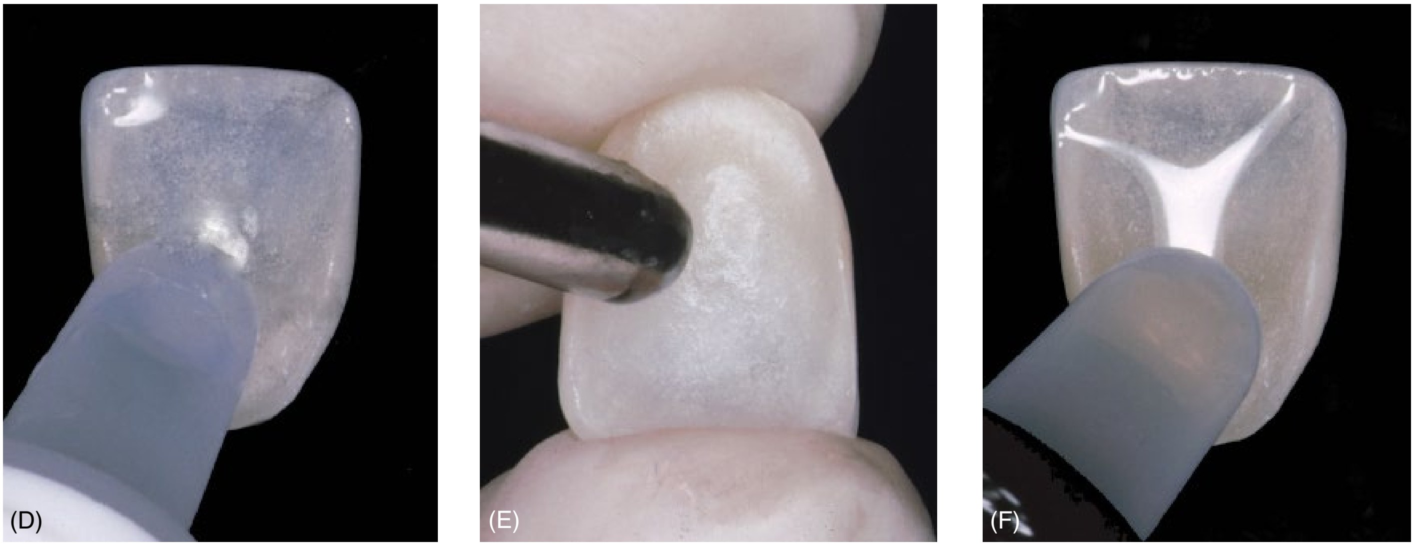

Figure 15.16 **(D)** Following color checks with try-in paste, the veneers are cleaned in an ultrasonic bath with denatured alcohol for 10 min then treated with hydrofluoric acid porcelain conditioner for 1 min. **(E)** Hydrofluoric acid porcelain conditioner is thoroughly washed off and then air dried. **(F)** Silane primer is applied according to the manufacturer's instructions.

2. After ascertaining individual fit, each veneer should be placed on one by one, until all are in place. Thus you can ascertain if there are any problems with the insertion paths and order of insertion (usually done posterior to anterior, except the centrals and laterals which should be placed centrals first, then laterals). Then check the collective fit and relationship of one veneer to another, especially in the contact areas.
3. Assess the shade and modify it as necessary. Since the prepared tooth color, shade, and opacity of the bonding resin and the veneer itself all contribute to the color of the veneer once in place, this phase of the try-in is essential.

A good initial test is to place one veneer in position with glycerin on the tooth and compare that veneer to a shade tab of the selected shade. If the veneer color is unsatisfactory, use try-in pastes that do not polymerize, or place a small portion

Figure 15.16 **(G)** The silane is dried with a warm air dryer or oil and moisture-free laboratory or chairside air syringe.

Figure 15.16 **(H)** The two central incisor preparations are etched; 15 s for dentin and 20 s for enamel.

Figure 15.16 **(I)** A 10 s air/water spray as used to wash off the etchant.

Figure 15.16 **(J)** Multiple coats of dentin/enamel bonding agent are applied and then dried and polymerized. The prepared tooth surface should now be slightly glossy. If not, repeat the process.

Figure 15.16 **(K)** Following application of a pre-bond resin, the two central veneers, filled with cement, are carefully placed and checked with an explorer to certify correct alignment.

Figure 15.16 **(L)** Holding the veneers in place, make certain the ultrathin (0.002 mm) matrix (Artus) provide adequate separation along the entire contact area.

of the luting composite on the veneer and then reset the veneer on the prepared tooth to check the color. If you or the patient is not happy with the shade, try the veneer with a lighter or darker shade of try-in paste or composite until the right one is found.

There is no absolute method of predetermining the exact shade of the veneer following cementation. However, using try-in pastes that are matched to the final shades can go a long way to satisfying most dentist and patient demands (Bisco Choice 2). Even so, there will almost always be a slight shade shift following polymerization. That shift will generally be towards the darker rather than lighter side. So, if there is a choice, choose the lighter shade cement. If the veneer appears lighter than expected at the trial phase, try adding tints or opaquers.

While it is ideal to have all of the necessary color contained in the porcelain, certain discolorations and problems present in the tooth itself may be too much for the veneer alone to correct, because of its thinness. In these cases, correction can be made for the individual tooth discoloration through the use of resins painted onto the internal surface of the veneer. In others, where the teeth are discolored in strips, lines, or small areas, only these discreet areas may need opaquing. When a satisfactory result is achieved, the veneers then can be bonded in position with the usual composite luting cement. This process allows a better coloration of the finished tooth but it does raise problems of added thickness and possible weakening of the bond. You also may

Figure 15.16 (M) Following a 5–8 s initial polymerization, excess cement is trimmed. Next, polymerize each aspect (labial, lingual, and incisal) for 40 s.

need to alter the tooth slightly in the event you need greater composite opaquing. This can be done by slightly preparing a concave area on the tooth surface under the part of the veneer that requires greater masking.

Caution must be used during this phase of the try-in to avoid exposing the veneer and composite luting agent to the operating light, which may initiate the curing process. It also is important to completely remove the composite material used during the try-in period prior to the final process of luting. Be sure to remember that ceramic veneers are fragile and are subject to fracture prior to bonding.[91]

Final insertion

After spending considerable time preparing the teeth, taking impressions, and constructing and trying in the veneers, the most crucial step comes: that of final insertion with adhesive bonding. The reason why this step is potentially the most demanding of all is because the actual final placement, shade chosen for the cement, and the ability to achieve lasting adhesion to cementum, dentin, and enamel will ultimately determine how long the veneer remains esthetically and functionally viable.

There are also several phases to this process, which may best be done with a local anesthetic. (Figure 15.16A–Z4).

1. **Soft tissue control**. Gingival retraction cord should be placed to decrease the crevicular fluid flow, which would interfere with the adhesion and seal between the veneer and underlying enamel. It also allows for direct visibility of the gingival margin.

   Ideally, a rubber dam is the best way to secure overall moisture control. However, in many instances of subgingival margins it is either impossible or impractical to precisely seat the veneers with a rubber dam in place. Therefore, other methods of securing a dry field must be used. Using the retraction cord can help but if bleeding is present after retraction, due to inadequately healed tissue, the insertion should be postponed. Several rinses with saline (a teaspoonful of salt to a glass of water) may help to control the seepage. One thing is certain: unless bleeding and gingival seepage can be controlled, the life span of the veneers will be drastically shortened by reducing bond strength, especially in the gingival area, and increasing the chance for bacterial penetration and eventual unwanted stain beneath the veneer.

Figure 15.16 (N) This 60-year-old woman looked older due to her discolored, worn, and eroded incisors.

Figure 15.16 (O) A younger and more attractive appearance was achieved by four porcelain veneers. Note closure of interdental space.

2. **Cleaning and etching**. In many cases the dental laboratory delivers veneer restorations with intaglio surfaces pre-etched with hydrofluoric acid (smoky white surface). This might make clinicians believe that the veneer is ready for adhesive bonding without further surface treatment, and silanation could be performed at the intaglio surfaces of the veneer immediately. Yet try-in procedures of veneers are necessary, which causes contamination of the bonding surface by saliva, blood, or the try-in glycerin paste (Figure 15.16A–C). Therefore, it is required to etch the intaglio surfaces once more with hydrofluoric acid for 20 s to 1 min, dependent on the composition of the silicate-based material used (Figure 15.16D). In case the ceramic surface was not pretreated by the laboratory, the veneer is cleaned with 99% isopropanol, and the inner surfaces are etched with 4.9% hydrofluoric acid for 60 s. The etched ceramic surface should be thoroughly sprayed with water for 60 s and dried with oil-free compressed air (Figure 15.16E).

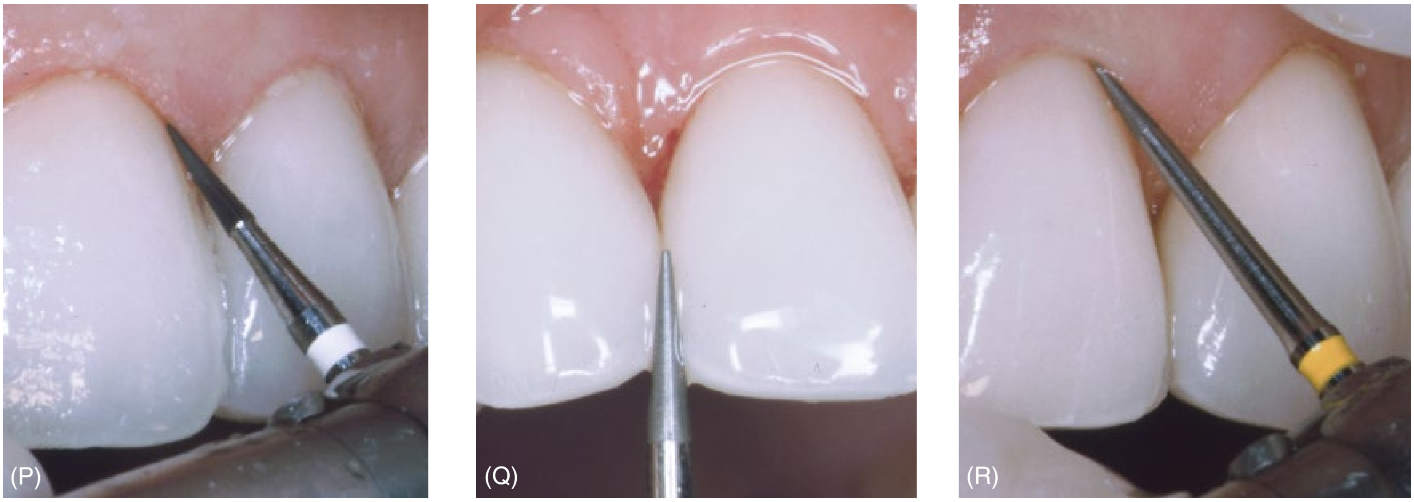

Figure 15.16 **(P)** The LVS-5 (Brasseler) is used to trim composite resin flash following polymerization. **(Q)** The LVS-6 is used to contour or reshape as necessary. **(R)** Gingival reduction shaping or contouring could also be easily managed with the LVS-7 15 µm diamond.

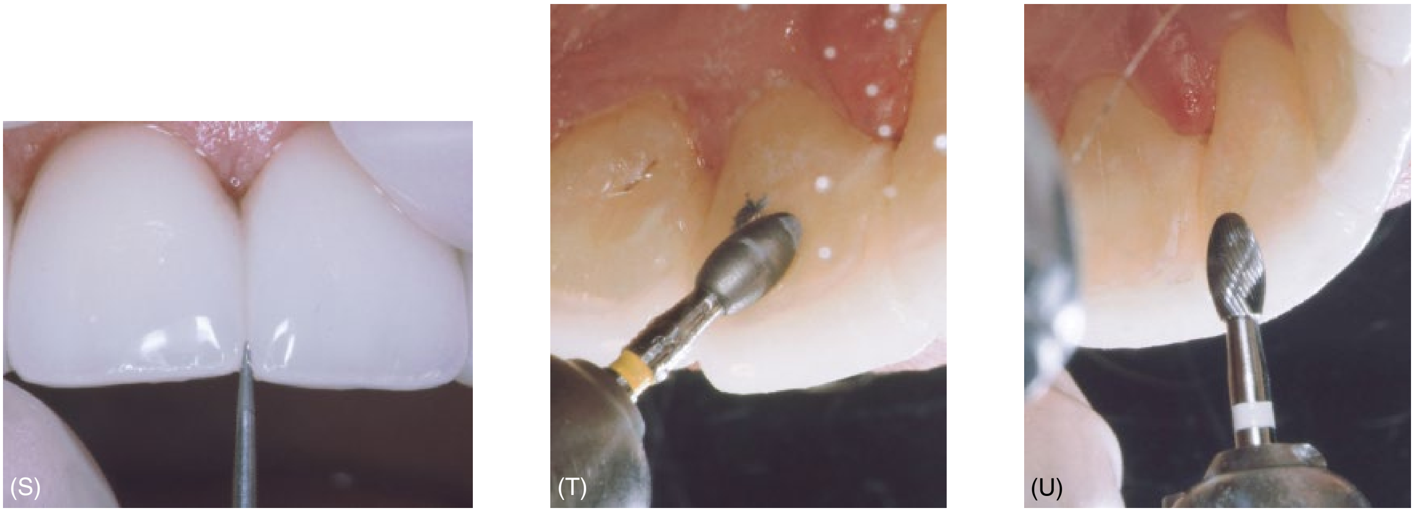

Figure 15.16 **(S)** The LVS-7 is also useful for contouring incisal embrasures. **(T)** The LVS-8 is helpful to establish appropriate occlusal anatomy and shape lingual surfaces. **(U)** Final porcelain finish should be done with the 30-bladed carbide (ETUF-OS1, Brasseler USA).

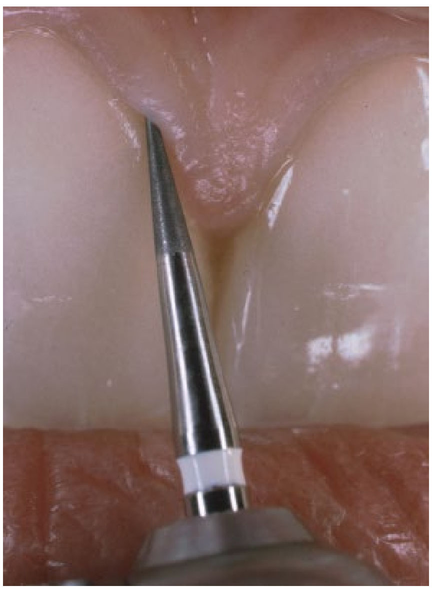

Figure 15.16 **(V)** Many clinicians prefer an 8 µm diamond (DET4UF) for final finishing of gingival margins.

3. **Silanation**. The bond of the porcelain veneer to the tooth is, in fact, a series of links: etched enamel to dental bonding agent to luting composite to hydrolyzing silane to etched porcelain. Common is the use of a one-component adhesive silane (e.g. Monobond-S, Ivoclar Vivadent or Etch 37, Bisco) (Figure 15.16 F). After a reaction time of 60 s the silanized ceramic surface can be dried with air (Figure 15.16G). Hereafter, the silanized intaglio surfaces of the veneer should not get in contact with water or other contaminants, or etching and silanization process needs to be repeated. Silane greatly enhances the adhesion between porcelain and resin and thus increases bond strength (Figure 15.16G).[92]
4. **Enamel etching**. Each prepared tooth is isolated, and then cleaned with a polishing brush and fluoride-free cleaning paste (e.g. Pell-ex Hawe Neos Dental, or Bisco). The prepared tooth structure is etched with 37% phosphoric acid (e.g. Total-Etch, Ivoclar Vivadent,), dentin for 15 s and enamel for 40 s (Figure 15.16H), sprayed with water for 15 s, and dried. 40 s etching time is sufficient if no dentin but only enamel is involved. (Figure 15.16I). The etchant must reach the entire periphery of the preparation where a tight seal is critical to the long-term success of the restoration. Gingival displacement is important to expose this margin and prevent contamination. If the patient rinses or in any way contaminates this etched enamel surface with saliva, the surface must be re-etched for 10 s, washed, and dried again (Figure 15.16I).
5. **Bonding**. Depending on the bonding system used, single or multiple steps are required to prepare the tooth surface. A classic and very durable three step bonding method is introduced here. A primer (e.g. Syntac Primer, Ivoclar Vivadent or All-Bond, Bisco) is applied to the etched surface with a brush for 15 s and blow-dried after a reaction time of 10 s. After conditioning of the surface with a primer, an adhesive (e.g. Syntac Adhesive, Ivoclar Vivadent or Porcelain Bonding Resin, Bisco) is applied for a reaction time of 10 s. Following, enamel and dentin are covered with an unfilled resin bonding liquid (e.g. Heliobond, Ivoclar Vivadent) blown to a thin layer. To avoid inaccuracies of fit, the unfilled resin bonding material should not be light-polymerized before restoration placement (Figure 15.16 J). The internal aspect of the veneer that has been silanated is now also coated with the unfilled resin bonding liquid, which is blown into a thin layer. The composite luting agent is now placed inside the veneer. Protect all these materials from strong light to prevent premature polymerization.

   An alternate technique includes a universal self-etch material (All-Bond SE, Bisco), which combines etching, priming, and bonding in one step.
6. **Placement**. Generally, the distal-most veneers in the posterior should be seated and polymerized first, followed by the next mesial-most veneer until the canines. Next, seat central incisor veneers together, then the laterals, and finally, the canines. Be sure to refit your adjacent or next veneer before you attempt to cement it to place (Figure 15.16 K). Frequently, a small cement excess or slight placement variation in the previous veneer has caused the fit between them to vary. Use a 15 μm diamond ET6F, or LVS (Brasseler USA), to slightly shape the adjacent surface, and then refit the next veneer until the fit is again perfect before proceeding. If you need to remove the glazed surface of a seated veneer, you need to repolish the surface with a ceramic polishing system. The pivotal last veneer on each side may give you the most problems because there will be more sides to adjust if there is tightness in the fit. *Adjust the contacts of the already seated veneers until you again achieve a perfect fit.*

   Handling a veneer full of cement is not as easy as positioning the cement-free veneer. Veneer carriers are available relying on glue tips or adhesive pads that can help to position the veneer correctly, although there is the distinct possibility that the glue bond might fail or the veneer might slide off, causing it to drop and become contaminated. When choosing to finger-hold the veneer you should avoid pushing the cement away from the edge of the veneer, leaving a bonding void. Also, make sure that well-fitting dental gloves are used.

   The adjacent teeth should be separated with matrix strips during both acid etching and insertion so the cement does not

Figure 15.16 **(W)** The Soflex (3 M) disk 1 s used to adjust the incisal length.

Figure 15.16 **(X)** Use waxed or unwaxed floss to test for any overhangs that might still need to be removed.

Figure 15.16 **(Y)** An ultrathin strip followed by abrasive strips, coarse to fine, will provide the best interproximal finish.

lock in or adhere to the adjacent tooth (Figure 15.16L). Since most clear Dental Mylar strips are too thick, it is better to use the Artus occlusal registration strips or Variolink Esthetic LC System, which allow proper seating of veneers. Dual-polymerizing composite cement (e.g. Ivoclar Vivadent) is advised for adhesive fixation. Apply composite cement to the prepared tooth and inner restoration surfaces. Insert the veneers gently with increasing pressure (≈5–10 N). Immediately remove excess cement in all marginal areas with foam pellets. Avoid cotton pellets, since cotton fibers will get stuck at the cementation composite. While placing the veneer, line up the incisal edge and the mesiolabial and distolabial line angles with the adjacent teeth. Use a sharp explorer to make certain the gingival margin is in place. Most of all, be careful not to torque the veneer, which could trap an air bubble underneath. Ten seconds of light polymerization at the incisal edge ensures stabilization of the veneer while other veneer surfaces should be covered with instruments or finger.[93] Remove residual interproximal cement gently with foam pellets, dental floss, and Superfloss (Oral-B) without dislocating the veneer. The most frustrating area for this to happen is at the gingival margin, since bacteria will usually penetrate, eventually causing a black stain to occur (see Figure 15.17). *In case the veneer moves or pulls away from the tooth in the gingival area*, it is highly advised to remove it, refill it with cement, and reseat it.

Figure 15.16 **(Z)** Ultrathin plastic pop-on discs could effectively reopen closed incisal embrasures.

7. **Polymerization**. A short polymerization period of about 5 s as you seat each veneer will be sufficient to allow you to remove the greatest bulk of marginal excess (Figure 15.16M). Some flash or excess marginal cement is healthy to make certain that polymerization shrinkage does not cause a marginal void. Remove excess partially cured composite with a Novatech 12 (Hu-Friedy). This double-ended instrument is quite helpful because its chisel end can gently pry off excess labial and lingual composite cement, and the sickle end is extremely large but perfectly suited to remove interproximal excess composite cement. Glycerin gel application at all restoration margins (e.g. Liquid-Strip, Ivoclar Vivadent, Schaan, Liechtenstein) ensures oxygen inhibition during light polymerization. The polymerization process is completed by curing the various areas of the veneer for at least 60 s with light intensity of at least 650 mW/cm^2, or 10 s with an argon laser or xenon light (Figure 15.16M–O). During this polymerization process it is essential to maintain complete stability of the relationship between the veneer and the underlying tooth. Although all flash should generally be removed; if you are inserting additional veneers, wait until the adjacent

Figure 15.16 **(Z1)** This 49-year-old woman wanted a lighter and more prominent look to her teeth.

Figure 15.16 **(Z2)** Twelve porcelain veneers were placed to satisfy this patient's desire for perfection.

Figure 15.17 Torqueing or accidental moisture contamination during cementation can eventually cause marginal leakage. This can result in a black, gray, or blue stain appearing underneath a porcelain veneer. Although it can be repaired, the best solution to this problem is remaking the veneer.

veneer is seated before you do any subgingival trimming with the bur to avoid initiating bleeding or seepage.

8. **Finishing**. When polymerization is complete, excess composite should be chipped off manually with a finishing instrument (e.g. Novatech 12, Hu-Friedy). Further, residual excess composite cement can be removed with a 15c scalpel (#371716, Bard-Parker; Becton-Dickinson). This method is favorable for epi- or subgingivally positioned restoration margins. The scalpel allows for cement removal without alteration of the ceramic surface and gingival tissue trauma. A 30-bladed carbide finishing bur with a straight emergence profile (LVS-5) from the Veneer System (Brasseler USA) (Figure 15.16P) can be used to gently remove all remaining excess composite at the gingival margin. Use a copious water spray to avoid heat build-up.

If the veneer surface is not a smooth continuation of the subgingival enamel, then recontour the excess porcelain with a microfine diamond point (LVS-6) (Figure 15.16Q). A 15 μm grit polishing diamond (LVS-7) is then used to refine this interface of tooth/composite/porcelain (Figure 15.16R and S). Refine occlusion with microthin articulating film, 0.02 mm (AccuFilm II, Parkell), and adjust occlusion if necessary with a 15 μm diamond (LVS-8) (Figure 15.16 T) and final finish with a 30-bladed carbide (ETUF-OS1) (Figure 15.16U). For final margin use an 8 μm diamond (DET 4, Brasseler USA) or a 30-bladed carbide ETUF 4 (Brasseler USA) of the same size (Figure 15.16 V). The final polishing of the veneer is done with a series of ceramic polishing kits and diamond-dust-impregnated paste with non-webbed rubber cups. The edge of the rubber cup is brought to just beneath the free gingival margin to bring the junction between the veneer, composite, and tooth to a high luster, ensuring that this area does not become a repository for microbial plaque. This final polishing can take 5 min per tooth.

The lingual margin is finished with the LVS-8 to remove excess composite (Figure 15.16 T). If the porcelain margin needs refining, use the 15 μm diamond (LVS-7). First, polishing is done with a series of flexible spirals (Dialite Feather Lite porcelain polishers, Brasseler USA) used in sequence. The final polishing is once again done with diamond impregnated polishing paste (Dialite intraoral porcelain polishing paste, Brasserler USA) on a disposable cotton polishing buff (Brasseler USA). Static and dynamic occlusion need to be checked. If necessary, adjust incisal length with flexible polishing discs (Brasseler or 3 M ESPE) (Figure 15.16 W).

A thorough study by Haywood and coworkers[94] compared various instruments and finishing and polishing sequences and found that the best results obtained were with a sequence consisting of diamond instruments with progressively smaller particle sizes at moderate speeds with water coolant, then a 30-blade carbide bur at high speed and dry, followed by a diamond polishing paste with a 2–5 μm particle size. In all polishing sequences, the best results were obtained with each individual instrument when diamond instruments were used at moderate speed, wet, and carbide instruments were used at high speed, dry.

Proximal contacts should be checked with dental floss (Figure 15.16X) and minor corrections can be made with a yellow-banded diamond finishing strip (VisionFlex Perforated diamond strips with Gateway, Brasseler USA). If the entire contact area needs thinning, then wider strips banded (Brasseler USA or Premier) (150 UF) can be used (Figure 15.16Y). In case the embrasure area needs to be reshaped, a 100 UF strip should be used. Incisal embrasures can be nicely thinned and polished with the ultrathin plastic discs (3 M, Brasseler USA, or Premier) (Figure 15.16Z).

The patient should return at weekly intervals to be monitored for tissue response. In the event of inflammation, the veneers can be further refined with the LVS microfine diamonds for esthetic and functional harmony, making certain that no porcelain or composite impinges on the gingival tissue.

Post-treatment care and instructions

Once veneers are cemented and finished, it should be the goal to help the patient obtain the longest life expectancy for the veneers as possible. First and foremost, a night appliance should be constructed to protect the veneers from the possible damage due to abnormal chewing, grinding, or clenching during sleep. One of the easiest to make and most comfortable to wear is a flat upper occlusal plane made of hard acrylic, with a soft acrylic liner (Annalan Laboratory).

Office-based maintenance should consist of at least four professional cleanings per year. Be sure to train your hygienist to avoid ultrasonic scaling on any tooth with a porcelain veneer, and to avoid air-powered abrasive instruments, which can attack the porcelain surface.[95] When hand scaling, advise your hygienist to be careful not to scale against the veneer margin, which could produce chipping, fracture, or worse, debonding. Rather, scale either from the veneer onto the tooth or laterally parallel to the margins.

The highly esthetic outcome and longevity made traditional porcelain laminate veneers the treatment option of choice for restoring the anterior dentition.[16,48,96] Many authors state that fractures are the most frequent cause for clinical failure of ceramic veneer restorations,[96,97] yet the percentage of reported clinical unacceptable fractures is very low: Magne et al.[98] showed 0%, Peumans et al. 2%,[96] and Dumfahrt and Schaffer 3%.[70]

Calamia[99] reported a study of 115 etched porcelain veneers 2–3 years after placement and found a low fracture rate, low debond rate, no incidence of caries, and minimal negative periodontal response. Strassler recalled 196 porcelain veneers with up to 13 years of service and an average of 10 years. None had debonded and all were color-stable. Over the course of this long-term study, only seven veneers needed replacement due to porcelain chipping—a 96.4% success rate.[100] All-ceramic veneers involving the incisal edge, the approximal areas and larger parts of the palatal surface (full veneers[16]) should be considered more often as an alternative to full crowns[26,62,98] (Figures 15.18A–R and 15.19A–P). During a 5 year observation period, a study by Stappert showed promising survival rates of 97.6% and 100% for IPS Empress press-ceramic veneers with overlap- and full veneer preparation design, respectively.[21] The results remained the same for the 7 year follow-up.[47] Decrease in marginal adaptation and increase in marginal discoloration are the most common esthetic compromises for veneer restorations.[28] To prolong the survival rate of ceramic veneers, maintenance and care is highly advised:

1. Special care immediately following placement of veneers. During the 72–96 hours during which the bonding resin continues to cure, the patient should avoid hard foods, alcohol, some medicated mouthwashes, and extremes in temperature.
2. Eating and other habits must be altered indefinitely to avoid damaging, discoloring, or eroding the veneers. The patient should be instructed to avoid biting into hard foods, whether candy or meat with bones. Behaviors such as nail biting or pencil chewing endanger their new smile. Many dentists recommend that patients use a soft acrylic mouthguard when involved in sports or activities likely to result in impact to the mouth. Apart from concern with fracturing, the patient also should avoid large amounts of highly

Figure 15.18 **(A)** This 30-year-old patient introduced himself for dental treatment of his upper diastema and color mismatched dentition.

Figure 15.18 **(B)** The diastema between the two central incisors measured close to 3 mm. Also teeth #6, #8, and #11 were almost two shades darker than the adjacent teeth.

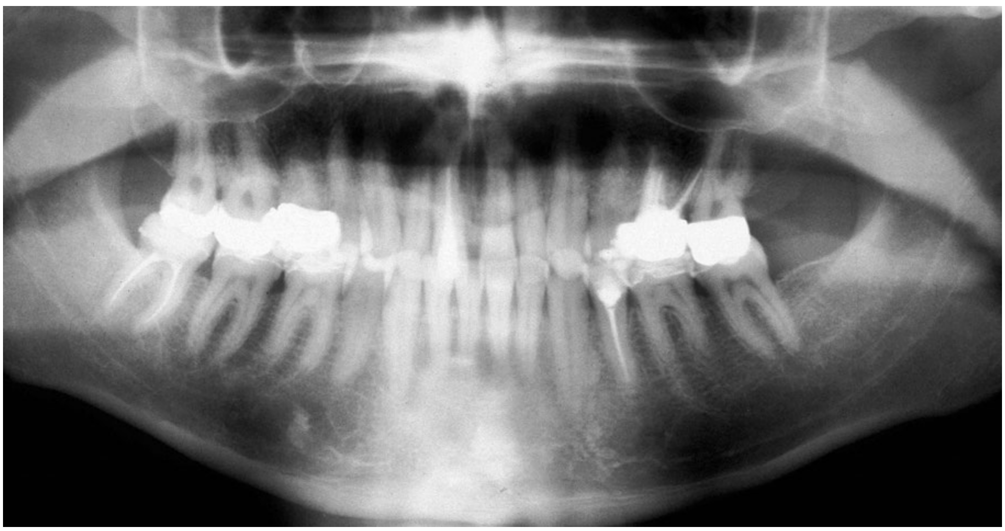

Figure 15.18 **(C)** Orthopantomogram demonstrates multiple posterior restorations, including a number of endodontic treatments, especially also for tooth #8.

Figure 15.18 **(D)** Close-up view of the facial display of teeth #6–#11. Tooth #9 showed off-axis labial disposition, yet gingival conditions were stable.

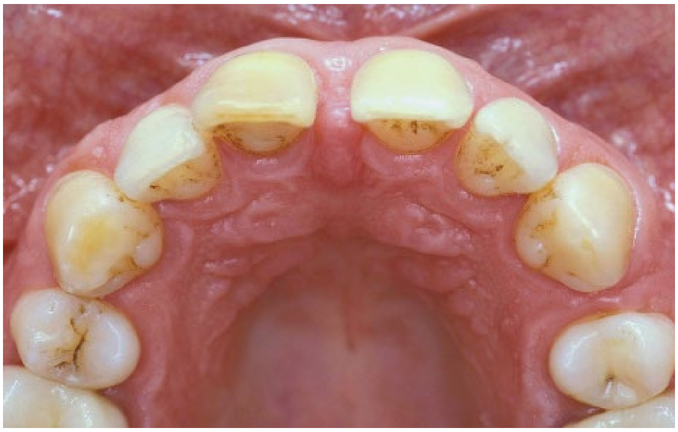

Figure 15.18 **(E)** Occlusal overview of the anterior dentition.

Figure 15.18 **(F)** Pre-fabricated shell provisional to restore teeth #7–#10 temporarily after extended veneer preparation.

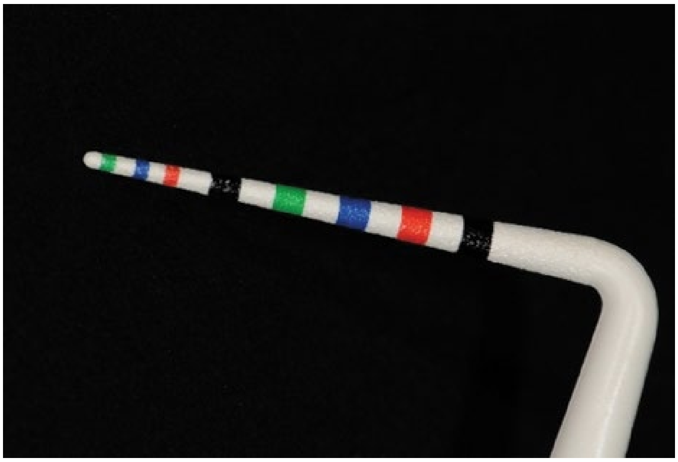

Figure 15.18 **(G)** The Goldstein multicolored ColorVue Probe (Hu-Friedy) is a useful device for measuring proper depth when preparing teeth for porcelain veneers since the tip of the probe to the red mark is in 0.5 mm increments and 1 mm increments afterwards.

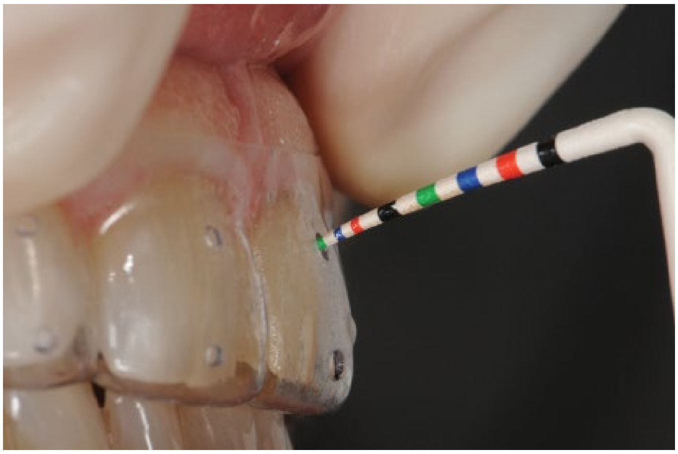

Figure 15.18 **(H)** A vacuform matrix with small holes for both gingival and incisal reduction combined with the bright colors of the probe assure sufficient uniform reduction for proper porcelain thickness.

Figure 15.18 **(I)** Following a wax-up and model analysis, a butt joint veneer preparation was performed for teeth #7–#10 to allow for better distribution of spaces between the teeth. It was panned to extend the incisal width of the lateral incisors to balance wider central incisors to close the diastema space. The patient was not interested in orthodontic treatment.

Figure 15.18 **(J)** Occlusal view of the anterior veneer preparations, following the arch form.

Figure 15.18 **(K)** Master cast of the final lithium-disilicate e.max Press restorations, utilizing the cut-back technique.

Figure 15.18 **(L)** Close-up of the two central incisor ceramic restorations to close the diastema.

Figure 15.18 **(M)** Relaxed lip position under a light smile, displaying the upper anterior restorations after adhesive bonding under dry conditions.

Figure 15.18 **(N)** Post-op facial view of the patients smile, four weeks after insertion.

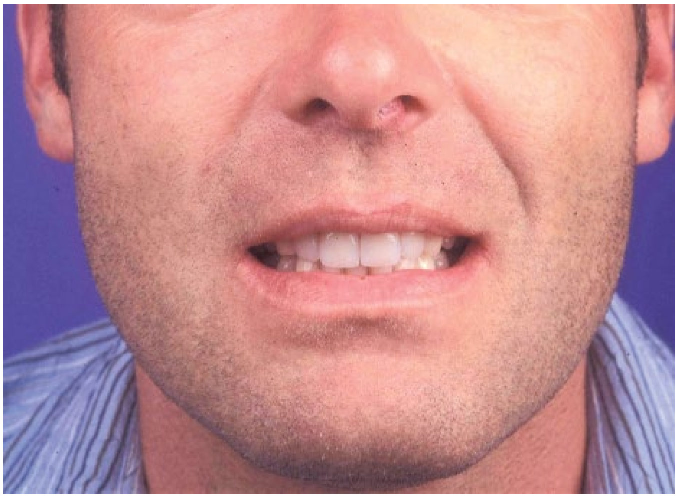

Figure 15.18 **(O)** Post-op: the patient's facial appearance and smile changed significantly. A week after the treatment, the patient showed improved self-confidence.

colored foods, tea, and coffee. And finally, the teeth can erode. Intrinsic erosion occurs primarily in anorexia nervosa or bulimia when gastric juices wash over the teeth during induced vomiting. But extrinsic erosion can also occur due to excessive consumption of acidic fruits and juices, which your patient should consume only at mealtimes or shortly before brushing.[101]

3. Home dental maintenance also takes on a slightly different nature. Instruct the patient to use a soft toothbrush with rounded bristles and to floss as with unrestored teeth. Maintenance of plaque-free teeth is essential to the longevity of the veneers as well as the health of the teeth and supportive tissues. Frequently the enamel has been lost and the softer dentin or cementum tends to decay much faster if not properly maintained. Mechanical plaque removal devices may be useful. In order to properly maintain cervical areas, especially when there is interdental tissue loss, a rotary cleaning device (Rotadent, DenMat) contains pointed brush tips that can easily clean these areas. The patient also should avoid acidulated phosphorus fluoride gels[102] or acidulated fluoridated mouthrinses, which can damage the surface finish of veneers. Nonacidic fluoride preparations (e.g. Prevident 1.1 % sodium fluoride; Prevident by Colgate Oral Pharmaceuticals or Clinpro 5000 by 3M ESPE) are effective in reducing caries and should be considered for patients with extensive porcelain or composite restorations.[103] Chlorhexidine antiplaque mouthrinses may stain veneers, although the stain can be removed by a hygienist.[68]

Figure 15.18 **(P)** Facial view of the intermaxillary anterior upper and lower dentition with extended ceramic restorations after 4 weeks.

Figure 15.18 **(Q)** Facial view of the intermaxillary anterior upper dentition *before* extended ceramic restorations.

Figure 15.18 **(R)** Facial view of the intermaxillary anterior upper dentition *after* extended ceramic restorations.

Figure 15.19 **(A)** A 44-year-old female patient presented with anterior crowding and bilateral reduction of the buccal corridor. Tooth #11 was missing and the first bicuspid had been moved orthodontically into the canine position, causing a crossbite occlusion on the left side. The patient refused additional orthodontic treatment.

Figure 15.19 **(B)** Due to discoloration, multiple composite fillings, and tooth position, the patient mainly disliked her upper anterior dentition. Following dental hygiene treatment, home bleaching trays were fabricated.

Figure 15.19 **(C)** Patient was instructed to perform six overnight sessions of home bleaching with 15% carbamide peroxide gel in the upper and lower jaw. The patient refused treatment on the lower crowns #22 and #27.

Posterior ceramic partial coverage restorations

Directly placed composite resins have made a tremendous impact on the field of esthetic restorations. But the current limitations of direct composites are most evident when you are working with posterior teeth.[104] The development of long-term wear-resistant, direct composite restorations that could stand up to the stresses of posterior occlusion and mastication has proven difficult.[105] Problems include fracture, post-insertion sensitivity, microleakage, loss of surface integrity, occlusal and proximal surface wear, and difficulty securing and maintaining interproximal contact.[106,107] Posterior composite placement and finishing techniques are markedly more difficult than for anterior teeth. When porcelain was introduced to restore the posterior dentition, Wiley[108] reviewed concerns of the potentially destructive nature of porcelain on the occluding surface. He concluded that the type of opposing occlusion should be the

Figure 15.19 **(D)** Based on dental evaluation and treatment planning, a wax-up indicated a significant change with five partial coverage and full veneers. Soft tissue evaluation indicated the need for recession coverage of tooth #10.

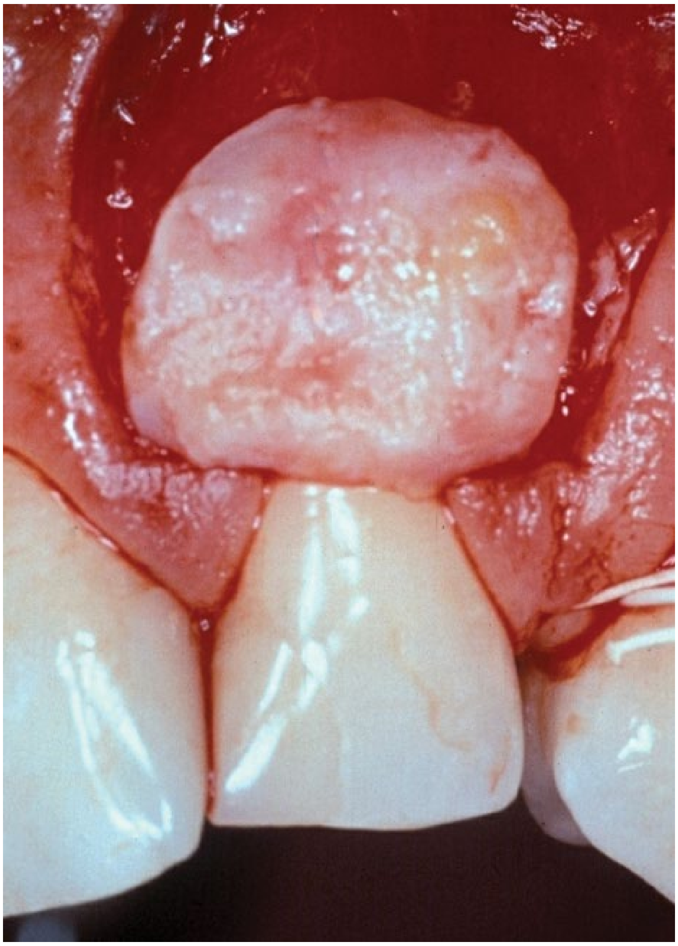

Figure 15.19 **(E)** Recession coverage with a connective tissue graft was performed on tooth #10.

Figure 15.19 **(F)** According to the preparation guide, teeth #7 and #8 were prepared subgingival, including all the areas of former composite restorations. Tooth #7 required a full veneer preparation (360° veneer) and tooth #8 a facial incisal overlap preparation with a butt joint. **(G)** Due to a distal defect, tooth #9 required a combination of an incisal overlap and distal partial coverage veneer preparation. A full veneer preparation was performed at tooth #10. **(H)** A master model was fabricated to generate ceramic IPS Empress pressed veneers. Thin spacer was applied to the prepared surfaces, sparing the preparation margins.

Figure 15.19 **(I)** When possible, anterior palatal tooth contact positions in centric should remain on natural tooth structure.[26] Defect size or tooth anatomy might require palatal tooth structure coverage shown at teeth #7 and #10.

Figure 15.19 **(J)** The preparation on tooth #12 was adapted to create the illusion of an existing canine #11. The preparation extended from the occlusal surfaces to the lingual cervical side.

major consideration. Porcelain occluding against porcelain works best, with the least amount of opposing wear. The next best solutions would be porcelain against composite, then porcelain against enamel, and the worst is porcelain against gold, which can produce severe wear of the gold surface. Many researchers and clinical dentists recommend that composite resins be restricted to smaller posterior restorations not subject to strong occlusal forces.[109]

Although new developments continually improve the composite resins used for indirect inlays and onlays, ceramic has numerous advantages as described previously throughout this chapter.[110] Porcelain is most like enamel in appearance and most closely approximates its physical and chemical properties. Etched porcelain bonds successfully to etched enamel, with excellent marginal qualities, when a composite resin-based cement is used.[111] This bond to the tooth preparation is what gives porcelain, which by itself has a highly breakable nature, its strength as a dental restoration.[112] New glass-ceramic materials with improved mechanical properties and higher inert fracture strength, plus the progress in adhesive bonding techniques including dentin-enamel conditioning, and further developments of luting composites,[113] replaced porcelain for the application of posterior all-ceramic partial coverage restorations.

In general, the longevity of ceramic inlays, onlays and partial coverage restorations depends on many factors.[47,98,114–116] The processing- and operator-related factors include experience of the operator, correct indication, cavity preparation (size, type, finishing), impression technique, correct choice of the ceramic material and experience with the material, handling and application, cementation material and process, correct occlusion, and recall schedule. The patient-related factors include oral hygiene, preventive measures, compliance in recall, oral environment (for instance, quality of tooth structure, saliva), size, shape, location of the lesion and tooth (number of surfaces, vital versus nonvital tooth, premolar versus molar), cooperation during treatment, bruxism, habits (high sugar intake, smoking, frequent chewing of hard foods), and participation in contact sports. Long-term clinical studies with observation periods of up to 12 years showed that the survival rates of ceramic inlays, onlays, and partial coverage restorations might range between 74 and 100%.[47,114]

Figure 15.19 **(K)** Finalized ceramic IPS Empress pressed veneers, using the cut-back technique at the facial surfaces in combination with coloring and glazed finishing.

Figure 15.19 **(L)** Incisal overlap veneer with butt joint ending demonstrates the advantage of a metal free restoration.

Indications

Etched ceramic partial coverage restorations are suitable for any clinical situation for which porcelain's superior esthetics, ability to restore strength to compromised teeth, and conservative treatment are indicated. The list of indications presented by Garber[50] remains current:

1. Small to moderate carious lesions for which the patient requests a highly esthetic restoration.
2. Large amalgam or composite restorations involving the mesio- or distolingual surface of a cuspid showing unacceptable discoloration or compromised contacts.
3. Large carious or traumatic lesions with undermined enamel to the extent that a cast metal restoration or a full crown would otherwise be necessary. In these situations the crosslinked resin-bonded ceramic restoration will bond to the remaining tooth structure, binding it together into what is, in effect, a homogeneous mass.
4. The endodontically compromised tooth where the access cavity has compromised the strength and prognosis of the tooth. An etched ceramic restoration can be a conservative alternative to a post-and-core and full-coverage crown.
5. Heavily undermined occlusal edge or proximal surface on a tooth requiring support to keep an otherwise pleasing intact tooth from fracturing.
6. Class IV restorations replacing missing occlusal and/or proximal aspects of the tooth.
7. Teeth opposed by existing porcelain restorations, which otherwise would tend to wear extensively.

Figure 15.19 **(M)** Three pressed ceramic partial coverage and full veneers to restore teeth #10–#12. Restoration #12 demonstrates canine contour facially and occlusally.

Figure 15.19 **(N)** Follow-up 15 month after insertion of the anterior veneer restorations. Tooth proportion and position of central and lateral incisors had been corrected.

Figure 15.19 **(O)** Before the treatment with ceramic veneers, the patient was dissatisfied with function and esthetic appearance of her anterior teeth.

8. Teeth where it is difficult to develop retention form. The bonded restoration's adhesive nature may be more effective than other means of developing retention such as pins, periodontal crown lengthening, or a post and core after elective endodontic therapy.
9. Patients for whom allergy to metal is proven or suspected.

Contraindications

1. Patients who will continue excessive parafunctional habits that can damage the ceramic restoration.
2. Patients who exhibit aggressive wear.
3. Patients who have gold restorations in opposing teeth.
4. Ceramic posterior partial coverage restorations are not simple, and this factor needs to be considered against all the numerous advantages and the situations in which they are an excellent solution to a restorative problem. The problems of maintaining a dry field, obtaining precisely fabricated restorations, and the necessary high degree of attention to detail during placement have been called by Garber a "contraindication in itself" for many dentists.[50]

Many advantages can be gained by preserving as much of the healthy tooth structure as possible. This can be achieved best by using a defect-oriented tooth preparation. The general benefits of using partial coverage preparations are as follows:

1. Preserving healthy tooth structure.[47]
2. Facilitating superior periodontal health.[28,47,98]
3. Facilitating cementation without hydrolytic behavior.[22,117,118]
4. Preserving the pulp's health.[47,48,98]
5. Preserving the tooth's anatomical shape.[17,47]
6. Facilitating visual margin control.[47,97,114]
7. Facilitating easier performance of oral hygiene for the patient.[73,74,97]
8. Improving the reliability of tooth vitality testing.[21,98,114,119]

Figure 15.19 **(P)** After treatment: The patient liked the new appearance of her anterior dentition. Especially the changes on the left side, correcting the cross bite and reshaping a canine, had a significant impact on the symmetry of her smile. The restorations were inserted in 1999 and are still in place.

Technique: preparation

Laboratory requirements for fabrication of ceramic restorations, as compared to cast gold restorations, require certain preparation modification. Cavity preparation is somewhat simpler than for gold.[120] All line and point angles should be rounded to facilitate fabrication and decrease the potential for propagation of fractures. The cavosurface angle need not be beveled, and a hollow-ground chamfer confined to the marginal enamel will aid in developing a more effective seal.[50,121]

The basic premise of the preparation is to preserve all that remains; unlike some other restorations, only those aspects of the tooth already compromised by caries or trauma should be reshaped. This should be done before deciding on the definitive form of the preparation and final restoration.

To achieve the rounded angles needed for porcelain, the preparation is performed with a two-grit diamond in the shape of a tapered cylinder having a flat end and a rounded "corner" when the flat end and shank meet. It is favorable to produce a flat pulpal floor with calculated divergent axial walls and a rounded line angle between the two highly retentive axial walls, which increases the surface area for bonding and develops mechanical retention. Finally, a well-defined cavosurface margin at the occlusal surface is necessary to develop the hollow-ground chamfer at the margin.[50]

When using strength enhanced glass-ceramic materials, Stappert et al.[23] concluded that a defect-oriented tooth preparation in the posterior region for the restoration of a compromised tooth with a partial-coverage ceramic restoration is justifiable. All-ceramic partial coverage restorations for molars made of IPS e.max Press are fracture-resistant, showing results comparable with those of natural unprepared teeth. The preparation designs in this study include standard mesio-occlusal-distal (MOD) inlay, MOD with reduction of mesiopalatal cusp, MOD with reduction of both palatal cusps, MOD with reduction of both palatal and distobuccal cusps, and MOD with reduction of all cusps. Ceramic coverage of compromised cusps did not demonstrate an increase in fracture resistance after fatigue when compared to less invasive partial coverage restorations.[122]

Stappert et al.[116] also showed that maxillary molars restored with IPS e.max Press and ProCad restorations survived loads within the range of physiological mastication forces.

Veneer onlay

There are times when you may wish to veneer the buccal surface of a posterior tooth but encounter a defective one-, two-, or three-surface posterior restoration.[123] The question is: should you further reduce the buccal wall and have only a strong lingual wall to help retention, or would it be better to save the buccal enamel? You could save the buccal wall by laminating the buccal surface and extending that veneer into the mesio-occlusodistal preparation, making it a "veneer onlay" (Figure 15.20E). Goldstein introduced the concept of a "laminate onlay" in 1998.[124] In 2005, Stappert called this a "veneer onlay," modified as "full veneer," for the treatment of premolars with cervical and occlusal/proximal defects or existing fillings for press ceramic materials in 2005.[27] Pressable e.max Press ceramic (first published as Experimental Press Ceramic, or EPC) was scientifically investigated for this application for the first time. Full veneers made of e.max Press ceramic reached fracture strength values corresponding to those of natural unprepared premolars. All-ceramic full veneers for premolars offer an excellent esthetic solution for premolars with multiple defects and proved to be highly fracture-resistant restorations[27] (Figure 15.20A–G). Therefore, this form of treatment should be considered as a less invasive and esthetic alternative to full crowns. In 2015, McLaren, Figueira, and Goldstein used the term "vonlay" to further describe the technique. The technique used feldspathic porcelain and, according to Goldstein, it never caught on mainly because of fear of fracture in the posterior with the then available materials and bonding techniques.[125]

Impression

Impressions for posterior etched porcelain are best taken digitally or with PVS. Since the gingival margin ends in a rounded shoulder, tissue displacement with retraction cord should be sufficient to obtain an excellent, easy-to-read impression of this area.

Insertion

Insertion for the etched porcelain restorations involves try-ins, one at a time, then in groups if necessary. The occlusion should not be evaluated until all of the restorations are initially seated.

Cementation of posterior ceramic inlays, onlays, and partial coverage restorations is similar to anterior veneers with certain differences. Foremost is the consideration that the inlay, onlay, or partial coverage restoration is much thicker than the anterior veneer, requiring more emphasis on a dual cement, or self-curing cement, to bond properly.[126]

Usually, once the shade was taken properly and the ceramic ingot chosen accordingly, the ceramic restoration matches or blends sufficiently to the residual tooth structure. Due to the increased thickness of a partial coverage restoration when compared to a veneer, the influence of the luting composite has less impact on enhancing the color of the final restoration. However, there are times when it takes a significant amount of opacifier or stain to influence the shade of the cement sufficiently to blend the color of a ceramic posterior restoration that is too light for the tooth.

Finishing

A major consideration in cementation of posterior restorations is the attention that must be paid to removing excess cement in the interproximal areas. The LVS-5 should remove all excess resin cement. A Mylar strip through the intact areas during polymerization should only be used if it is approximately 0.002 mm thick or less (matrix strips made of Dupont Mylar 0.002 gauge, 10 cm × 1 cm; Henry Schein). The danger in using

Figure 15.20 **(A)** This 62-year-old female had erosion and discoloration of her maxillary teeth. She was particularly concerned about the defective amalgam restorations showing through the maxillary right bicuspids and first molar.

Figure 15.20 **(B)** The occlusal view shows how closely involved the posterior amalgams were to the buccal surface. Choices for treating this problem were posterior composites, posterior ceramic inlays/onlays, or full crowns. The compromise solution was the veneer onlay.

Figure 15.20 **(C)** CIP-I (Brasseler USA) diamond was used to prepare the occlusal portion, removing all defective amalgam, and then glass ionomer liners were placed as build-ups for the dentin defects.

anything thicker than this is in the increased possibility of not fully seating the restoration. It is wiser to insert the ceramic restoration and carefully observe the cementation set, using a 5–8 s polymerization time, and then removing the interproximal excess cement before final polymerization. Make sure that floss will clear the contact area. If the floss does not go through, an ET3 or end-cutting ET may be successful in removing the excess. Another quick way to break through the contact is to use a interproximal finishing and contouring strip (Brasseler ET Flex or Qwik Strip, Kerr). However, if some of these thin pieces remain, they may eventually be dislodged through normal occlusal function. Therefore, have the patient go home with a well-balanced occlusion, and check within 1 week to attempt clearing the contact area if excess cement still remains. Occlusal adjustment is accomplished by using the OS1 in a 30-or 15 μm grit. If necessary, the OS2 then places or corrects initial grooves, followed by the OS3 for final groove finishing plus smoothing of any pits or fissures. The final finishing is done with either a 30-bladed carbide or 8-mm diamond (DETUF series). Final polishing can be accomplished with impregnated points then porcelain polishers such as Dialite Feather Lite spiral porcelain polishers in sequence (Brasseler USA).

Patient instructions

Instructions to patients with new partial coverage restorations are similar to those for porcelain veneers, with emphasis on good homecare and plaque removal.

Alternative techniques

The production of ceramic restorations using the lost-wax press technique has been addressed already; yet modern CAD/CAM technology also allows fabricating veneers, inlays, onlays, and partial coverage restorations with similar precision and significant less laboratory procedures. Two representative CAD/CAM systems will be introduced, the CEREC and the Carestream systems.

Figure 15.20 **(D)** The buccal view shows that the bucco-occlusal wall is reduced sufficiently so that the porcelain can lap over to the occlusal surface and have sufficient thickness and strength to resist breakage.

The CEREC system

The field of dentistry has witnessed a remarkable transformation in many areas, especially when considering digital impression technology for manufacturing indirect restorations. Ever since the development of CEREC, an acronym for *ce*ramic *rec*onstruction, by W. Mörmann and M. Brandestini, the profession has taken advantage of providing same-day dentistry while maintaining quality in a best-practices approach. This CAD/CAM technology has evolved for the better part of 30 years; however, despite its longevity in the field, CEREC has made significant advances in recent years, not just on the technology frontier, but also as an increased treatment modality for the general practitioner. CEREC (Sirona) integrates computer technology with CAD/CAM and infrared optical imaging cameras,

Figure 15.20 **(E)** This view of the veneer onlay shows the buccal portion and how it is connected to the posterior inlay portion.

Figure 15.20 **(F)** This occlusal view shows the veneers cemented in place. Occlusion is correctly supported and there have been no fractures in the 20 year postoperative history.

Figure 15.20 **(G)** The buccal view shows that the veneer onlays blend in as if they were full crowns. This means that on normal viewing the restoration looks more like a natural tooth, even more so than a simple veneer, which may not overlap onto the occlusal surface.

which then allows the design and milling of these porcelain/ceramic materials.

The system's chief appeal is its immediacy: restorations can be milled, fitted, seated, and finished in a single appointment. Another advantage of computer-generated restorations is that they provide a more economical restoration than the traditional, laboratory-produced ones. CEREC saves time and costs for both patient and dentist since it eliminates the impression, temporary restoration, and laboratory. Limitations of the early CEREC systems included their inability to do internal staining and the presence of greater marginal gaps than with conventional, indirect laboratory methods. The later generation, CEREC 3 was introduced based on 3D technology, while the first three models were based on 2D technology. 3D software was introduced in 2003, and allowed dentists to construct restorations based on virtual 3D models using the computer. Since 2006 software versions have included the options of automatic adjustment of a selected digital full-crown anatomy to the individual preparation, the proximal contacts, and the occlusion.[127] The latest software (CEREC software version 4.5.1) simplified the user interface that allows dentists to work on several restorations with a single process.

The CEREC Omnicam, launched in 2012, has many advantages over its predecessors. The main benefit is its ability to continuously acquire data, generating a 3D model in a powder-free manner. The length of the camera sleeve is 108 mm, the height and width of the tip are 18 mm, and it weighs 313 g. The size and weight allows the digital impression to be quickly taken, which is beneficial to the dentist and most importantly the patient.

In addition to the inlays and onlays produced by the original systems, the later generations are much more diverse, allowing the practitioner to manufacture veneers and crowns with the basic milling operating system.[74] The different ceramic materials even with the basic milling hardware include feldspar ceramic, glass-ceramic, lithium disilicate, translucent zirconium oxide (TZI), and hybrid and mono-sized polymer blocks. There is also a multitude of packages for the hardware and software if the practitioner is interested in complete autonomy from a dental laboratory. If the practitioner has an in-office laboratory, the possibilities allow access to the complete CAD/CAM spectrum including four-unit bridges, zirconium oxide and lithium disilicate abutments, and implant surgical guides. The practitioner can also digitally impress a field to be restored and send the digital information to a chosen laboratory via Sirona Connect, aiding in optimal dental esthetics. Another advantage of the CEREC system is utilizing integrated implantology for the surgical and prosthetic planning of implant placement.

There are now a multitude of ceramic blocks that can be selected depending on the type of indirect restoration. So, dentists can choose from an array of Sirona, Vita, 3 M, or Ivoclar Vivadent blocks. Some of the commercially available ceramic blocks include feldspathic porcelain-based Vita Mark II, leucite glass-ceramic IPS Empress CAD, and lithium disilicate glass-ceramic IPS e.max CAD blocks.[128] Each block has advantages and disadvantages;

therefore, the dentist's knowledge of each available material is important.[115] Many factors need to be considered before choosing which material to use, but the most important factor to consider is the size of the preparation. The superior esthetics required for anterior restorations can easily be achieved through various forms of custom shade modification including external staining and in-office firing in a small porcelain furnace.[75]

CEREC uses a smaller diamond grain size to increase the marginal integrity of the restorations. There are different milling bur options, but as far as the orientation of the milling instruments, the left milling bur is a step bur designed to mill the intaglio surface of the restoration while the right milling bur is a cylinder pointed bur responsible for milling the occlusal surface of the restoration. These burs allow the restorations to be fabricated with significantly improved accuracy of ±25 μm.

Shade selection

Selecting the shade of the CEREC ceramic block requires visualizing the size, shape, and location of your intended restoration. Ideally, the dentist should determine the block shade at the outset before the tooth has had a chance to dry out and change color (Figure 15.21A–C). If color characterization is desired, you can make adjustments using stains or shaded bonding materials at the time of cementation. Conveniently, if the patient is dissatisfied with the crown after milling, a closer shade can be selected, finer detail can be adjusted to the restoration, and a new block can be milled if necessary.

Preparation

Clearly defined, smooth cavosurface and cervical preparation margins are recommended (Figure 15.21D–F). Important considerations for the practitioner are to avoid undercuts and "lips" or "spikes" specifically on the margin. Finally, finish the preparation with a fine or superfine bur to smooth all sharp angulations and artifacts. The reasoning behind this is the milling burs will not sacrifice material for the sharp artifact resulting in an inaccurate fit. It is important that the practitioner knows the minimal thickness requirements for each restorative material selected.

Figure 15.21 **(A)** Pre-op picture with secondary decay at teeth #14 and #15.

Figure 15.21 **(B)** Leaking amalgams were causing patient sensitivity.

Figure 15.21 **(C)** Bitewing X-ray of teeth #14 and #15.

Figure 15.21 **(D)** Periapical X-ray of teeth #14 and #15.

Figure 15.21 **(E)** Removal of amalgam restorations showed visible decay at teeth #14 and #15. Distal and lingual crack noted for tooth #15.

Figure 15.21 **(F)** Final result of tooth #14 with direct two-surface (occlusal, lingual) composite restoration. Restoration was finalized under rubber dam. Final preparation for an indirect CEREC onlay restoration was performed for tooth #15.

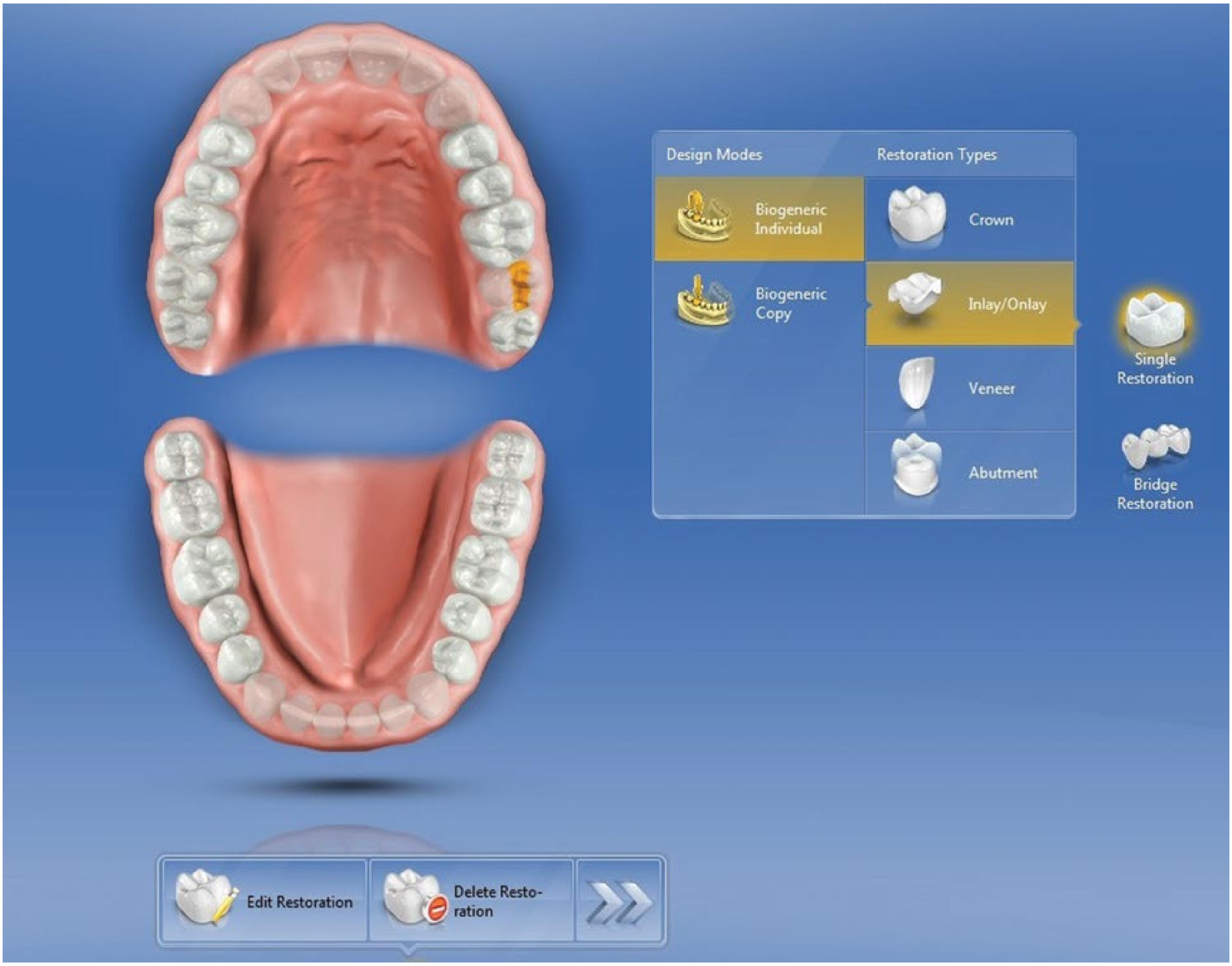

Figure 15.21 **(G)** Initiation of intraoral CEREC Omnicam scan for onlay restoration at tooth #15.

Digital impression

With the advances in technology with the Omnicam there is no need for powder when creating the digital impression, making it much easier for the practitioner and more convenient for the patient. The camera is moved 0–15 mm away from the tooth surface, capturing precise 3D images in natural color. The continuous capture of the tooth is simultaneously displayed on the monitor enabling the practitioner to efficiently move the camera over the field. The digital impression reduces chair time and improves the level of comfort and treatment acceptance for patients.[122,129,130] Another advantage of the digital impression is removing the need for impression trays, impression guns, and adhesives[130] (Figure 15.21G and H).

Design and milling procedures

During the design phase the practitioner has the ability to design the restoration with precision and efficiency, and there is a convenient tool to capture the original tooth anatomy (Figure 15.21I–J). The computer can then use this data to fabricate a final restoration that closely resembles the tooth prior to preparation. The practitioner also has the option to fabricate a customized restoration for each individual patient (Figure 15.21 K). After the restoration is designed, the computer analyzes the data and provides instructions to the milling machine. The milling of a single-tooth restoration can take upwards of 11 min and it is possible to digitally impress and design the restoration in 2–4 min (Figure 15.21 L). Once the practitioner becomes familiar with the software, it is possible to have the final crown milled approximately 15 min after the tooth is prepared (Figure 15.21 M and N).

Placement

The digital impression and milling processes reduce inaccuracies that can result from the laboratory fabrication process and the CEREC technology is able to manufacture a restoration that fits within the 50–75 μm range.[131,132] After the fit is assessed and approved, the restoration can be cemented in place using dual-cure microfilled composite resin cement (Figure 15.21O and P). Research has shown that the microfilled particle composite wears two to three times better than a hybrid composite.

The CEREC is a CAD/CAM system that produces full ceramic restorations of various kinds in a single step, by means of a fully automated grinding process, within a short period of time.[133] Computer-generated restorations can offer a lower-cost tooth-colored restoration for the patient and with the advances of technology and materials it is now possible to esthetically please the most demanding of patients even when considering a single anterior restoration. Therefore, for the great majority of patients, the advantage of a one-appointment ceramic restoration outweighs this slight esthetic deficit and makes it an ideal solution.

Research

In 2003, a study by Posselt and Kerschbaum evaluated 2328 ceramic inlays and onlays in 794 patients and reported a survival rate of 95.5% at 9 years.[134] A 10-year study completed by

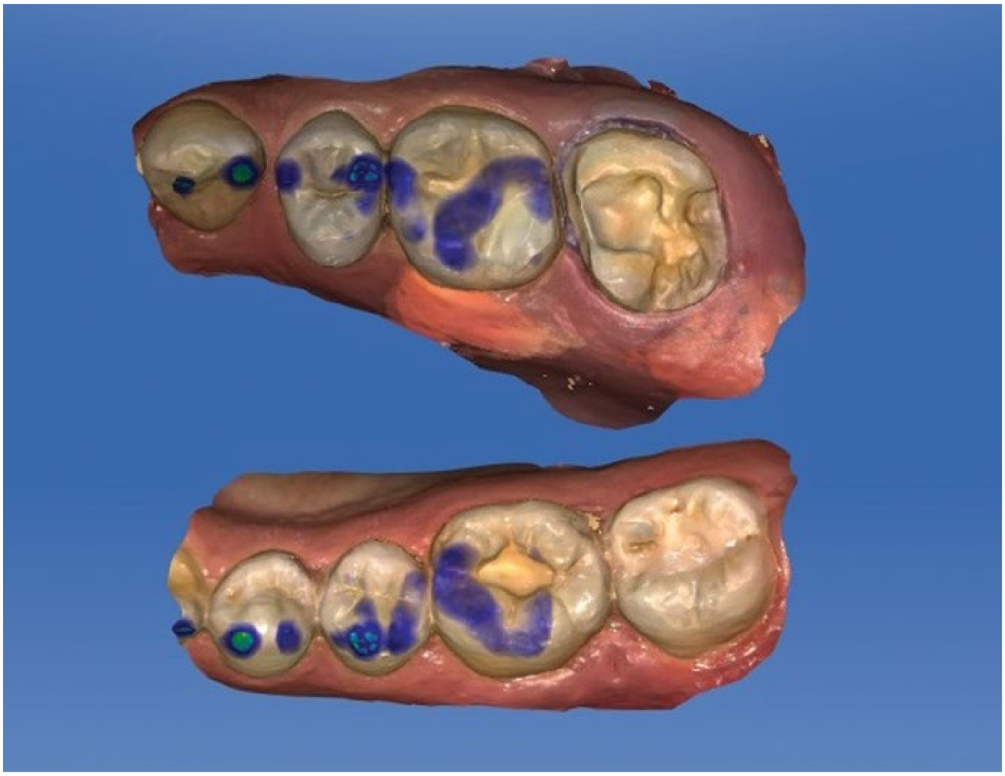

Figure 15.21 **(H)** Pictures of Omnicam digital impressions and restoration design.

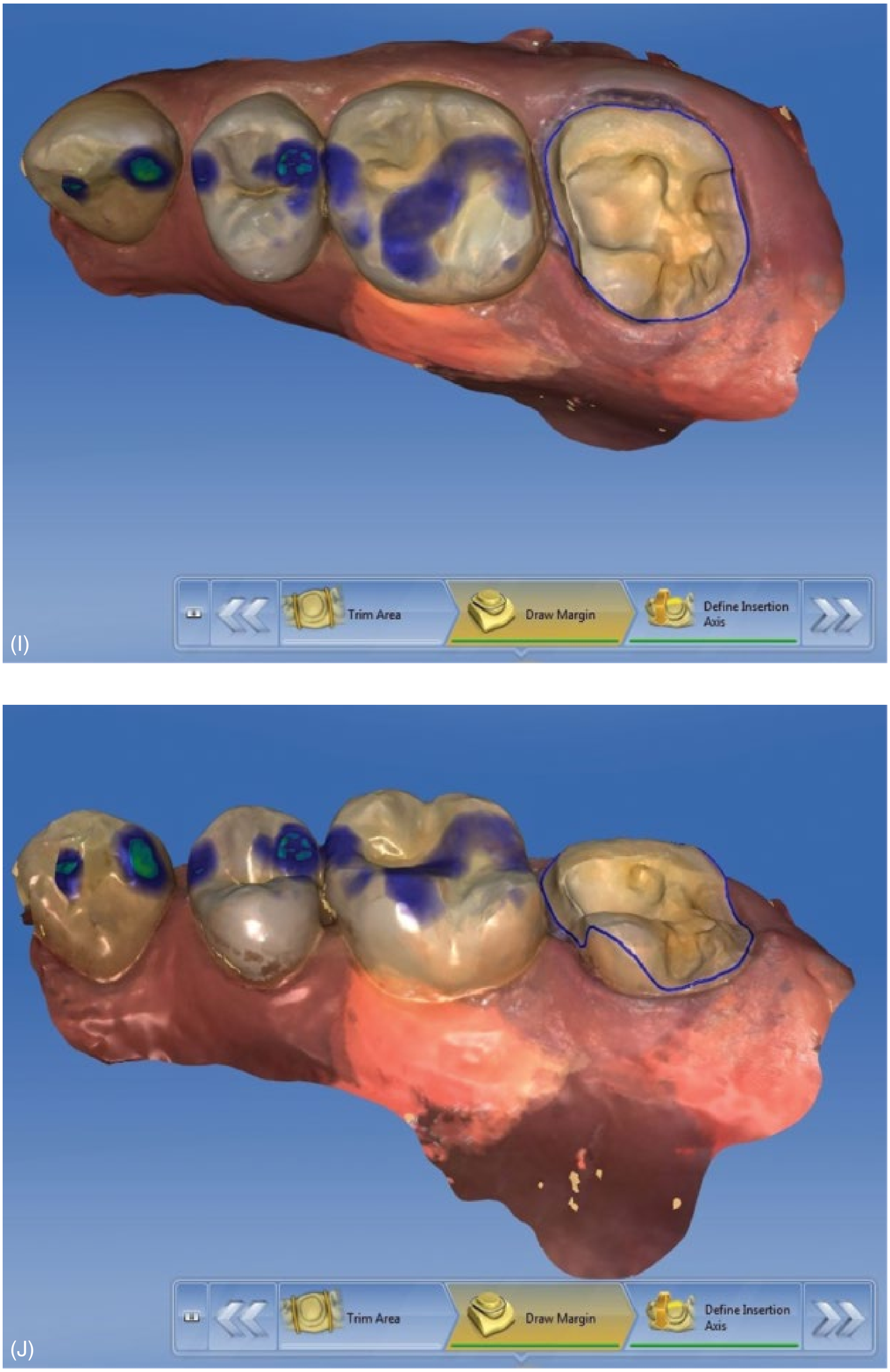

Figure 15.21 **(I and J)** Preparation margins are defined by drawing the borders of the onlay restoration: occlusal and lateral views.

Zimmer et al. assessed the longevity of the CEREC restorations placed in Class I and Class II preparations.[135] The study demonstrated a 94.7% survival rate after 5 years and an 85.7% survival rate after 10 years. They concluded that the CAD/CAM restorations are durable alternatives to direct and laboratory-fabricated restorations. In another 10 year study Sjögren et al. evaluated the performance of Class II CEREC inlay restorations with two different types of cement.[126]

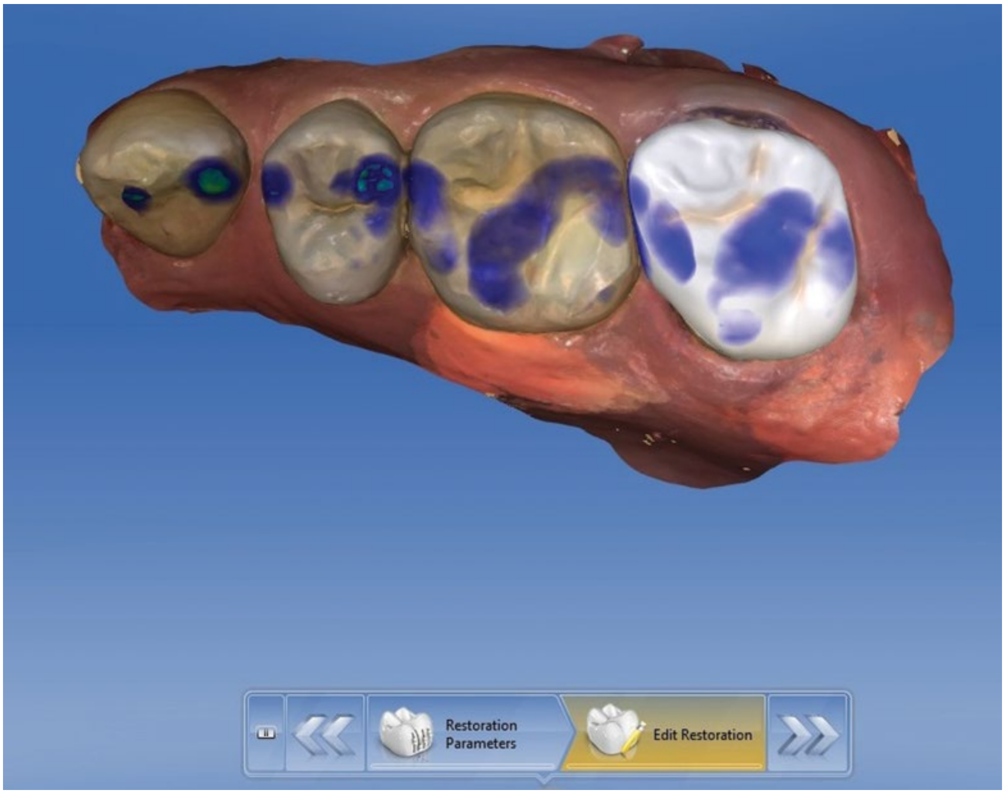

Figure 15.21 (K) Restoration parameters, restoration extension, and contact areas are digitally defined.

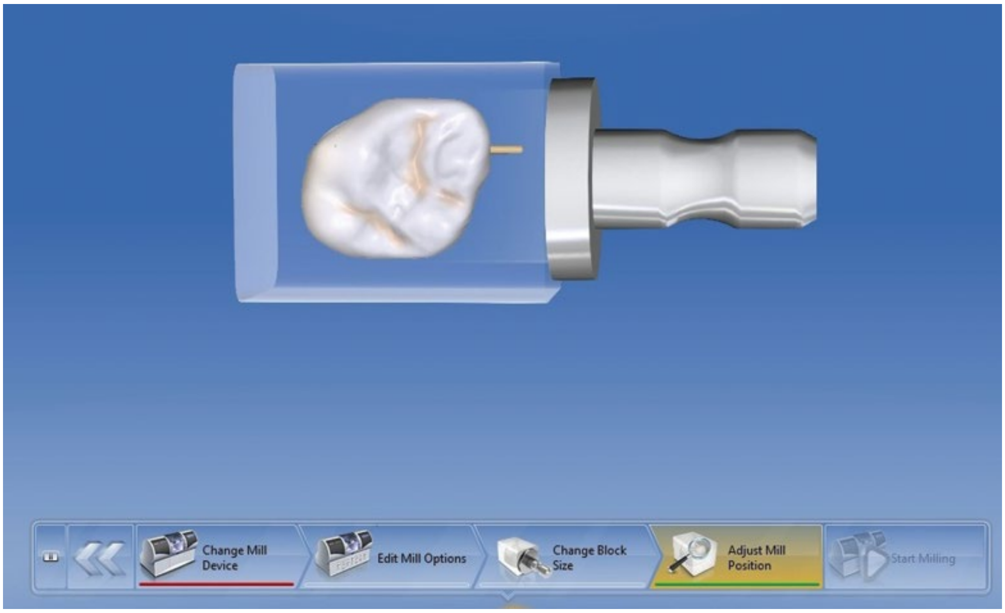

Figure 15.21 (L) The final workpiece gets finalized; block type and size are chosen, and positioning of the ceramic restoration in the milling block defined.

They showed an 89% survival rate after a 10 year reevaluation and demonstrated a statistically significant difference when comparing the survival of inlays cemented with dual-cured resin composite-luted inlays (77%) and chemically cured resin composite-luted inlays (100%). Furthermore, they state that "patient satisfaction with and acceptance of the CEREC inlays were high, and the performance after 10 years of clinical service was acceptable, especially regarding the inlays luted with

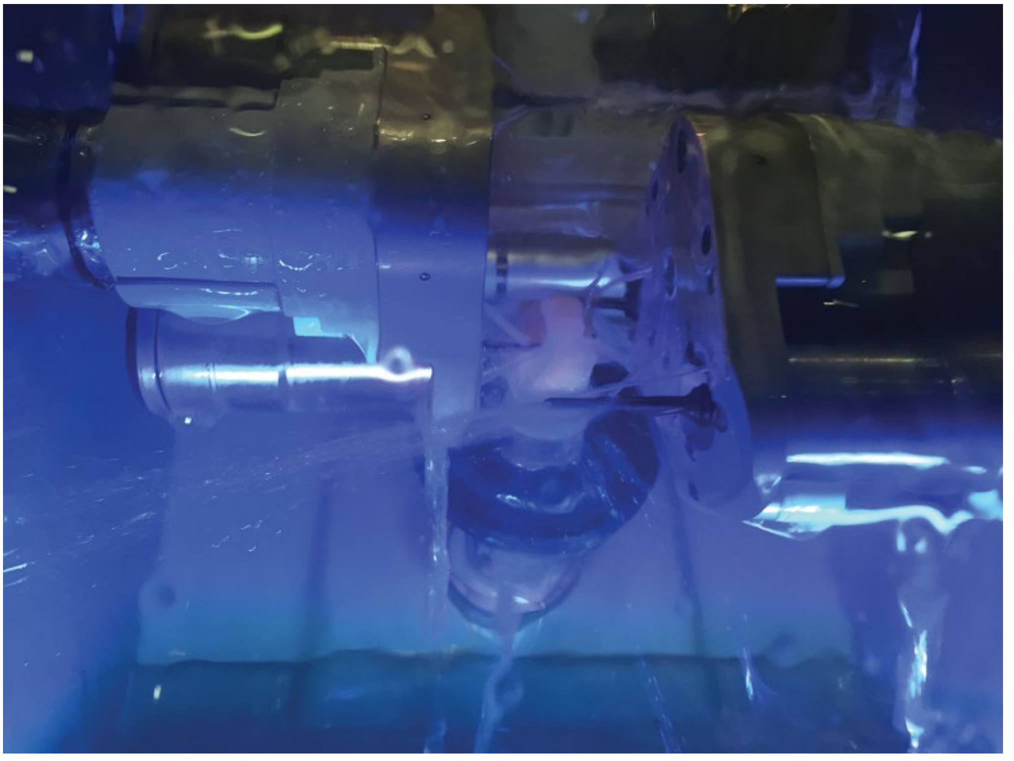

Figure 15.21 **(M)** CEREC milling of the CEREC e.max CAD restoration in process.

Figure 15.21 **(N)** Custom anatomy and staining of e.max CAD indirect restoration.

the chemically cured resin composite." Fasbinder concludes that CEREC restorations have reportedly approached a 97% survival probability for 5 years and a 90% survival probability for 10 years.[136] He states "the low rate of restoration fracture and long-term clinical survivability document the effectiveness of the CEREC system as a dependable, esthetic restorative option for patients."

Researchers measured margins of approximately 50 μm, suggesting that the marginal fit of CAD/CAM-generated restorations is clinically acceptable.[137,138] Denissen et al. reported average marginal accuracy of 85 μm for onlay restorations manufactured by CEREC 3, which was similar to laboratory-fabricated onlay restorations[139] (Figure 15.22A–D).

The Carestream system

CS Solutions from Carestream offers the ability to scan, design, and mill and place restorations in one appointment. It consists of an intraoral scanner, cone beam computed tomography (CBCT) impression scanning system, restoration design software, and a relatively small milling machine that can be easily placed in the dental office. As with other similar scanning systems, if the dentist does not want to mill in the office there is a web-based platform which can share and manage restoration cases between dentists and laboratories.

There is minimal training required via a light guidance system during image capture, easy but fast impression scanning, intuitive restoration design, and simple milling instructions. The entire milling process takes about 15 min.

Using the CS 3500 intraoral scanner images can be acquired in true color, and 2D and 3D digital impressions. It offers high-angulation scanning of up to 45° and goes to a depth from −2 mm to +13 mm. There is no powder required to obtain quite clear images. Its internal heater prevents mirror fogging during the scanning procedure. Once the scanning is complete, the CS Restore CAD software helps design the restoration, featuring advanced algorithms to help create contours and anatomy of the restoration (Figure 15.23A–C). However, there are also controls

Figure 15.21 **(O)** Final adhesive bonded CEREC restoration at tooth #15, and final direct restoration at tooth #14, occlusal view.

Figure 15.21 **(P)** Lateral view of restored teeth #15 and #14. Case courtesy of Jacob Truan DMD.

Figure 15.22 **(A)** A 28-year-old male patient with mesial decay under a gold restoration on tooth #30.

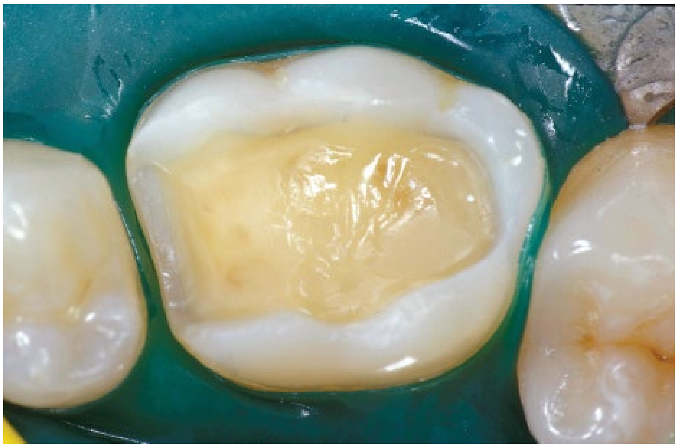

Figure 15.22 **(B)** The gold restoration was removed and decay eliminated. A preparation for a CEREC e.max CAD ceramic restoration was performed followed by an intraoral scan.

Figure 15.22 **(C)** Final CEREC CAD/CAM inlay restoration, with occlusal surfaces customized by coloring and glazing technique, was prepared with hydrofluoric acid and Monobond-S (silane) for adhesive cementation.

Figure 15.22 **(D)** Final result after adhesive bonding under rubber dam of the CEREC inlay restoration. Color match and marginal adaptation were achieved.

Figure 15.23 **(A)** This patient had caries under her old amalgam restoration plus occlusal-lingual and occlusal-buccal micro cracks.

Figure 15.23 **(B)** The buccal-occlusal-lingual preparation shows caries removed in the central groove area.

to be able to individually customize the restoration by enlarging, taking away, and building up the occlusion or walls if desired (Figure 15.23D). One tip is to magnify the marginal lines to make sure they are precisely where you want them to be. If in doubt, extend the margin so it will not be necessary to redo the scan and repeat the design since it is much easier to just trim back any overextended margin.

The CS 3000 milling machine is a CAM unit that features a four-axis brushless motor that produces restorations with ±25 μm accuracy. It is relatively quiet and can even be rolled into the treatment room if desired (Figure 15.23E). Certainly one of the most important advantages of the entire system is that a trained dental assistant can perform much of the required procedures once the preparations are completed by the dentist (Figure 15.23 F–I).

Conclusion

The original purpose of offering reversible bonded restorations was to take advantage of future technology. That seems to have been a worthwhile approach. Many patients, who 10, 15, or even 20 years ago trusted us to give them restorations with what was then a new procedure called bonding, still have their composite resin posterior restorations and veneers in place. Some return to take advantage of the increasingly better materials and replace their composite restorations with porcelain restorations. The future of esthetic restorative dentistry will no doubt see considerable improvement in longer-lasting cementing materials, ease of construction, and the porcelain materials themselves. Finally, future advancements in CAD/CAM capability will no doubt have a positive effect on all aspects of both anterior and posterior restorations.

Acknowledgment

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Figure 15.23 **(C)** The Carestream CS Solutions scanner was used to capture the restoration and occlusal bite registration.

Figure 15.23 **(D)** The proposed restoration was easily designed for marginal fit and occlusal contact on the computer.

Figure 15.23 **(E)** The restoration was milled in 15 min on the Carestream CS 3000 milling unit.

Figure 15.23 **(F)** Inlay restoration captured, still connected by the sprue pin to the CAD/CAM ceramic ingot.

Figure 15.23 **(G)** Rubber dam is applied and the restoration cemented with a resin luting cement (Duo-Link Universal, Bisco). Then the sprue pin residue is cut off and contoured.

Figure 15.23 **(H)** Occlusal adjustment is performed and final polishing is accomplished using Dialite Feather Lite flexible spirals (Brasseler USA).

Figure 15.23 **(I)** The final ceramic restoration was placed to complete a 1 h appointment.

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Chapter 16 Crown Restorations

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A dental crown restoration can offer a remarkable service for a dental patient. The objectives of a crown are to restore function and esthetics for a treated tooth. This process may involve caries removal, endodontic therapy, periodontal therapy, and treatment of multiple teeth. A careful evaluation of the patient's occlusion provides the opportunity to establish ideal function. Meticulously observing tooth shape, shade, and texture ensures a pleasing result in the appearance of the new crown. When carefully crafted, the dental crown restoration has excellent long-term survival.

Indications for a complete coverage crown

The following are indications for a complete coverage crown:

- teeth with extensive caries
- teeth weakened by extensive restorations
- teeth with excessive wear
- teeth severely weakened or prone to fracture as a result of endodontic treatment

Ronald E. Goldstein's Esthetics in Dentistry, Third Edition. Edited by Ronald E. Goldstein, Stephen J. Chu, Ernesto A. Lee, and Christian F.J. Stappert.

- teeth fractured or compromised with extensive microcracks
- restoration of the plane of occlusion as in the case of extruded teeth or teeth below plane of occlusion
- malformed teeth
- abutments for fixed partial dentures
- teeth with excessive interdental spaces
- teeth with excessive recession where soft tissue grafting is not appropriate
- restorations on implant abutments.

A patient should be informed of the ways that a full coverage crown can benefit them; however, the patient must also be informed of the potential complications of treatment. In some situations, detection of caries or cracks under existing restorations may require additional dental treatment, such as endodontic or periodontal therapy.

A crown can potentially remain functionally sound for the life of the tooth, but there are several factors that can affect the lifespan of a crown. After insertion of a restoration, the dentist should emphasize the importance of good home care and compliance with hygiene recall appointments, as a natural tooth is still susceptible to caries underneath the margins of a crown. Crown material fracture is a risk with all ceramics and porcelain. Changes in soft tissue and bone and changes in shade of adjacent natural teeth may also require remake of the crown at some point in the future.

Diagnosis

Some crown failures result entirely due to the lack of proper diagnosis and treatment planning from the onset. Major considerations that confront the dentist are patient expectations, existing disease, and esthetic and functional diagnosis. Treatment technique, material choice, and communication with the dental laboratory technologist are critical to successful patient care.

Adjacent teeth and the opposing ones need to be examined and evaluated for esthetics and function. An opposing tooth or neighboring tooth may need to be reshaped or restored to create a correct plane of occlusion or to give the desired esthetic result of a patient's smile (Figures 16.1A–B and 16.2A–F).

Photographs

Digital photographic records should be used as part of diagnosis. Photographs allow the dentist and the patient to see the issues from the same perspective and serves as a discussion point for esthetic and functional goals. Pretreatment photographs can help predict how complex the esthetic correction will be (Figures 16.1A and B). It should become evident to the patient that the range of problems present and the relative difficulty of the treatment can affect treatment time and case fee. *It is preferable to subtly introduce the relationship between difficulty and fees at this early stage rather than later.* Photographs also open a dialogue with the dental laboratory technician about the challenges they will encounter with the patient's treatment.

An effective photographic technique has been developed by Kuwata.[1] In this quick and easy-to-use system, photos can be made and stored in computer photographic software such as Apple's Aperture or Adobe's Lightroom™. The photographs can be downloaded to the storage program and minor adjustments made so that they are presentable to the patient and the images can be easily e-mailed to the technician or printed. The dentist can also place some images into presentation software such as Apple's Keynote or Microsoft's PowerPoint™ and draw lines defining symmetry and occlusal or esthetic planes. An extraoral digital video camera can also be very effective to determine the display of teeth during speaking, laughing, and with the smile analysis.

Technical considerations

An understanding of dental laboratory procedures is important because the quality and accuracy of the restorations may impact why esthetic restorations fail. Often, failure arises from poor planning and neglect of details by the dentist or the technician, so the dentist must give the technician a clearly defined and detailed laboratory prescription.

Figure 16.1 **(A)** This patient presented with esthetic and functional concerns. Due to a loss of vertical dimension and loss of canine guidance, the anterior incisors tooth length was significantly reduced. Additionally, a crossbite on the upper left side made her upper left teeth almost invisible.

Figure 16.1 **(B)** Clinical thorough evaluation, planning models, wax-up simulation and photo documentation led to an comprehensive treatment planning to restore periodontal, functional and esthetic concerns of the patient (Figures 16-2A–F).

Figure 16.2 **(A)** After periodontal treatment, a mock-up of the new inter-maxillary dimension was used to minimize tooth structure reduction. The anterior dentition was prepared for butt-joint veneers, and the posterior dentition received thin lithium-disilicate 360° crown-veneers.

Figure 16.2 **(B)** The patient has high esthetic demands, and expectations. A request for 'very white teeth' should be addressed in a reasonable range of brightness, since too white teeth often lack recognizable surface texture and transparency.

Figure 16.2 **(C)** To restore the dental display at the left buccal corridor, and adjust the vertical inter-maxillary dimension, IPS e.max Press 360° monolithic crowns and veneers were fabricated. Average ceramic thickness ranges from 0.3 to 1.2 mm.

Figure 16.2 **(D)** The ceramic restorations were delivered with adhesive bonded resin cement under Rubberdam. Note the improvement in character, color, and shape. The new incisal position allowed for a steeper anterior guidance and provided adequate posterior separation.

Figure 16.2 **(E)** Anterior central incisor and canine veneers follow the lower lip-line, barley touching the lower lip. Visibility of the upper and lower teeth during a light smile, creates a youthful impression.

Figure 16.2 **(F)** The patient is seen happily smiling with her new ceramic restorations. The buccal corridor displays beautiful teeth on both sides evenly. The lower facial third becomes more recognizable, guiding the observer's view in a triangle between the patient's eyes and smile. Courtesy of Insititute of Advanced Dental Education GmbH, Zurich.

Successful esthetic and functional results primarily depend on adherence to sound principles of form, correct occlusion, articulation, and contacts. This is emphasized in a retrospective study of 320 crowns by Gropp et al.[2] Regardless of the materials used, abnormalities of occlusion and articulation were found in 14% of all crowns. Missing interproximal contacts were present in 19%, which caused noticeable inflammation in 9.5%, pocket formation in 5.5%, and radiographic abnormalities of the marginal periodontium in 6% of the cases. The cervical portion of the tooth was denuded in 31% of the cases, resulting in a 12% incidence of cervical caries. Esthetics will also be compromised when functional breakdown occurs.

Choice of materials with associated technique considerations

The choice of an appropriate restoration material depends on the functional and esthetic demands that will be placed upon it. Gropp et al.[2] also indicated that, functionally, the all-cast crown was the most successful, especially when precision casting techniques were used. This was followed in clinical acceptance by porcelain-fused-to-metal crowns, full ceramic crowns, and then full acrylic crowns. Whereas previously the standard of care for esthetic ceramic materials was porcelain fused to gold or all-ceramic materials, the standard for quality individual restorations today is principally a monolithic all-ceramic. The all-ceramic materials have developed from Dicor, In-Ceram, Ivoclar Porcelain System (IPS Empress), to bilayer zirconia–feldspathic porcelain combinations to monolithic IPS e.max Press or CAD and all-zirconia restorations.

Gold

The full gold crown has always been considered by dentists to be the most functionally sound, longest lasting restoration of its type. Its excellent marginal adaptation can be seen in Figure 16.3. It is a conservative restoration requiring much less reduction of tooth structure than an all-ceramic or porcelain-fused-to-metal crown, and its wear rate approximates that of natural enamel. If patients cannot see a gold restoration or they have little objection to it or the increasing cost, a yellow gold restoration is an excellent dental material to be used with partial or full coverage single tooth restorations. However, there are still some patients who prefer the longevity of full gold restorations (Figure 16.4A–C).

Figure 16.3 The gold crown exhibits excellent long-term stability and marginal integrity. The first bicuspid is restored with an e.max inlay, and the second bicuspid with an Empress crown.

Plus, a micro-etcher or air-abrasive device can dull or antique the gold sheen of the crown (Figures 16.5A–C and16.6A and B).

Resins

Resin technology has developed significantly but does not have the physical strength characteristics necessary for use as final restorations with the expectation of long-term survival. Resin technology has been one of the most notable advancements in esthetic dentistry; therefore, it is important to understand a modern historic perspective of the different materials.

Acrylic resin or composite resins have been used to construct anterior full crowns (Figure 16.7A and B). Translucency, reasonable color stability, ease of construction and color matching, and economics have enhanced its popularity as a provisional restoration. It is relatively easy to obtain a good fit, and the material is biologically acceptable for short periods. Wear at the contact areas does not appreciably affect arch length or embrasure form. However, the material will abrade along the incisal edge. Because it also absorbs bacterial biofilms, leading to staining, it may be poorly tolerated by tissue and is too elastic.[3] An acrylic crown should be used as a long-term provisional fixed bridge or individual crown only in those instances where it is specifically indicated by circumstances or lifestyle, or when it may take the patient several years before they will be in a financial position to undergo correction in metal or ceramics, or a combination of the two. To reduce wear and staining, acrylic veneers or crowns can be hardened by heat processing[4] and curing under pressure.[5]

A later generation of veneering materials is light-polymerized composite resin (Dentacolor, Jelenko/Kulzer, Inc., Isosit-N, Ivoclar; and Visio-Gem, ESPE GmbH). Designed for indirect veneering in the laboratory, these composite resins had definite advantages over acrylic resins.[6] Composite resins may also be valuable in the repair of metal–ceramic restorations from which the porcelain has chipped off or fractured. If the restoration is otherwise serviceable, then the porcelain may be repaired by first creating micromechanical retention with an air abrasive, then acid etching, using silane coupling agents, and bonding with composite resin.

The two most significant problems with resins or composite resins are microleakage and occlusal wear. For example, Gallegos and Nicholls found that when opposing porcelain over a period of time, Isosit-N lost approximately 70% of its matrix filler, which was greater than that of Visio-Gem, but significantly less than the loss of porcelain under the same simulated functional forces.[7]

Composite resins often chip away from the restoration (Figure 16.8). Greenberg and Rafetto, studying Visio-Gem (ESPE), caution that it must be at least 1.5 mm thick and should not be used on masticatory surfaces because of its potential to chip.[8]

Feldspathic porcelain

Full-feldspathic porcelain crowns manufactured on platinum foils were one of the first attempts to create durable all-ceramic restorations. Today, glass-ceramic materials with enhanced fracture strength are predominantly used for all ceramic crown restorations, but all-feldspathic porcelain material is commonly used for esthetic porcelain veneers.

Figure 16.4 **(A)** This 69-year-old man had previously been functionally and esthetically satisfied with his all-gold crowns. However, when it came time for replacement, another dentist encouraged the patient to choose metal–ceramic, which shortly thereafter began to chip.

Figure 16.4 **(B)** The patient returned and had the restorations replaced with all-gold crowns.

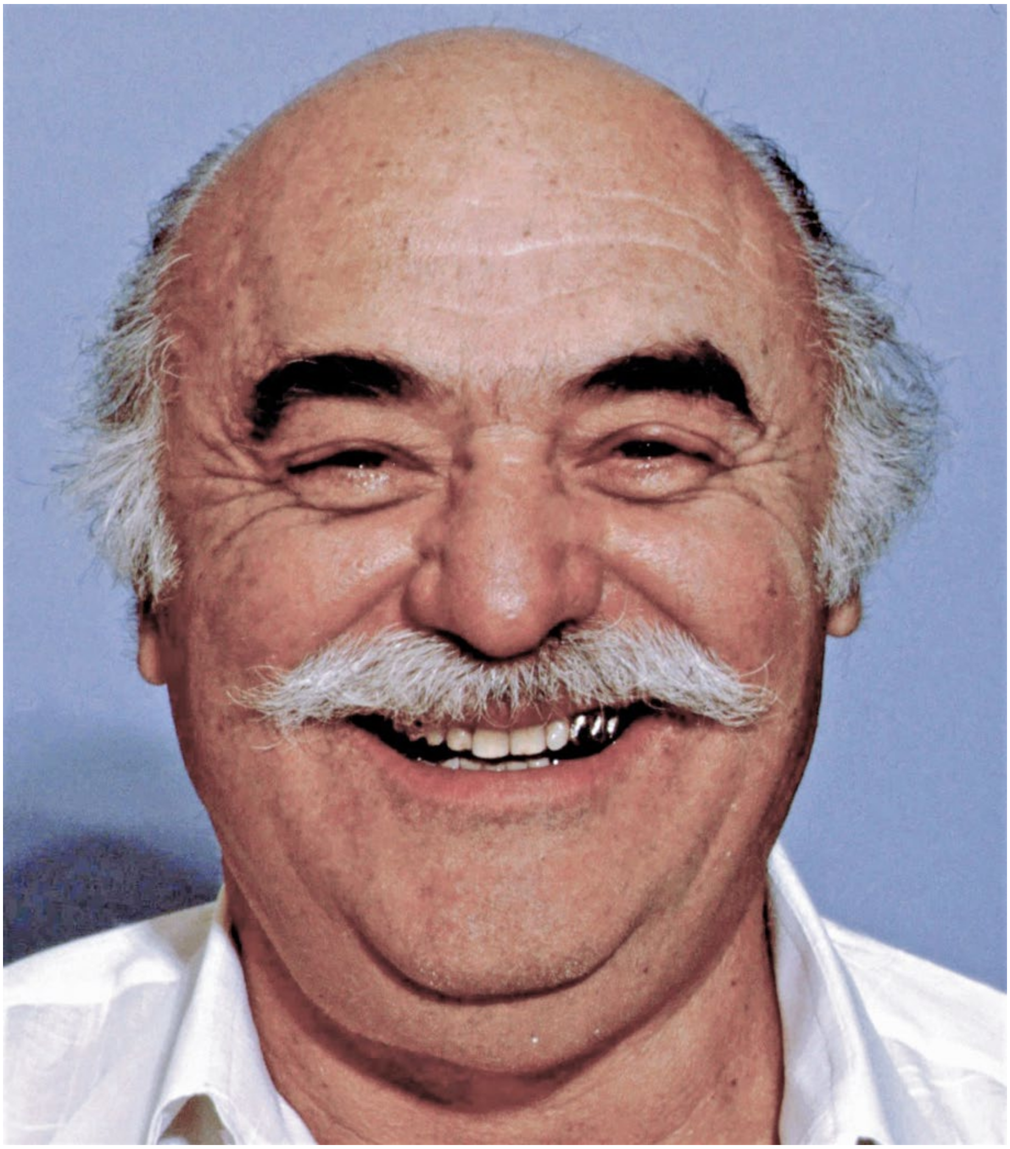

Figure 16.4 **(C)** The patient is seen happily smiling with his gold restorations.

Figure 16.5 **(A)** This three-quarter gold crown on the maxillary first molar shows during smiling.

Figure 16.5 **(B)** Note the esthetic improvement when the patient smiles.

Figure 16.5 **(C)** A simple application with a micro-etcher (Paasche) or air-abrasive device dulls or antiques the gold sheen of the crown.

Figure 16.6 **(A)** This 35-year-old female wanted the longest lasting restorations available. Although she did not want gold showing, esthetics were a secondary consideration.

Figure 16.6 **(B)** The two small areas of gold that showed when she smiled did not concern this patient.

Figure 16.7 **(A)** This patient presented with a fractured fixed-partial denture spanning the maxillary anteriors. Beneath the fixed-partial denture, one of the abutments had fractured and soft tissue recession had occurred.

Figure 16.7 **(B)** Long-term poly(methyl methacrylate) provisionals were provided to allow for an esthetic interim restoration during grafting and endodontic procedures.

Figure 16.8 This indirect, composite resin crown fractured after only short-term use. *Source:* Photograph courtesy of Dr Joseph Greenberg, Philadelphia, PA.

Figure 16.9 An excellent tissue response is typical of this well-fitting, all-porcelain crown.

Advantages

All-porcelain ceramic veneers are considered by many dentists to be state of the art, esthetically pleasing, and minimally invasive restorations. They have the potential to be translucent, color stable, brilliant, and lifelike. If they are acid etched and cemented principally to etched enamel, they have a long life expectancy in most patients. A properly fabricated and artistically produced porcelain veneer is often almost impossible to detect visually. The advent of vacuum firing has reduced bubbles, producing a fine-textured restoration with improved translucency, and increased impact strength. Porcelain is biologically acceptable and well tolerated by the soft tissues (Figures 16.9 and 16.10A and B).

Disadvantages

Feldspathic, IPS Empress, or IPS e.max ceramic veneers must be bonded and cemented preferable to etched enamel. If ceramic veneers are cemented to dentin, the moisture in dentin could hydrolyses the dentin bonding agent and in time could decrease the effectiveness of the bond strength of the adhesive cement.

Contraindications for traditional ceramic veneer use

1. When the tooth has limited enamel present or has interproximal composite resin restorations, where there is extensive dentin exposure.
2. When existing tooth color is so dark or low value that the veneer would not be likely to correct the unesthetic color. (For further information on ceramic veneers please see Chapter 15).

All-ceramic restorations

Figure 16.10 **(A)** This patient was displeased with her smile and requested full porcelain crowns for the longest restorative life expectancy.

Figure 16.10 **(B)** A high degree of naturalness was obtained in these anterior all-porcelain crowns. Proper texture, shade variation, incisal translucency, contours, and embrasures contribute to the esthetic result.

Dicor

Dicor glass-ceramic material (Denstply International, York, PA) was developed by Peter Adair of Boston University Graduate School of Dentistry and David Grossman at Corning Glass Works[9,10] in 1978. After working out details for clinical applications,[11] the material was released to the dental community in 1982. Dicor was a fluorine-containing tetrasilicic glass-ceramic in the Pyroceram family of glass-ceramics. Restorations were made using the lost-wax technique. The casting had to be cerammed to develop internal mica-based crystals to create glass-ceramic form. Dicor was a well-researched dental material that could be used as a monolithic ceramic with surface metallic oxide colorants or used as a bilayer ceramic where it was used as a core with feldspathic ceramic applied as a veneering material. Dicor was first developed to be luted to teeth with zinc phosphate or glass ionomer luting agents. Grossman created a 10% ammonium bifluoride etchant[12] to both clean and etch the surface to allow composite resin luting. Clinical investigations have examined the many variables that might affect the long-term survival of Dicor complete coverage restorations.[13–15] Improved physical and clinical performance was described when Dicor was acid etched.[13] Other studies examined the effect of breaking strength of Dicor related to gender,[13] tooth position,[13] thickness,[14] margin design,[14] and the type of luting agent.[15] Studies have related the fracture resistance of Dicor crowns to crown length and the effect of varying the elastic moduli of the underlying supporting structure.[15,16] The effects that flaws in Dicor or luting agent spaces had on fracture potential and tensile strength were tested, as well as the effects of physiologic aging, abrasiveness, wear, and surface roughness.[4,17–30] The cast-glass preparation required a shoulder with rounded gingivo-axial line angles, or a deep (120°) chamfer. The axial surfaces should be reduced by 1.3–1.5 mm and the incisal or occlusal surface by 1.5–2.0 mm (Figure 16.11A–D) and free of undercuts. Impressions, casts, and dies are obtained in the usual manner. The crown was waxed to full contour, sprued, and invested in a phosphate-bonded investment. Once the crown was cast, it was then heated (cerammed) to grow the proper and mature crystalline form and increase strength. It was then shaded with surface metallic oxides and feldspathic colorants to match the shade and create translucency. Geller and coworkers[20,21] described another application for castable glass. This application involves using the cast glass as a substructure core, upon which porcelain Vitadur N or Vitadur Alpha can be baked (Willis glass). The advantages of using cast glass in this manner include precise marginal fit, margins that do not distort from multiple firings during the porcelain build-up process, favorable reaction of periodontal tissue to the glazed material, and improved esthetics.[22] The combination of a more translucent core, over which internally stained colors and effects are built in, can provide a highly esthetic result. Dicor was researched extensively, and many lessons were learned from its use. It has not been on the market for many years. Table 16.1 covers the most frequent problems concerning all-ceramic crowns.

In-Ceram

In-Ceram glass-ceramic material (Vita, Bad Sackingen, Germany) was developed by Michael Sadoun[7] and originally described as a slip-cast aluminum oxide ceramic. It initially consists of a densely packed slurry (80–82 wt%) of pure aluminum oxide, which is then fired at 1120 °C for 3 h on a refractory die. A lanthanum glass is infiltrated into the porous coping and fired again to 1100 °C for 4 h, producing a coping without shrinkage yet having high mechanical strength (In-Ceram alumina is similar in mechanical properties to 99.9% pure aluminum oxide). The infiltrated In-Ceram coping is dense, homogeneous, and of high strength. This opaque coping is veneered with feldspathic porcelain, creating a bilayer ceramic restoration (Figure 16.12A–L). To minimize surface cracks and to maintain its physical strength, the In-Ceram restoration cannot be acid etched and, like all all-ceramic materials, must never be sandblasted.[23] This ceramic can be luted with either conventional (reinforced glass ionomer) or composite resin luting agents. Clinical investigations have examined the long-term survival in function.[20,24] Because of its purported strength, posterior crowns were made, but the frequency of fracture and long-term survival did not meet expectations.

Figure 16.11 **(A)** This 51-year-old business woman wanted to replace her defective amalgam restorations with esthetic crowns that did not contain metal. Two cast-glass (Dicor, Dentsply) crowns were constructed for the first and second molars while more conservative porcelain onlays were made for the bicuspids.

Figure 16.11 **(B)** The cerammed restorations are tried-in and cemented to place. Since the two cast-glass crowns were placed over amalgam-stained dentin, a colored opaque cement was used to help mask the discoloration.

Table 16.1 Troubleshooting Esthetics Guide for All-Porcelain Crowns

Problem	Solution
Tooth preparation is visible through porcelain	Add porcelain to labial aspect
	Reprepare the tooth to allow porcelain to be thicker
Teeth are unnaturally even	Provide for variation in tooth length and enhance illusion of spacing by shading and shape
	Open incisal embrasures
Glaze is too high	Break up light being reflected by texturing the porcelain
Crown is too opaque	Use more incisal shading or surface stains
Shade varies excessively	Select shade using color-corrected artificial light and outside light
	Laboratory must use same lighting
	Stain by using sectional shade chart (see Figure 16.2A)
Crown shade is dull	May be due to use of opaque-type cement
	Use a cement with more translucency, such as silicophosphate, composite, or glass ionomer
Porcelain is fractured	Correct to minimal occlusion in anterior teeth
	Provide greater thickness of porcelain
	Reduce stress factors by removing sharp edges or corners in tooth preparation
	Avoid inadequate length of preparation
	Change to aluminous porcelain or metal–ceramic

Alumina– or zirconia–feldspathic bilayers

Procera, Lava, Cercon, and Katana uses CAD/CAM technology to fabricate an all-ceramic crown incorporating a densely sintered zirconia or high-purity aluminum oxide coping. A computer-controlled design system in the dental office or laboratory collects tooth preparation and coping design data that is transmitted via modem to the manufacturing site. After fabrication, the coping is delivered to the dental laboratory where the ceramist completes the restoration with the addition of veneering porcelain. This system produces a crown that is color stable, translucent without being transparent, and biocompatible with the opposing dentition.[25]

Sadan and Hegenbarth[26] report that because the high-purity aluminum oxide copings are fabricated in an industrial process, the risk of introducing microcracks and flaws into the completed restoration is minimized. Furthermore, the high strength and accuracy of fit of the copings permit the utilization of these crowns in any segment of the dental arch. Labor-intensive, time-consuming, and technique-sensitive procedures for coping fabrication are eliminated while achieving an esthetic, strong, and durable restoration in a practical and simplified manner. This bilayer application can be used for the single crown and with the addition of zirconia for multiple unit all-ceramic anterior and posterior fixed bridges. The significant issue and reservation with the zirconia–feldspathic bilayer is severe and unpredictable chipping of the feldspathic veneering porcelain.[31] This has limited the use of this material, but with time improvements will be developed. It has been reported that slowing down the cooling rate after firing improves the reliability against chipping.[27]

The use of monolithic zirconia is increasing in popularity and has great potential in prosthetic dentistry. The ability to infiltrate colorants into the presintered zirconia that are improving the color properties of the restorations led to a breakthrough in dental acceptance. It would appear that monolithic zirconia will survive a very long time due to fracture strength exceeding more than 1500 MPa, without creating problems, and since it is

Figure 16.12 **(A)** This 39-year old patient had received multiple dental treatments - tooth loss, multiple endodontic treatments and many porcelain-fused-to-metal restorations (PFM). Being treated by various dentists over time, he was dissatisfied with his dental function and esthetics.

Figure 16.12 **(B)** Under the failing fixed crown and bridge work, the remaining teeth required core built-ups and endodontic revisions. Dental implants were placed. The restorable dental cores and the implant ceramic abutment (CerAdapt, Nobel Biocare) show a high variation in color.

Figure 16.12 **(C)** Aluminum-oxide crown copings (Procera Alumina, Nobel Biocare) were manufactured and veneered with matching feldspathic veneering porcelain (Alumina Rondo, Nobel Biocare).

Figure 16.12 **(D)** The clinical outcome demonstrates the esthetic potential of alumina-oxide crown restorations. The opacity is sufficient to cover discoloration of the underlying tooth structure. Chipping rates were very low and clinical survival rates match PFM crown restorations.

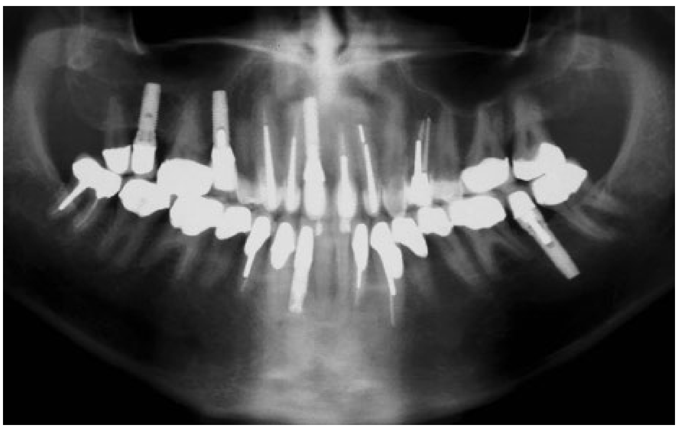

Figure 16.12 **(E)** The panoramic x-ray demonstrates the amount of dental procedures performed. The anterior dentition was treated with Alumina crowns (teeth # 4 to #13), posterior upper and lower teeth were conventionally treated with PFM restorations.

Figure 16.12 **(F)** These clinical results of 2002, mark an example of a coming change from metal-ceramic restorations to all-ceramic crown and bridge oral rehabilitations. Today, it is common to restore posterior teeth also with all-ceramic restorations.

Figure 16.12 (G) Before: This image shows the initial metal-ceramic anterior bridge restoration and esthetic limitations. The biological response of the periodontal tissues was compromised.

Figure 16.12 (H) After: The anterior Alumina rehabilitation, created a natural and transparent dentition, and proofed to be more bioinert to the soft tissue. Presently, the full rehabilitation is 16 years in-situ. Courtesy of Clinical Research Group, University of Freiburg, 2002.

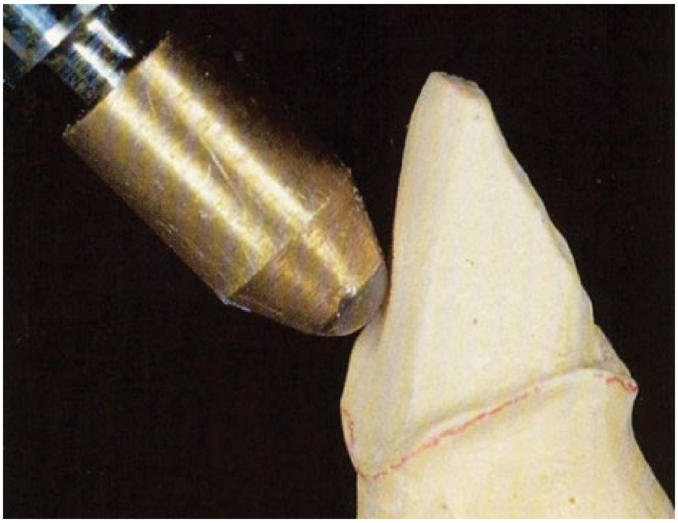

Figure 16.12 (I) The scanning probe reads every part of the tooth surface and inputs the measurements into the computer. Next the finish line and thickness of ceramic coping is established.

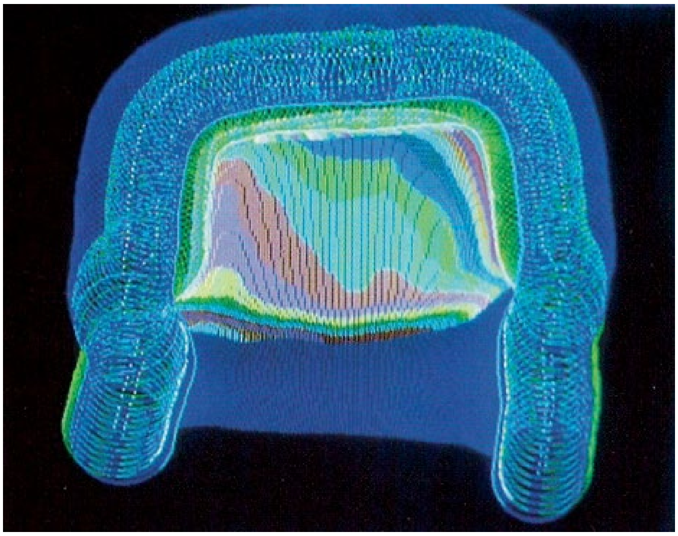

Figure 16.12 (J) This three-dimensional computer image is an example of the type of complete design for a molar all-ceramic core. The information is sent to Sweden.

Figure 16.12 (K) Procera cores are fabricated in Sweden and sent to the dental office or laboratory in 4 days. Porcelain veneer preparations are prepared on foil and opacious dentin applied and then baked. Next, full-body and incisal affects will complete the veneer and full-crown buildups simultaneously.

Figure 16.12 (L) The final veneers are bonded with Choice (Bisco) translucent dual cure resin cement, and the crowns are final cemented with Panavia (Kuraray). Note the harmonious blend of color and internal characterization.

such a dense, smooth surface, bacteria will not grow into it, and it will be clean. Significant improvements in this technology are occurring monthly. Concerns about wear are less today, and materials are being created to polish and adjust areas that have required alterations. Further details on full-zirconia restorations will be adressed at the end of this chapter.

IPS *Empress*

The IPS Empress all-ceramic material (Ivoclar Vivadent, Inc.,) was developed in association with Arnold Wohlwend and Peter Scharer[21] of the University of Zurich. A leucite-reinforced glass-ceramic, IPS Empress is manufactured through the controlled crystallization of minute leucite crystals found in the glassy matrix through the use of nucleation agents (Figure 16.13). As a monolithic ceramic, this material can be pressed to full or partial contour and colored appropriately; it can also be layered with a corresponding IPS Empress veneering ceramic powder, which is then sintered for an optimal color match. In this respect, it handles to some appreciable extent as feldspathic porcelain. IPS Empress as a silicate-based ceramic is amenable to acid etching and can then be luted to teeth with a composite resin cement system. Numerous authors have described the esthetic potential of this material, and various researchers have attested to its physical properties and long-term survival.[2,28] A major advantage of the all-ceramic crown over posterior metal–ceramic restorations is less occlusal reduction as possible in order to create a uniform thickness of the porcelain (Figure 16.14).

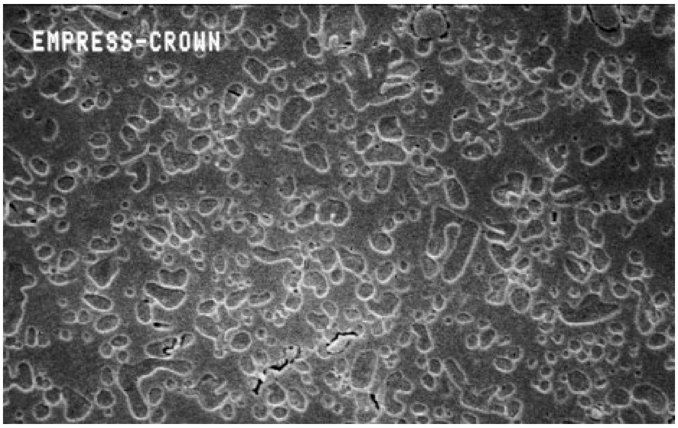

Figure 16.13 Empress is a ceramic that is made up of leucite-reinforced glass-ceramic within its crystalline form.

Because the ceramic can be somewhat translucent, the color of the underlying tooth structure may be transmitted through it. To account for this effect, a stump die resin material is available in seven different dentin shades to reproduce the shade of the dentin of the prepared tooth. A specially formulated shade guide, the stump or "dentin" shade guide, is used after tooth preparation to select the shade to be used. The shaded die materials contribute to the highly esthetic outcome of these restorations, as well as the material's inherent natural fluorescence.

The completion of the restoration can then be achieved in two ways: surface colorants or a layering technique. Surface colorants involve using glycerin on the internal surface of the restoration to transmit the color of the dentin-shaded die through to the final shaded restoration. The final intrinsically characterized restoration may require between two and four firings.

The layering technique of IPS Empress is a method recommended for developing ideal esthetics in the anterior region. An anatomic coping is fabricated from a colored ingot, and a cut-back is done to provide the space required for the enamel and

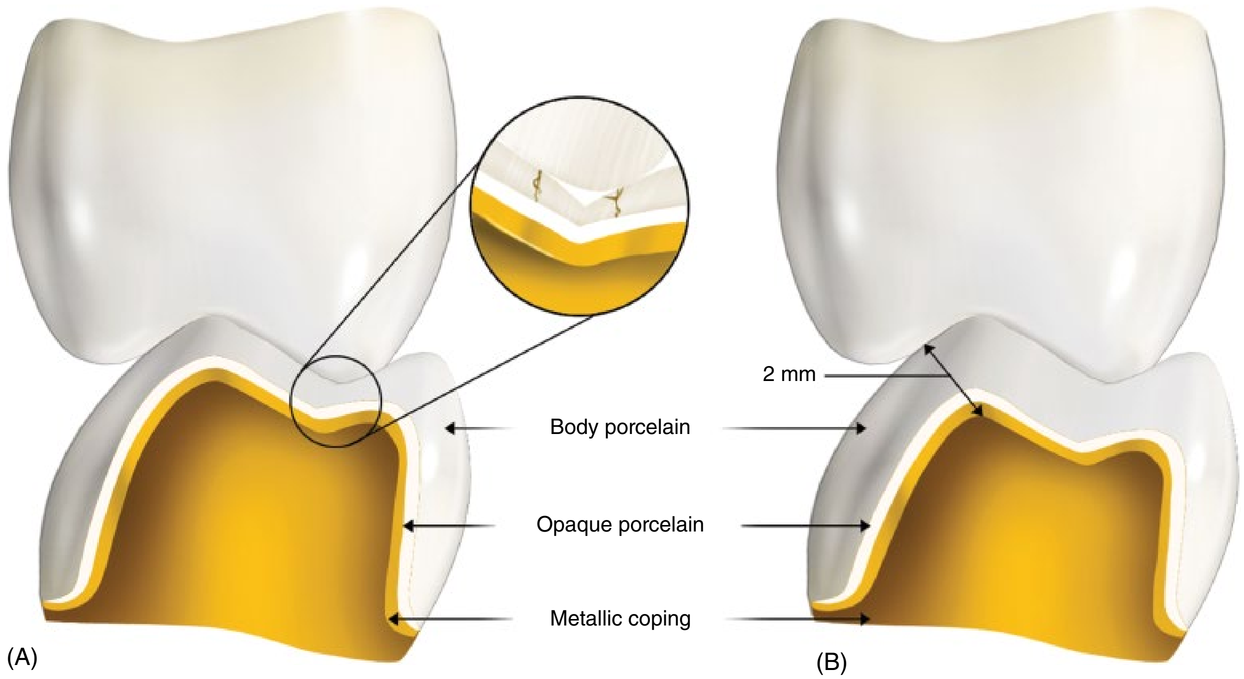

Figure 16.14 **(A, B)** A major problem with posterior metal–ceramic restorations is insufficient occlusal reduction in order to create uniform thickness of the porcelain. The failure to do this is one of the most frequent causes of fracture.

incisal layers. Body and incisal veneering ceramic (crushed Empress) and modifiers are applied when necessary to further customize internal structure, and the tooth form is fully developed and shaped (see Figure 16.15A–E).[24]

From an esthetic standpoint, surface characterization seems to be less crucial for IPS Empress, which is less opaque than conventional aluminous core restorations but less translucent than Dicor. IPS Empress has multiple ingots that provide different levels of translucency. To match more complex tooth shades, a body build-up (simulating dentin) is created, which is then covered with veneering porcelain up to 0.3 mm thick.[29] Lehner and Scharer found that several coats of a heavily pigmented colorant followed by a glaze (to total 50–60 μm in thickness) will enhance fracture resistance to external compressive forces.[29]

Advantages of the Empress system include simple processing, accurate reproduction of the wax pattern and margins, high flexural and tensile strength (which increases with each firing), and good esthetics. This new line of ceramic materials has a high degree of stability during the subsequent shading or layering technique. The IPS Empress ceramic has one of the best long-term survival rates[30] of any all-ceramic material previously tested but has been replaced in the market by the stronger and more durable IPS e.max lithium disilicate.

Lehner and Scharer point out that long-lasting esthetic results may be better achieved by using materials that allow internal colorants and shades rather than relying only on thin surface stains.[29] Also, external surface characterization is subject to surface loss due to the prescription acid-based stannous fluoride

Figure 16.15 **(A, B)** This 71-year-old man wanted the best esthetic result without using metal on his lower anterior crowns. By cosmetically contouring the lingual surfaces of the maxillary anterior teeth, it was possible to create a favorable occlusion for cast-glass crowns.

Figure 16.15 **(C)** The four incisors are prepared and ready for the impression.

Figure 16.15 **(D)** It is essential that the occlusion be carefully and completely adjusted during the try-in.

Figure 16.15 **(E)** The final shade is slightly lighter than, but in the same range as, the cuspids.

gels. Neutral fluorides must be prescribed for these patients. A long-term deficiency often seen when surface colorants are used to color or shade porcelain restorations is that, after years, there may be a loss of color as a result of functional demands and abrasion.[29] Surface roughness appears,[29] and there is clinical evidence that these materials generally abrade the enamel of the opposing teeth.[32] The color of an IPS Empress restoration, when fabricated from a colored ingot, is less affected by surface abrasion and occlusal attrition.

Marginal adaptation and occlusal harmony are dependent on the skill of the ceramist, who often has personal preferences. One needs to choose a ceramist (or ceramists) based on the unique needs of the practice and the results they can consistently deliver. Regardless of which ceramic system one may choose for a particular patient, the versatility of most ceramics should allow an acceptable esthetic result. Most systems have an esthetic range that will allow them to be used for most restorations. Only in cases of extreme opacity or translucency will it make a difference. This is one reason why the metal–ceramic restoration has remained so popular throughout the dental world.

IPS *e.max*

Lithium disilicate was developed by Ivoclar Vivadent and is principally a monolithic ceramic that can be utilized as a pressed (lost wax) or CAD/CAM ceramic. It is a highly esthetic, high-strength material that can be conventionally cemented or adhesively bonded. The pressable lithium disilicate material is indicated for inlays, onlays, veneers, partial crowns, anterior and posterior crowns, three-unit anterior bridges, three-unit premolar bridges, telescope primary crowns, and implant superstructures. In some cases, minimal tooth preparation is desired (e.g., thin veneers), and IPS e.max lithium disilicate enables laboratories to press the restorations as thin as 0.3 mm while still ensuring strength of 400 MPa. If sufficient space is available (e.g., a retruded tooth), no preparation is required. For laboratory ceramists, the versatility and performance of lithium disilicate enables them to optimize their productivity when fabricating restorations using this material, since either lost-wax pressing or CAD/CAM milling fabrication techniques can be used (see Figure 16.16A and B).

Glass-ceramics are categorized according to their chemical composition and/or application. Lithium disilicate is among the best-known and most widely used type of glass-ceramic. The IPS e.max lithium disilicate, for example, is composed of quartz, lithium dioxide, phosphor oxide, and other components. Overall, this composition yields a highly thermal shock-resistant glass-ceramic due to the thermal expansion that results when it is processed. This type of resistant glass-ceramic can be processed using either well-known lost-wax hot pressing techniques or state-of-the-art CAD/CAM milling procedures.

The pressable lithium disilicate (IPS e.max Press) is produced according to a unique bulk casting production process in order to create the ingots. This involves a continuous manufacturing process based on glass technology (melting, cooling, simultaneous nucleation of two different crystals, and growth of crystals) that is continuously optimized in order to prevent the formation of defects (e.g., pores, pigments). The microstructure of the pressable lithium disilicate material consists of approximately 70% needle-like lithium disilicate crystals that are embedded in a glassy matrix. These crystals measure approximately 3–6 μm in length (see Figure 16.17A). Polyvalent ions that are dissolved in the glass are utilized to provide the desired color to the lithium disilicate material. These color-releasing ions are homogeneously distributed in the single-phase material, thereby eliminating color pigment imperfections in the microstructure. Machineable lithium disilicate blocks are manufactured according to a similar process, but only partial crystallization is achieved in order to ensure that the blocks can be milled fast in a crystalline intermediate phase (blue, translucent state). The partial crystallization process leads to the formation of lithium metasilicate crystals, which are responsible for the material's processing properties, relatively high strength, and good edge stability. It is after the milling procedure and the restorations are fired that they reach their fully crystallized state and their desired strength. The microstructure of partially crystallized IPS e.max CAD lithium disilicate consists of 40% platelet-shaped lithium metasilicate crystals embedded in a glassy phase. These crystals range in length from 0.2 to 1.0 μm. The postcrystallization microstructure of IPS e.max CAD lithium disilicate materials consists of 70% fine-grain lithium disilicate crystals embedded in a glassy matrix (see Figure 16.17B). Similar to the pressable lithium disilicate, the millable IPS e.max CAD blocks are colored using coloring ions. However, the coloring elements demonstrate a different oxidation state during the crystalline intermediate phase

Figure 16.16 **(A)** Tooth #9 has a resin veneer that has aged and discolored. The patient wanted a more permanent esthetic solution.

Figure 16.16 **(B)** A lithium disilicate e.max press crown was fabricated. The facial-incisal third was layered with fluorapatite to better match to the adjacent central incisor.

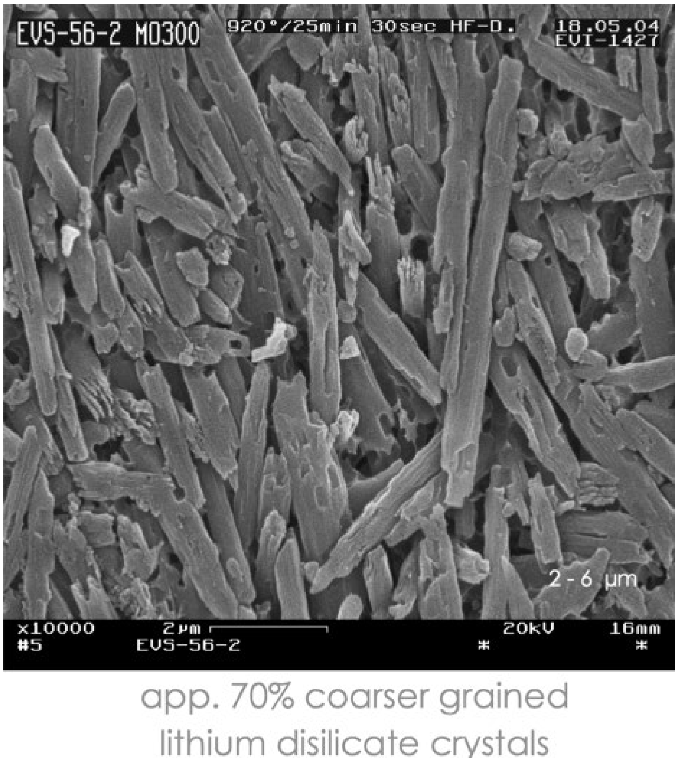

Figure 16.17 **(A)** The electron microscopic view of the e.max press crystalline structure shows highly compacted and coarse lithium disilicate crystals compared with the e.max CAD.

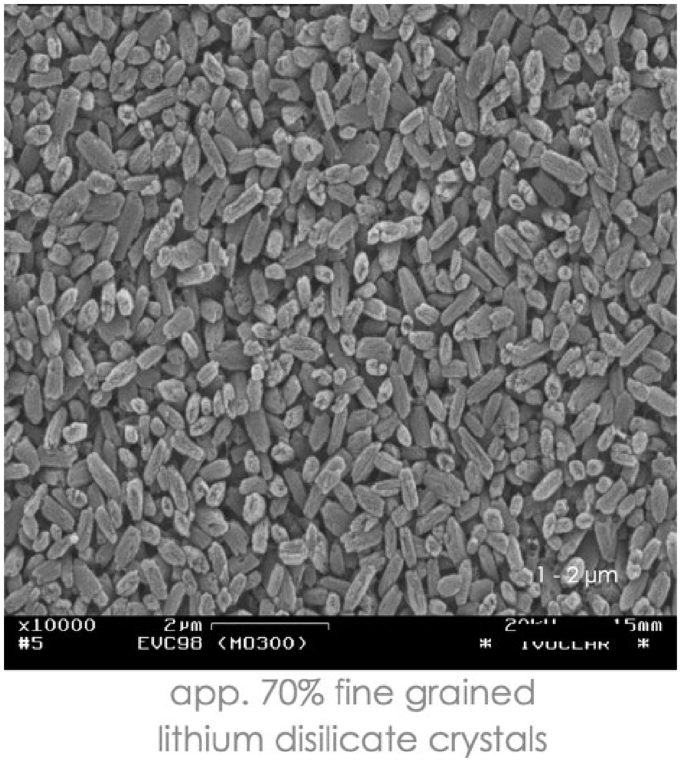

Figure 16.17 **(B)** The crystalline structure of e.max CAD has finer lithium disilicate crystals.

Table 16.2 Clinical Gross Database of All-Ceramic Units to October 22, 2012

Ceramic	Dicor	In-Ceram	Empress	e.max	Totals
Start	Mar 1983	Feb 1990	Jun 1992	Dec 2008	Mar 1983
Months	356	273	245	47	356
Patients	414	137	692	391	1534
Gross nos.	1501	331	2130	1354	5316
Failures	239	49	97	0	385
Gross failure (%)	15.92	14.80	4.55	0	7.24
Chipping	4	13	30	3	50
Replaced	227	48	142	45	462

than in the fully crystallized state. As a result, the blocks exhibit a blue color. The material achieves its desired tooth color and opacity when the lithium metasilicate is transformed into lithium disilicate (during the postmilling firing process).

The lithium disilicate material (IPS e.max Press and IPS e.max CAD) has been in clinical trials for the past 4 years with adhesive and self-adhesive/conventional cementation, and the results have been extremely positive with minimal fracture, chipping, or need for replacement. In one study, over 1200 different-style restorations were completed with no failures and minimal chipping observed (Malament Clinical Database—see Table 16.2). Other physical tests have included mechanical testing of strength using static load with a universal testing machine, subcritical eccentric loading using a chewing simulator (Willytec), and a long-time cyclic loading with a chewing simulator (eGa). The results of these tests demonstrate that:

- To ensure maximum success using the lithium disilicate material, it is important to consider the minimum thickness of the lithium disilicate frame.
- The inside of the crown should *not* be sandblasted.
- Regardless of whether the in vitro test is performed, in comparison with various restorative dental material for crowns (e.g., leucite glass-ceramic, metal–feldspathic ceramic, zirconia–feldspathic ceramic), the lithium disilicate material demonstrates superior results.[33–35]

This is because the strength of the ceramic material in contact with opposing teeth, to fulfill masticatory functions, is about 100 MPa for veneering material and about 160 MPa for leucite glass-ceramic. However, for the pressed lithium disilicate (IPS e.max Press LT and HT), the strength is in the region of 400 MPa in its final anatomical-shaped crown form.

Indications for the machineable lithium disilicate material are inlays, onlays, veneers, partial crowns, telescope primary crowns, and implant superstructures. For a posterior crown fabricated to full contour using CAD methods, lithium disilicate offers 360 MPa of strength through the entire restoration. As a result, restorations demonstrate a “monolithic” strength unlike any other metal-free restoration. Overall, these materials demonstrate specific advantages to dentists and patients, including higher edge strength versus traditional glass-ceramic materials (i.e., can be finished thinner without chipping), low viscosity of heated ingot enabling pressing to very thin dimension (i.e., enabling minimal prep or no prep veneers), and chameleon effect due to higher translucency.

Metal–ceramic restorations

Porcelain fused to metal

History

The metal–ceramic restoration has been the standard of care in esthetic dentistry for more than 30 years. According to Kuwata,[1] in his book *Creating Harmony in Dental Ceramics*, Katz and Katz were the earliest pioneers in fusing feldspathic porcelain to metal, in the late 1940s, and first perfected this technology for dentistry. Later, with major investment backing from the Weinstein brothers, the first patent was granted to fuse porcelain to metal. Over time many people have played important roles in the early development, but Kuwata's contributions were significant, particularly in the areas of particle size and color pigment selection, as well as for his research on the coefficient of thermal expansion of both metal and porcelain to allow a long-term fusion. From an esthetic viewpoint, porcelain is a material capable of maintaining its surface texture and color for extended periods without losing its naturalness. However, because of excessive fragility, porcelain alone has its limitations. This limitation is overcome by the use of porcelain-fused-to-metal alloys.

Precious/nonprecious

The American Dental Association has developed a classification system for casting alloys. The classification is:

- high noble—≥60% gold, platinum, and palladium, and gold ≥40%;
- noble—≥25% gold, platinum, and palladium; and
- base—<25%.

(Noble metals are gold, platinum, palladium, and other platinum-group metals.) In the early 1970s, increased fluctuation in the cost of gold increased interest in alternative metals for casting, so base metals were developed. These metals are based on nickel and chromium. Other nonprecious ingredients are added to base metals to modify their properties, casting accuracy, and porcelain-to-metal compatibility.

Gettlemen defines noble metals differently. He states that noble metals are alloys of gold, palladium, and silver (not a noble metal), with smaller amounts of iridium, ruthenium, and platinum. They are primarily used as a substructure for ceramic application, with the rest used as inlays, onlays, and unveneered crowns. Base metal alloys, principally made of nickel, chromium, and beryllium, are used widely in the United States, owing to their lower cost and higher mechanical properties.[36] Most of the alternative base-metal casting alloys, he states, have superior mechanical strength, porcelain bond strength, high-temperature sag resistance, and corrosion resistance. The principle deficiencies of base metals are the potential for allergic reaction in patients who are hypersensitive to nickel, chromium, or beryllium.

When selecting an alloy the decision should be based on the type of restoration involved. The porcelain to be used is an important factor, in that only certain porcelains are compatible with specific metals. When a tooth is to be restored with a porcelain-fused-to-metal restoration, the alloy should be <5% silver due to the adverse effect silver has on porcelain color.[37] Different alloys offer different degrees of hardness; the differences are a result of the minor constituents added. For example, copper is added as a hardener. A long-span bridge would require a harder alloy than a single unit or a short-span bridge.[38] Nickel chromium base alloys also result in color changes, which are detectable by trained dental observers under ideal viewing conditions. However, it may be well within an acceptable range under normal viewing conditions.[37]

Indications for metal–ceramic restorations

1. For anterior crowns with complex color requirements.
2. Where there is need for multiple splinting of crowns together.
3. For fixed partial dentures with any number of pontics or short cantilevers.
4. With complex implant prosthodontics requiring gingival ceramics.

Contraindications for metal–ceramic restorations

1. Adequate tooth structure cannot be removed to allow ample space for both metal and porcelain.
2. The clinical crown is too short. Since an incisal or occlusal reduction of 2 mm is essential to allow space for metal and porcelain coverage, retention and stability of the crown may be inadequate.
3. Use in extensive long-span bridges or splints is not routinely recommended.

Technical problems

1. Pulp exposure can occur if required tooth structure is removed to allow for thickness of materials and to achieve sufficient parallelism for crown retention after insertion.
2. Breakage can be minimized by careful attention to tooth preparation, coping, or frame design.

3. Potential esthetic deficiency where single crowns, crowns splinted together, or fixed partial dentures using porcelain fused to metal suffer a loss of separateness that detracts from the appearance. As Bronstein points out, ideal deep interproximal carving is greatly limited by the proximity of the metal truss arms, which join the crowns. This is not as much of a problem in posterior segments of the mouth, where shadows and oblique angles make them less visible.[39]

Advantages

1. Porcelain fused to metal can be used to crown the abutment teeth of removable clasp-type partial dentures, since it resists abrasion by the clasp arms; and if necessary, rest seats can be made in the metal framework.
2. Porcelain may be contoured to provide desirable retentive undercuts and guiding planes for removable partial dentures.
3. They can be used for the placement of internal attachments for removable partial dentures. The cast metal can contain the female portion of the attachment.
4. Metal permits a good marginal seal and adds strength.[40]

Disadvantages

Aside from teeth that are heavily discolored, Zena and Abbott[41] propose that cervical shadowing or "black line" is caused by "disruption of the light harmony between the root and crown" of the prepared tooth and the overlying soft tissues. That is, the dentin and root structure of a tooth refract less ambient light, leaving a darkened, shadowed appearance of the root surface, as do metal substructures such as metal posts and cores (see Figure 16.18A–C). To avoid this esthetic problem, one may wish to place the facial margin subgingivally, but no more than halfway between the gingival crest and the depth of the sulcus. A soft tissue model can be used to ensure ideal facial emergence from the gingiva.

Figure 16.18 **(A)** One of the myriad of reasons for the use of all-ceramic crowns is their relative translucency. When light is passed through a prepared tooth (or natural tooth), it illuminates the root as well.

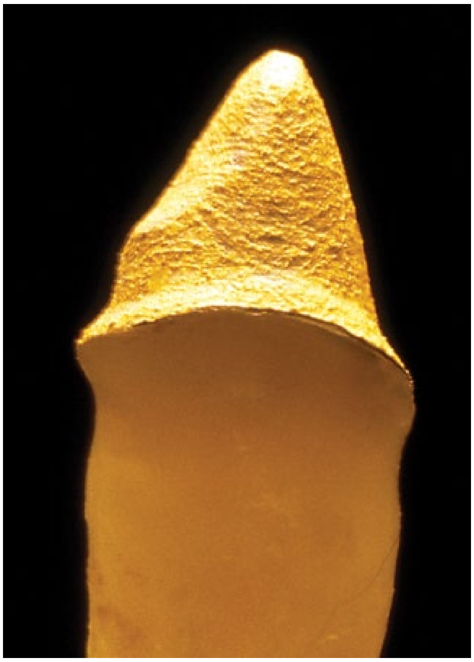

Figure 16.18 **(B)** Once a cast coping is placed over the prep, light stops being transmitted into the root and leaves a darkened cervical third, and even a shadow in the gingiva.

Figure 16.18 **(C)** Even with a porcelain butt margin, transmission of light into the root is impaired and can still yield a darkened cervical third.

Adjunctive procedures

As noted by Pameijer,[42] the fabrication of a soft tissue cast has been strongly advocated to provide the laboratory technician essential information concerning the morphology of the gingival tissues surrounding the metal casting. An accurate replication of the height and contour of the marginal gingiva and of the interdental papilla is very helpful in establishing the emergence profile and cervical contour and helps the technician control the length of the metal collar for subgingival margins.

When writing the laboratory prescription, include as much information as possible in order to aid the technician in creating appropriately shaped teeth. Final shaping and contouring to reflect personality, age, and sex should also be done at this time.[28]

Esthetic considerations

With fixed partial dentures or splinted crowns, the loss of individuality in the anterior segment can be significantly improved by the design of the restorations where one may overlap crown forms to hide the opaqued or exposed connectors or by specific coloration technique for the interproximal porcelain. Eliminating the metal collar with a buccal butt porcelain margin improves esthetics. There should be subtle variation in the body and incisal porcelain to break up light and thus help create the illusion of naturalness.[42] The success of a buccal butt porcelain shoulder restoration is improved by proper tooth preparation.[43] Frame design is altered by finishing the labiogingival portion of the metal back to the gingivopulpal line angle, leaving metal substructure against the axial wall (which is 0.3–0.5 mm thick). This allows for an opaque porcelain layer from 0.2 to 0.3 mm thick and 0.7 to 1.0 mm of shoulder porcelain (see Figure 16.19).

The advantage of a porcelain shoulder in a porcelain-fused-to-metal crown, according to Harrison et al., is that the finish line can be kept supragingival or just slightly apical to the free gingival margin. Its major disadvantage is that the loss of metal along the facial margin may give less than an optimal margin closure, and it is possible that fracture of the facial porcelain caused by a lack of metal support may be increased. For this reason one must be careful if using a direct lift-off margination technique to avoid displacement or breaking of the porcelain shoulder build-up and deformation during firing.[43] However, the use of a bonded resin cement to either etched enamel or dentin helps to seal the margin and at the same time provides additional marginal support.

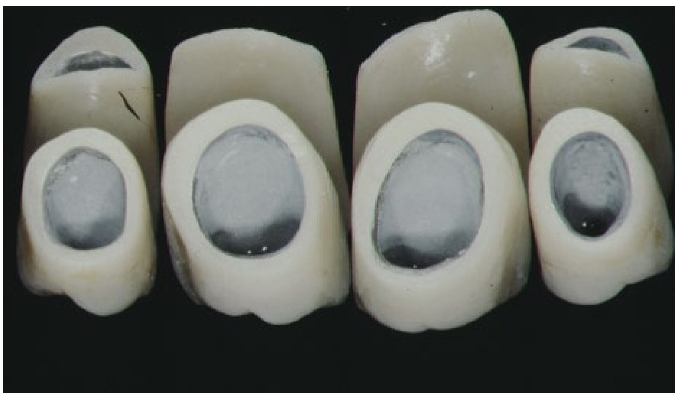

Figure 16.19 Porcelain butt margins on four anterior crowns. The metal does not extend onto the shoulder.

When both esthetics and strength are essential, consider the metal–ceramic butt joint (refer to Figure 16.20). This type of crown provides almost all the esthetics necessary, and yet the metal core adds great strength. Further discussion of esthetic considerations may be found later in this chapter.

New approaches to the metal–ceramic system compensate for the inherent esthetic problems with the advent of opalescent ceramic systems—Creation Porcelain (Jensen), Vintage Opal Porcelain (Shofu), and Omega Ceramic (Vita Co.).

These systems are based on the concept of opalescence, a naturally occurring phenomenon in the semiprecious opal stone. An opal's surface resembles that of enamel in opacity and translucency, so by mimicking enamel with a specially filled ceramic, which maintains its opalescence during firing, the metal–ceramic restoration appears more natural. An additional advantage is that laboratory construction is simplified, using only a two-layer build-up, versus the three needed for conventional porcelain restorations.[24]

Technical considerations

Substructure design

After diagnosis, treatment planning, and tooth preparation, the design of the metal substructure is of the greatest importance. As Dresden[40] states, poor design of the substructure is probably the primary reason for failure of the metal–ceramic restoration. Because of the strong influence of the opaque masking the metal framework on the final shade, uniform thickness of the body porcelain is paramount. Specific case design is usually determined by the nature of the preparation in relation to the esthetic and functional requirements. There are several major considerations in creating the metal substructure. The metal should be constructed to provide a uniform thickness of porcelain. Since labial surfaces may be particularly weak at the incisal and gingival areas, there should be incisal and gingival thickness to support the porcelain required for a full shoulder margin. A metal-reinforced margin, such as a chamfer or beveled

Figure 16.20 The maxillary arch is restored with individual porcelain-fused-to-metal restorations all with porcelain butt margins. The esthetic integration between the ceramic and the gingiva is heightened when the porcelain butt margins are used.

shoulder, can increase the strength. These may be designed in several ways for maximum function and esthetics. Figure 16.21A illustrates the beveled shoulder labially and lingually with porcelain fused to metal. The porcelain gingival margin is extended below the gingival crest. An alternative to this is porcelain coverage with the occluding surface in metal (Figure 16.21B). Alternatives to the beveled shoulder margin are the porcelain butt joint (Figure 16.21C) and the chamfer margin (Figure 16.21D). The surfaces of the metal to which the porcelain is to be bonded must be well rounded with no sharp angles in concavities and convexities (Figure 16.22A and D). Especially sharp inner angles must be avoided, because porcelain shrinks

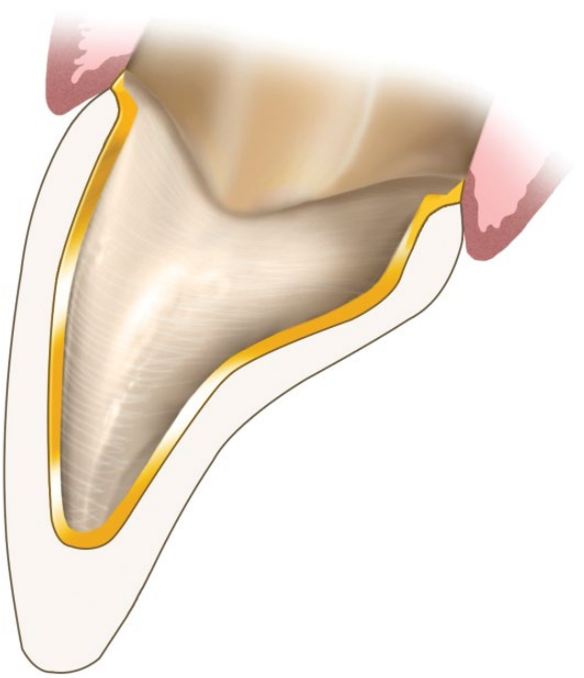

Figure 16.21 **(A)** The beveled shoulder margin can work well both labially and lingually when the patient has a low lip line or thick fibrous gingival tissue that diminishes the chance of tissue recession.

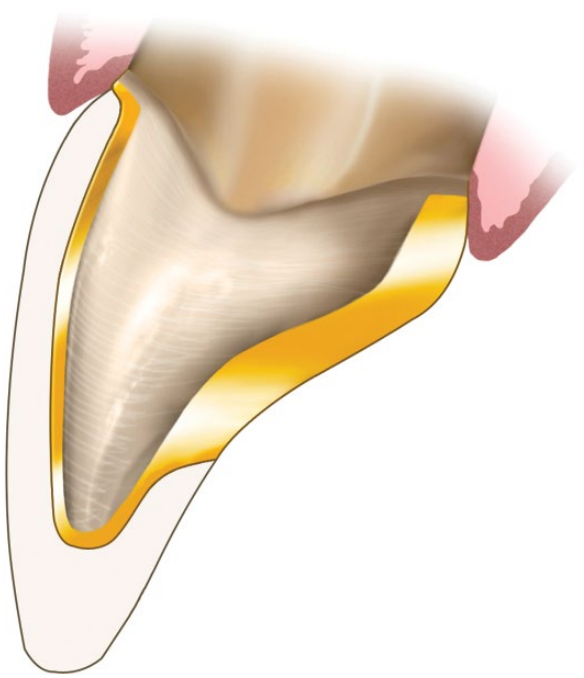

Figure 16.21 **(B)** An alternative to the porcelain lingual surface is to place the occluding lingual surface in metal.

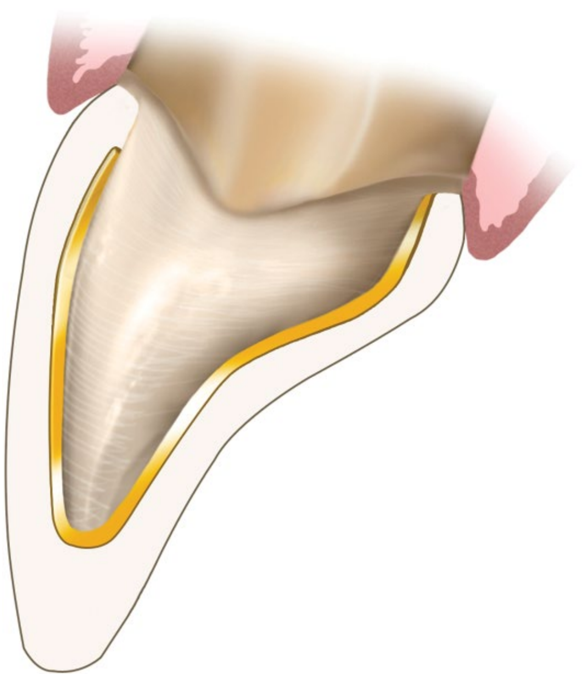

Figure 16.21 **(C)** For most situations the best esthetic margin is the porcelain butt joint.

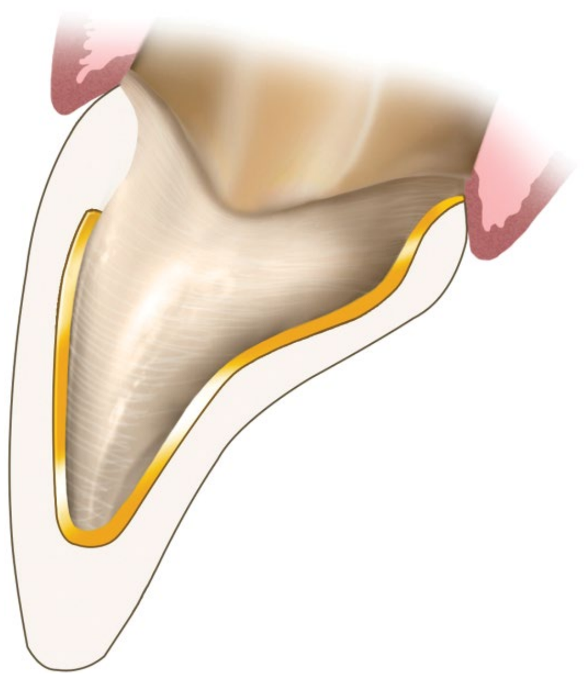

Figure 16.21 **(D)** There are situations where the chamfer margin is a good replacement for the beveled shoulder.

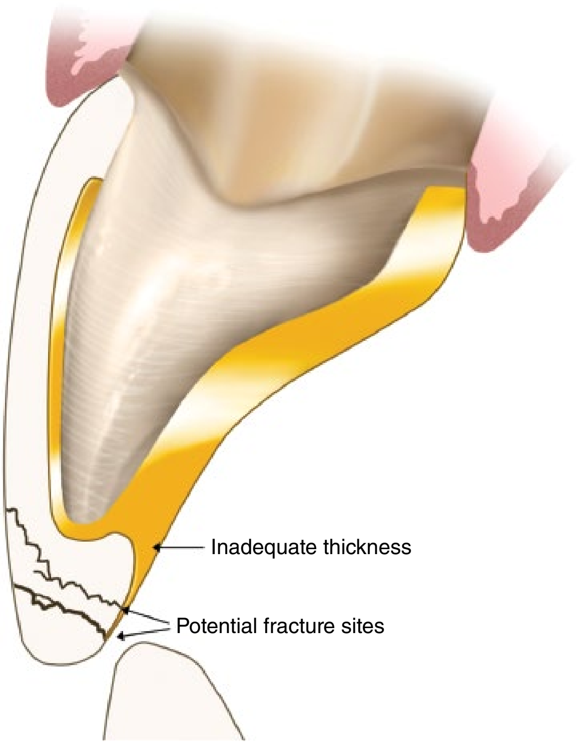

Figure 16.21 **(E)** An inadequate thickness of incisal metal can potentiate fracture, especially if the metal–ceramic junction occurs in an occluding area.

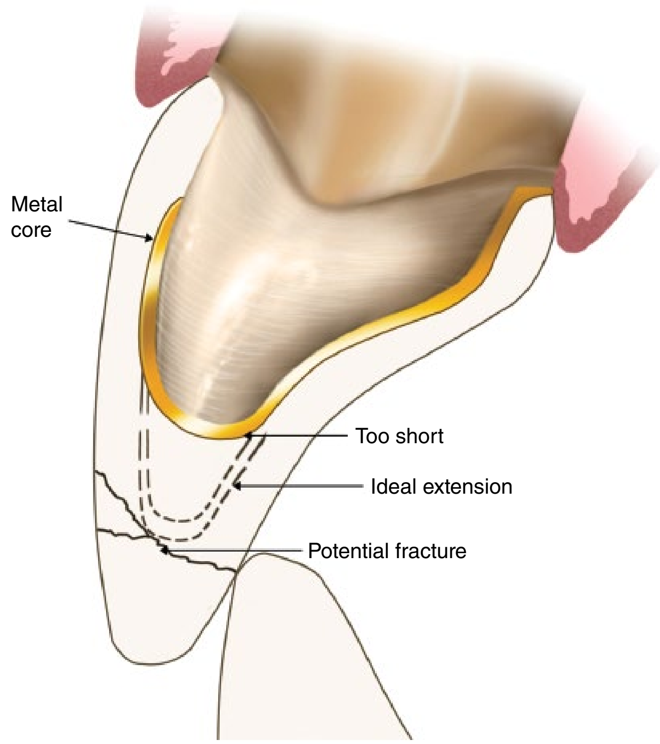

Figure 16.21 **(F)** The metal should always be constructed to provide for uniform porcelain thickness. If the substructure is too short it may require too much porcelain incisally, which could significantly weaken the restoration, causing fracture.

15–20% upon firing, and a layer of metal oxide develops to create a bond between metal and porcelain. Potential points of cleavage, which may occur if there is stress on the porcelain, will also be avoided by smoothing off any sharp angles.[44,45] Also, if the metal is too thin (less than 0.4 mm), porcelain shrinkage during firing can distort the fit of the metal substructure.

Metal fracture can also occur if the coping is poorly designed with an inadequate thickness of incisal metal (Figure 16.21E). This may result from deformation of the metal under masticatory stresses or when seating the preparation in the mouth. According to MacGibbon, failures may be due to the great difference between the elasticity of the porcelain and that of the metal employed.[46] Be certain, therefore, that the incisal metal coverage is thick and broad, not thin toward the lingual surface. If the substructure is too short, it may require too much porcelain incisally, and that could significantly weaken the restoration (Figure 16.21 F). The coping should be built up to allow for uniform porcelain thickness.[21] This principle also applies to full coverage, porcelain-fused-to-metal posterior restorations. Uniform material thickness is illustrated in Figure 16.23A. Note that the metal may be designed to go higher in the linguogingival area, unless the patient objects to the slight display of metal.

The type of labiogingival junction of porcelain and metal also depends on esthetic demands. If the patient has a high lip line when smiling, the porcelain should end beneath the crest of the gingiva. For upper posterior teeth, never place the visible porcelain–metal junction at the bucco-occlusal line angle in an occluding area, as this is a potential site of fracture. Instead, finish the porcelain on the lingual surface or halfway between the tip of the buccal cusp and the central fossa (Figure 16.23B).

Tooth preparation

Preparation

Successful esthetic and functional results obtained with all-feldspathic porcelain crowns cannot be credited solely to the quality of the particular material used. The method of preparation also has a significant influence on the final result. Control over the esthetics in the anterior porcelain crown is determined by the fit of the crown and its proper termination within the gingival sulcus. Strict observance of the rules of tooth preparation, soft tissue management, and techniques of impression is essential. Failure in any of these steps may result in poor crown adaptation, gingival irritation or destruction, and the resulting changes in tissue appearance. An adequately reduced (1.5 mm), clearly defined shoulder is necessary to achieve good margins and provide strength.[47] The strength of a porcelain restoration is highly dependent on proper crown preparation. Advocating careful preparation, Berger states that the shoulder should be carefully developed and brought to its final finishing line in the sulcus late in the process of preparing the tooth rather than establishing its location early in the procedure.[16]

Every effort should be made to minimize injury to the gingival tissues. The margin preparation must never exceed the depth of the sulcus. In a healthy mouth this distance may only be 1–3 mm. Therefore, the margin of the crown should be ideally placed in

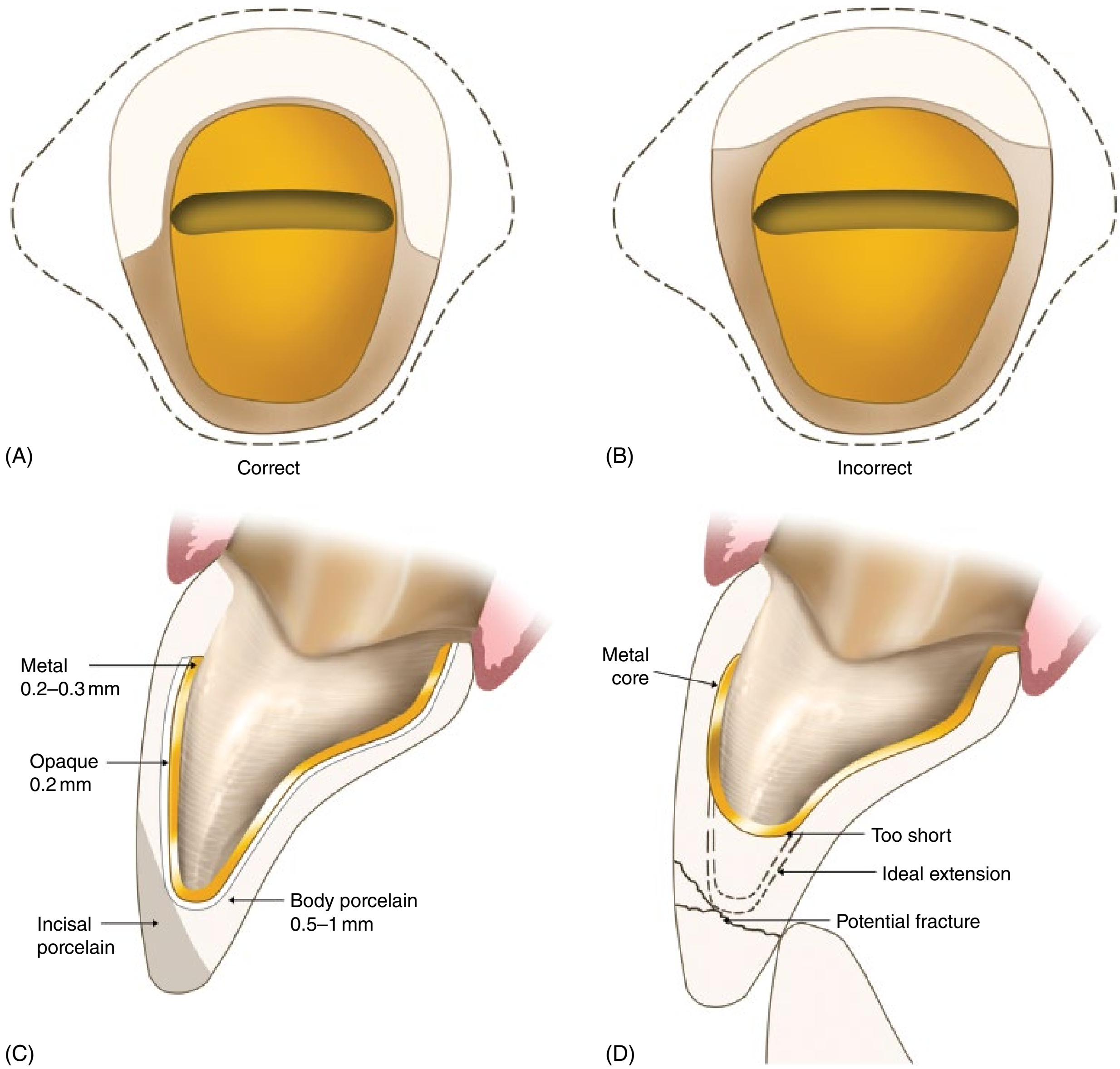

Figure 16.22 **(A–D)** These illustrations show the method of extending the porcelain well into the gingival embrasures for maximum esthetics. They also help to point out the use of rounded inner line angles to avoid potential points of cleavage, which may occur if there is stress on the porcelain. Figure 16.22C illustrates the correct thicknesses of each material layer of an anterior porcelain fused to metal crown and incisal edge design.

the sulcus 0.5 mm below the gingival crest.[38,48] Placing the margin of the shoulder as deep as possible into the sulcus can be a grave error. If the biologic width is compromised, there is a potential for changes in the underlying osseous structure with possible gingival recession and/or pocket formation. If recession can be avoided, then a major problem in esthetics is eliminated.[48]

Tooth structure apical to the margin is important also to ensure maintenance of the integrity of the gingival attachment apparatus. Extension of the crown too far apically can damage the attachment apparatus during try-in. Also, if the finish line is in an area that is inaccessible for cement removal, plaque can accumulate, and inflammation will result.[48] Kaiser and Newell state that margins should not be placed over 1.0 mm subgingivally to the retracted level of the free gingival margin to ensure that the margin is hidden under the healthy tissue.[49] They further emphasize that the potential for tissue recession is greatly dependent on its health before preparation; at cementation they endorse the use of a nonmedicated retraction cord of a size that does not require excessive pressure for its placement into the sulcus.

The problem of tissue recession may occur regardless of the care taken not to irritate the gingival fibers during preparation. The best way to avoid irritation is to extend the gingival margin into the sulcus after cord retraction so that clear vision is possible (Figure 16.24A and B). Deflection during gingival retraction and impression techniques can also produce enough irritation to the tissue to cause shrinkage and to eventually expose a margin;[50] therefore, use extreme care to avoid unnecessary deflection, in both duration and force, when inserting the cord. Interproximal

Figure 16.23 **(A)** The strongest metal–ceramic restoration is one that features wraparound, uniform porcelain thickness.

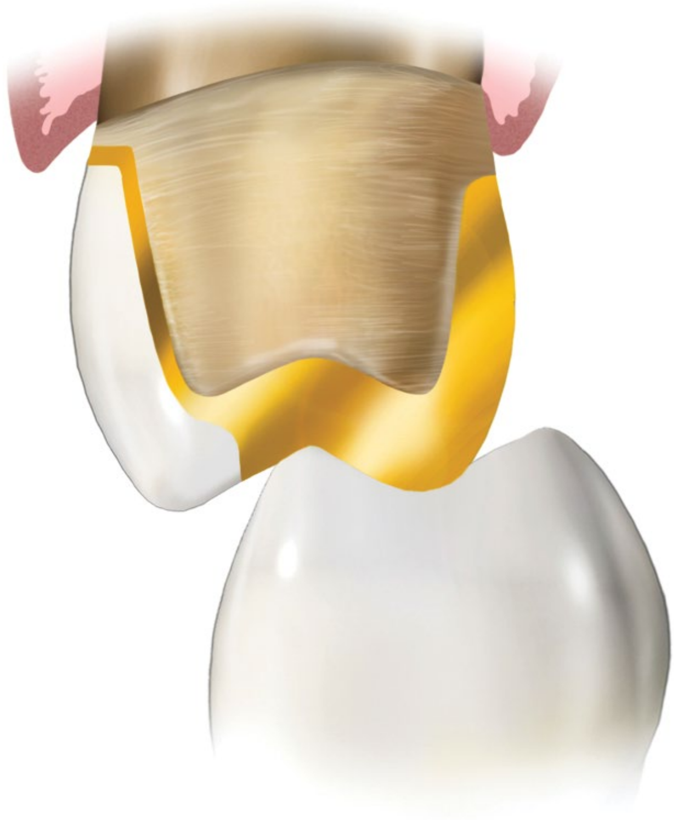

Figure 16.23 **(B)** Place metal–ceramic junctions in low- or no-stress areas.

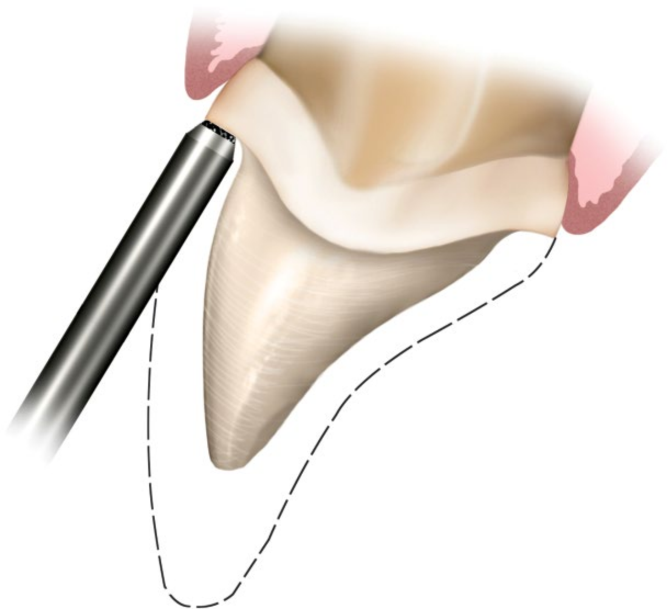

Figure 16.24 **(A)** This beveled end-cutting diamond (TPE-Shofu or TGE-Premier Dental Products) helps protect the gingival tissue as it extends the shoulder margin subgingivally.

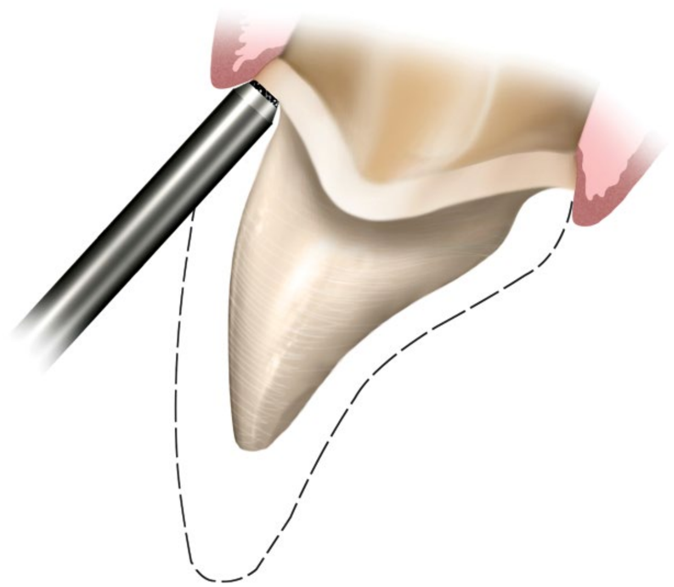

Figure 16.24 **(B)** As the diamond cuts the shoulder deeper into the gingival sulcus, the bevel protects the gingival epithelium by pushing it out of the way.

contacts between full crown restorations or with the natural dentition also play a role in maintaining gingival health. Southard et al. presented a study in which they conclude "posterior dental contact tightness, generally regarded by dentists as a static feature of occlusion, varies significantly as a function of posture."[51] The recumbent patient showed a mean decrease in posterior contact tightness, which increased after a return to an upright position. Aside from gingival health, as proposed by Sturdevant, excessive pressure between restored teeth may ultimately result in undesirable tooth movement.[51] From an esthetic standpoint, such shifting of the teeth may compromise the optimal restorative results one worked so hard to achieve.

Following the construction of the crown, check the shoulder fit and contour of the crown. Remove rough or excess porcelain, as it will increase plaque retention and cause gingival irritation. A poor marginal fit may eventually produce granulation tissue or gingival recession, which, in turn, may cause the gingival tissues to appear bluish or become puffy and reddened. Blame may be erroneously placed on the restoration rather than on poor planning or technique.[16] Some nonpathologic tissue changes occur with time. Under these circumstances, replacement for purely esthetic reasons is a matter for the patient to decide. Friedman and Jordan suggest that composite luting or bonding of the porcelain crown may reduce the incidence of fracture,[52] and they cite research that concludes that bonded porcelain crowns strengthen the remaining tooth structure to a degree comparable to the strength of a fully intact normal tooth.[53] In addition, the use of composite luting materials instead of traditional cements provides more control over the color of the restored tooth, because the composite functions like a core stain.[52]

Certain factors must be considered in preparation for metal–ceramic restorations. First, there must be adequate space for porcelain, opaque, and metal coverage (Figures 16.22C and 16.26). For anterior teeth this means reduction of 1.5 mm axially and 2 mm incisally (Figure 16.22C). Coughlin says the labioincisal reduction of the anterior teeth or the buccal cusp in posterior teeth should not be less than 2.0 mm and should roughly duplicate the contours of the original surface in order to gain uniformly adequate space for a metal coping, opaque porcelain, and body porcelain into which can be built occlusal anatomy.[54] The lingual cusp and marginal ridge should have a clearance of at least 1.0–1.5 mm in all lateral excursions. If this is sacrificed, shade control suffers, because all porcelains need depth to maintain shade. The porcelain must not be less than 0.5 mm thick anywhere. Otherwise, the shade is progressively lightened. Good porcelain coverage in the anterior restoration is illustrated in Figure 16.25A–E. Correct porcelain coverage design for the posterior restoration is illustrated in Figure 16.26. After impressions, casts and dies are made and a treatment wax-up that can be placed intraorally, which can help the dentist and technician

Figure 16.25 **(A)** The patient had a recurrent squamous odontogenic cyst excised from the papillary area between #6 and #7 and wanted a way to mask the defect.

Figure 16.25 **(B)** To facilitate communication with the technician, a shade tab photograph is taken (or multiple). It is generally better to use the necks of the shade tabs, rather than the incisal edges.

Figure 16.25 **(C)** A treatment wax was placed in the mouth before fabricating the final restoration to allow the patient to visualise the end result of the prosthesis.

Figure 16.25 **(D, E)** The final restoration in place. The crown was fabricated with metal–ceramic in order to create the pink replacement papilla.

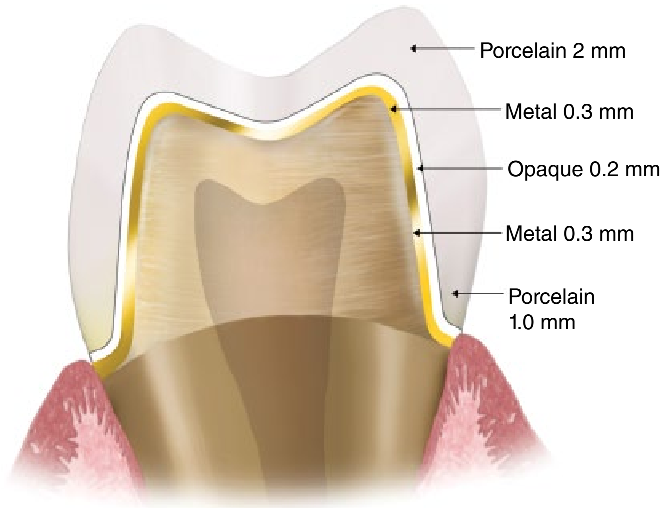

Figure 16.26 This diagram illustrates the correct thickness of a posterior metal–ceramic restoration using a bevel shoulder margin on the lingual and a porcelain butt joint on the labial.

visualize the potential esthetic results. With the patient's input, the treatment wax-up serves as a blueprint for both the metal–ceramic frame and the final ceramic restorations (see Figure 16.25C).

Choice of margin

Deciding what type of margin is obtainable is a prerequisite to crown selection. The best functional margin is gold supragingivally. However, when esthetics are of concern, the procedures of masking or covering the metal become essential.

The mere presence of metal in the mouth is enough to bother some patients. In this case, an all-ceramic crown or a porcelain-fused-to-metal crown with a porcelain butt joint should be used (see Figures 16.21C and 16.22C).

If periodontal disease is present, control of the depth of the sulcus is feasible if there is prior discussion of the esthetic goals among patient, dentist, and specialist. According to Kramer, periodontal treatment can be successful and still leave a manageable 2 mm deep sulcus to hide the metal margin.[55]

A number of finish line shapes have been discussed, including the labial shoulder chamfer and beveled shoulder. Any one of these provides adequate reduction in the labiocervical area, providing for good functional and esthetic results. This becomes particularly important where the maxillary anteriors or bicuspids are involved. Consideration must be given to how the finish line will ultimately relate to the marginal adaptation of the crown in the labial or buccal areas.

The possible labial margin designs using the previously mentioned finish lines include (1) a labiogingival porcelain–metal chamfer margin, (2) a labiogingival metal collar, and (3) a porcelain butt joint (Figures 16.21A–D). Almost always this can be hidden under the gingival sulcus, especially in maxillary anteriors and premolars. When the tissue is either thin and transparent or at zero sulcus depth, a porcelain butt joint is preferred. In designing the substructure, labial metal is carried to the shoulder but not on to it (Figure 16.26).

The labiogingival metal collar margin has an esthetic disadvantage in anterior restorations in cases where the metal collar is located incisal to the free marginal gingiva, thereby allowing for an unsightly display of metal. If the free gingival tissue on the labial is thin, the metal collar may create a dark bluish gray at the margin. Therefore, the metal collar seems most useful in the cervical areas of maxillary molars and in all mandibular teeth where the cervical areas are not visible, even if the patient smiles broadly.

Currently, according to Lanzano and Hill,[56] there are three main techniques being advocated for the fabrication of the metal collarless crown, but the finish line for all three techniques is identical. The facial finishing line should be a 90° shoulder of 1.5 mm in depth. This provides enough depth for adequate esthetic characteristics and sufficient bulk to provide strength. The lingual finishing line can be whatever the dentist would like to use with a traditional metal–ceramic restoration.[56]

The coping designs, as detailed by Anusavice and Hojjate, may terminate at the axiogingival junction or with the extension of the coping along the gingival floor but short of the facial margin. The most esthetic option is associated with the metal coping restricted to the axial wall and not extending into the shoulder area of the porcelain–butt joint margin.[10] A precise margin is difficult to obtain in porcelain, but methods have been developed to improve the fit in this critical area.

How to choose the right crown for esthetics

There is no one ideal crown for all situations. Each case is different, with varying factors that influence the choice of crowns. Patients have different esthetic demands that may or may not compromise function. The decision that one restoration is more esthetic than another is essentially based on visual interpretation. In certain mouths, anything will do (uniform tooth color, no distinguishing marks, etc.). In others, different identifying marks have to be matched, and a decision must be made as to whether to use gold, nonprecious metal, acrylic, or porcelain.

One should balance esthetics and function for each patient, and that balance will be different for each patient. To make the decision therefore, there must be an understanding of certain principles. Assuming the lithium disilicate or gold crown to be the most functional, it is the restoration of choice when esthetic needs are not compromised. For posterior teeth, if the patient agrees, full or partial coverage in lithium disilicate or gold should be used. Clearly, the advantages of the lithium disilicate restoration are that bacterial plaque does not form readily on its surface and that it is less thermally sensitive than gold. A disadvantage might be difficulty in maintaining adequate isolation for the bonding process.

The choice is ultimately based on a consideration of many factors.

1. **Lip line.** Does the gingival margin show when the patient speaks, smiles, or laughs? If so, one should select a crown system with an all-ceramic margin. Is the tooth to be crowned visible when smiling? Figure 16.29A shows a wide smile line of a female.
2. **Length of esthetic life expected by both patient and dentist.** This is a function of several factors:
   a. **Wear patterns.** Acrylic or composite resin restorations will not last as long as lithium disilicate or porcelain.
   b. **Acid content of the saliva.** Acid level and the amount of stain accumulated by natural and restored teeth are indicators of the life expectancy of acrylic, composite resin, and even cementing materials.
   c. **Although still in its infancy, the known survival data of different ceramic materials today favor the lithium disilicate ceramic.**
3. **Space limitations in tooth preparation.** For example, will the pulp preclude sufficient reduction for metal plus opaque plus porcelain? Evaluate the alveolar support.
4. **Occlusion.** Is the occlusion favorable for a full porcelain occlusal surface? It is always best to have porcelain functioning against porcelain. If the opposing occlusal surface is gold, the chances are the porcelain occlusal surface will wear the gold considerably faster. Even enamel can wear quickly against a porcelain occlusal surface. The lithium disilicate restorations wear very similarly to enamel.[57]
5. **The gingival sulcus.** Can one predict the long-term health of the sulcus? Even the most perfect gingival sulcus can become diseased and deformed within days, so one can never really be certain of long-term gingival margin coverage. How regularly is a patient receiving dental prophylaxis, and if previous disease was treated, is the patient maintained with periodontal care?
6. **Tissue type.** Is the tissue thin and transparent, thick and fibrous, or alveolar mucosa or keratinized attached gingiva? The thin, transparent type will be the most likely to recede or to show a metal margin. On the contrary, if a patient possesses thick fibrous tissue, one may choose a metal margin and be esthetically protected.
7. **Appearance of surrounding teeth.** How much translucency or opacity exists in adjacent or opposing teeth? Do they need to be recontoured before beginning treatment?
8. **Financial considerations.** Is the patient willing to pay for use of a high-quality laboratory or master ceramist, including specialized characterization procedures, or do they want the most economical treatment? Certainly, one of the more difficult decisions will be to match a fee to the level of difficulty presented by the patient. This difficulty may be expressed by the esthetic requirements of the patient, or even by the patient's attitude.

The patient and dentist should attempt to answer all these questions before a final decision to commence treatment is made. Many times, this choice cannot be made until the teeth are actually prepared, in order to determine how much space is available for the restoration.

The mouth must also be as disease-free as possible. The type of restoration should never be decided at the first or second appointment if there is periodontal disease or advanced caries or posterior bite collapse. Because the condition of the mouth can change, any decision would be premature. Since esthetic correction is accomplished in the provisional crowns or splinted fixed prosthesis, final decisions can be postponed and the options reevaluated later. When esthetics is a primary concern in both anterior and posterior teeth and there is not the need to splint restorations together, the all-ceramic restoration would be the primary choice for a long functional life and excellent esthetics.

Specific problem: the discolored pulpless tooth

Crowning one central incisor to match an adjacent tooth is one of the most difficult tasks in esthetic dentistry (see Figure 16.27A–D). When the compromised tooth happens to be nonvital and discolored, the procedure can become even more complex. The goal is to decide what type of restoration can best solve a patient's problems. The decision depends on what type of discoloration is present and whether or not a post and core will be needed that also could complicate the use of an all-ceramic crown. Recently,

Figure 16.27 **(A)** The patient had a composite resin restoration that debonded and presented for a more permanent restoration. Because of the significant recession and the root caries, a crown was chosen as the restoration and lithium disilicate e.max as the material.

Figure 16.27 **(B)** With adequate reduction, matching the shape, hue, chroma, and value becomes less of a challenge.

Figure 16.27 **(C)** A treatment wax is tried in, and the patient approves the esthetic direction chosen by the restorative dentist and the laboratory technician.

Figure 16.27 **(D)** The final restoration shows a very close match with the adjacent tooth. With adequate photography and shade communication, excellent matches can be achieved. Even radicular discoloration can be closely matched. Later the carious class V lesions will be restored with composite resin.

it has been possible to press lithium disilicate to a metal post and cover potentially more of the axial wall as an extended ferrule (see Figure 16.28). This can be very effective in masking the underlying discolored tooth.

If discoloration is the only problem, one may choose to use a porcelain veneer. However, this approach may make it more difficult to obtain a perfect match. One cannot remove extra tooth structure because porcelain veneers need to be bonded primarily to enamel. The problem of obtaining an optimal result can be made more difficult due to the effect of the underlying composite resin cement on the shade of the porcelain veneer. The tooth shade can also vary somewhat after seating the veneer because of a color shift in the polymerized composite resin cement. In fact, it may take several days to a week for the final color to be apparent, and by that time, one will obviously have no ability to change the color. Therefore, a crown may be the preferable choice, especially if the patient is a perfectionist. A crown's color and depth of stratification can be altered a few times as necessary to obtain the proper color.

Opaquing

Although an opaque can be applied to the tooth to mask the core and could conceivably help if the restoration is either a porcelain veneer or an all-ceramic crown, it may still be insufficient to mask the darkened tooth. The most predictable way is to have the laboratory incorporate the correct amount of opaquer in the ceramic material itself. Although this may sound like a simple solution, it is not. Until one actually seats the crown with cement one will not be assured the choice of material and opaquer is the correct one.

The most effective solution to this problem is to use a metal–ceramic crown with a metal substructure that is fully opaqued, masking out even the darkest of teeth or metal post and core. Masking of the opaque layer is also an esthetic necessity. It can be accomplished either by thickening the body porcelain layer or by tinting the opaque. To optimize esthetics, a porcelain shoulder that wraps around the entire preparation is quite

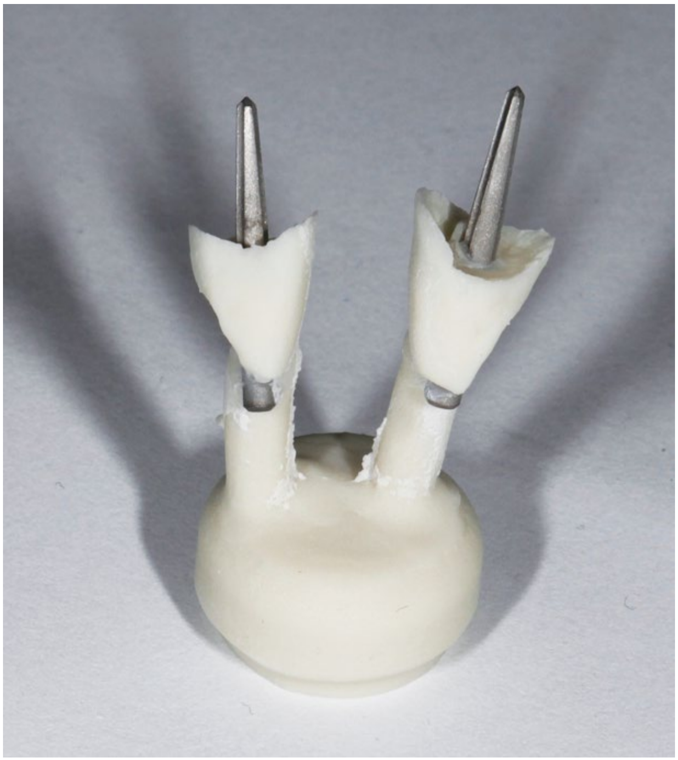

Figure 16.28 Lithium disilicate can be pressed onto a prefabricated gold–palladium post (Cendres Metaux) and used as a very rigid substrate to support an all-ceramic restoration.

effective, using metal along the axial walls only and not encroaching upon the visible marginal areas (see Figure 16.26). A problem can still exist if the root itself is discolored. In this condition, the margin area and gingival tissue may not be the correct color.

Principles for esthetic restorations

There is no substitute for the beautiful, healthy appearance of tooth enamel. This is precisely why it is so important to apply every conceivable esthetic principle in construction of a ceramic restoration. Using these principles is the best means of achieving the goal of a truly esthetic restoration. The concerned dentist must continually study the subject of esthetics, not only by attending courses and reading the literature, but also by being a keen observer of the natural smile and the use of diagnostic casts and digital photography. Shapes of teeth and their arrangement in the arch are crucial to obtain an esthetic result in artificial restorations, as the objective is to make the artificial restoration look believably natural. The following discusses some of these principles and solutions to the most common esthetic problems.

Lip line

The type of lip line almost always determines the number of teeth to restore. Observe not only the number of teeth exposed when the patient is smiling naturally, but also every tooth that is visible when the patient smiles widely. This is necessary to properly analyze the esthetic component (the teeth visible during smiling) in order to communicate to the patient exactly how the smile will look after restorative treatment. Often, the patient will seek to restore only the six anterior teeth, failing to realize that the improved shade or character of the restorations may call attention to the adjacent untreated teeth, which will no longer match. Thorough explanation of the smile analysis is necessary so that the patient can understand the results of the restoration before treatment begins. In addition, the use of lateral close-up and full-face views with computer imaging is essential in this instance. Few patients can visualize their smile past the six front teeth. To determine whether the lip line is high, medium, or low, observe the tooth length exposed when the patient smiles.[58]

High lip line

A high lip line is one in which all supragingival tooth structure and some gingival tissue are visible upon smiling (see Figure 16.29A).[58] The patient with the high lip line may not be the best candidate for a full crown because tissue tends to recede in time and a previously concealed margin may become visible. If the restoration is metal–ceramic, even a small metal collar may become exposed. Thin, transparent gingival tissue is more apt to recede. Even if the margin is not exposed upon insertion of the crown, such exposure may occur at a later time and make the patient extremely unhappy. It may be preferable to suggest a compromise treatment plan using ceramic veneers.

When the patient has a high lip line and a full crown becomes a necessary restorative choice, one should ideally use an all-ceramic restoration or with a metal–ceramic restoration the use of a full shoulder preparation on the labial surface with a porcelain butt joint as the margin. This will assist in maintaining an acceptable esthetic appearance if the tissue does recede in the future.

In the event that the tissue recedes after the impression appointment but before cementation, an immediate repair can be made to a porcelain butt margin. Even at the try-in appointment the labial shoulder margin can be extended into the gingival sulcus. Refit the crown with softened low-fusing compound attached to the labial margin. Make certain the new shoulder margin is recorded in the compound and pour a new die. After adapting foil to the die, the compound is removed and the porcelain added to establish the margin. An alternative impression compound would be polyether (Impregum, ESPE), since it has sufficient body hardness and is tenacious enough to record the new margin if one can achieve adequate tissue displacement.

Medium lip line

A medium lip line is one that shows up to, but does not include, the cervical margin of the anterior teeth (see Figure 16.29B).[58] A small portion of the interproximal gingival papilla also shows in a wide smile. The medium lip line presents only moderate difficulty in crown restoration, because the gingival margin is only seen in the widest of smiles. For normal speaking or slight smiling, there is no exposure of this area, thus a slight hint of a metal collar should present no unusual difficulty for most patients. However, for those patients who are extremely critical of any metal showing, the all-ceramic restoration should be used or the porcelain butt joint with a metal–ceramic crown.

Low lip line

In a low lip line the gingival margin is never revealed;[58] therefore, no problem exists with exposed margins except, possibly, in the patient's mind (see Figure 16.29C). Ideally, if the restoration can be a single unit, the all-ceramic crown is the state of the art. A metal–ceramic restoration with a metal collar is an ideal restoration when posterior teeth need to be splinted together or with fixed partial dentures only. If anterior teeth are splinted together the use of the buccal butt technique is required. The esthetic requirements may be less critical for a patient with a low lip line because with time the metal–ceramic restoration may display color deficiencies but they cannot be seen unless the patient retracts the lip with their fingers to look at the gingival margin; it becomes important to communicate this fact and allow the patient to participate in the final decision about treatment. It is necessary to explain to the patient exactly why their lip line will allow one to create the best possible biocompatible restoration. However, some patients, even those with low lip lines, may have emotional reservations about the presence of any exposed metal in their mouths; therefore, this must be dealt with on a psychological as well as a functional basis.

Arch irregularity

An arch irregularity generally exposes more coronal area on one side of the mouth than the other upon smiling (Figure 16.30). It is essential that the patient is made aware of this problem during the diagnostic stage. A patient needs to know that the crowns may not be bilaterally symmetrical in the final restoration. Take both full-face and close-up prerestorative photographs to preserve a good record of the patient's original intraoral condition in both smiling and lip-retracted positions. Computer imaging is also helpful to point out to the patient the irregularity and what one can do, if anything, to correct it.

Inclination of teeth

The inclination of teeth is an important consideration with all restorations. In the metal–ceramic restoration, because of the inherent qualities that exist in a crown with metal, opaque, and porcelain layers, this may be even more important. Proper color must be built into the restoration rather than relying on the use

Figure 16.29 **(A)** A patient with a high lip line shows a continuous band of gingiva across the entire smile. These cases are considerably more challenging due to overwhelming exposure of the teeth and the supporting tissues.

Figure 16.29 **(B)** A patient with a moderate lip line generally shows only the papilla. These cases can still be challenging, in particular with implant prosthodontics.

Figure 16.29 **(C)** A patient with a low lip line will show no tissue and, furthermore, only show a limited amount of tooth structure. This is widely considered to be the least difficult due to the limited amount of visibility.

Figure 16.30 An arch and lip irregularity in the patient's smile causes more teeth to show on the patient's left side.

of surface stains. This will prevent lingually inclined upper anteriors from appearing to have different and darker shades in low lighting conditions. This may also apply in the case of extreme labially tipped upper incisors. Under certain conditions, when the head is tilted back exposing more of the lingual surface, the same situation may occur. Lingually inclined maxillary posterior teeth may need to be built out labially to achieve the most attractive overall smile.

If the crowns are satisfactory in their form and shade reproduction, the next concern is that they appear natural in their surroundings. Three factors that most often influence this are interincisal distance, and incisal and gingival embrasures.

Interincisal distance

The interincisal distance refers to the difference in incisal lengths of the maxillary central and lateral incisors. Generally, the central incisors should be slightly longer than the lateral incisors. The greater the distance, the younger the smile appears (Figure 16.31). As teeth wear, the incisal length of the centrals becomes reduced, making the four maxillary anterior teeth more equal in length. If an older look is desired, less interincisal distance is used. If a younger look is the objective, a greater interincisal distance is incorporated. This must be coordinated with incisal guidance, the incisal table of the mandibular incisors, and the cusp tips of the posterior teeth. Some patients can tolerate longer central incisors, whereas others may complain that their lips cannot accept the added length. Even speech can be a problem for them. One should observe the patient in saying "F," "V," and "S" sounds to understand the proper position of the anterior incisors. Whenever planning a greater interincisal distance, the patient should observe this in a treatment wax or a direct mock-up. The corrections may be created in the provisional restorations and ideally left to function for several weeks to determine the suitability of the altered incisal length.

When a high lip line exposes all the upper teeth in almost every facial expression, it is usually advantageous to vary the interincisal distance. Even altering the length of the central incisors by making one slightly longer than the other can create a more natural appearance, since this is frequently found in the natural dentition.

Incisal embrasure

The incisal embrasure refers to the space between the incisal tables of adjacent teeth. Lack of proper incisal embrasures usually results in an artificial-appearing restoration (Figure 16.32A and C). In each patient, it is usually best to duplicate the adjacent, natural incisal embrasures. Study photographs of the patient's smile as well as other people's smiles to appreciate the variation of incisal embrasures that exist in different individuals. An entire personality or cosmetic change can result from increasing or decreasing embrasure length and width.

Gingival embrasure

The esthetic restoration requires an adequate zone of attached gingiva and a proper embrasure that permits interdental tissue to exist without impingement (Figures 16.32B and D). One cause of

Figure 16.31 Aging in the smile line can be influenced by varying the interincisal distance. **(A)** A more youthful smile because of greater interincisal distance; **(B)** depicts increased wear, and thereby an older smile.

Figure 16.32 **(A–D)** Properly formed incisal and gingival embrasures are necessary for an esthetic restoration. (A, C) "Chicklet" appearance of a typical restoration lacking well-formed incisal and gingival embrasures. Absence of the gingival embrasures produces gingival impingement resulting in inflammatory response, which is unesthetic and functionally unacceptable. (B, D) Esthetic improvement is shown when both gingival and incisal embrasures have been included.

an unesthetic restoration is inflamed tissue due to overbuilding porcelain in the gingival area. The best prevention is, at the try-in, to mark the porcelain with a sharp pencil and open the area between adjacent teeth to encourage healthy tissue. An alternative method of creating proper gingival embrasures is to make a duplicate model showing exactly where the tissue is. Because tissue must be adequately supported, undercontouring porcelain may also cause a problem. A correct emergence profile is essential for both functional maintenance and an esthetic appearance. A gingival papilla will be present or absent in part by the amount of inter-root space that exists.[59] When roots or roots to implant are close, a gingival col anatomy will be present and generally the papilla will close the gingival embrasure. When the roots are far apart, the gingival anatomy becomes keratinized, and the gingival col flattens down and becomes convex. In this condition the papilla is lost.

The stage at which most problems should be resolved is before the impression, at the time one makes the provisional restoration. There are several reasons why all intended corrections should be incorporated in the provisional restorations. First, it allows the patient to wear the new look and to adjust to any esthetic and functional changes. Many esthetic changes may not be readily accepted by one's peers. This type of criticism is better to be received and evaluated during the temporary phase.

Second, it allows evaluation of the preparation before taking final impressions. After the intended shape and contour of the temporary restoration is completed, examine the thickness in every portion to be sure there will be sufficient room for metal, opaque, and body and incisal porcelains. If there are thin spots due to the labial convexities that are necessary to achieve an esthetic result, then alter the preparation to gain extra space for the final restoration. When presence of pulp tissue makes it impossible to remove additional tooth structure without potential damage, inform the patient that a vital pulp extirpation might be necessary to achieve the desired esthetic correction. It is important that the patient be a part of this decision, especially if the esthetic result would be compromised by an inadequate tooth preparation.

Another reason for making the provisional restoration before the impression is to examine the occlusion and make any alterations on the opposing arch that will improve the result.

These types of changes can only be made during tooth preparation. If one waits until the esthetic try-in, the final restoration may be a compromise rather than the esthetic result it can and should be. Always try to anticipate decisions of this sort so that the patient will be prepared and not become defensive when one realizes too late that one must reduce the opposing arch.

Tooth contour and shape

After the restorative material has been chosen, the next important factor is the shape and contour of the restoration. Natural teeth have rounded contours, rather than the square that may often be found in unnatural-appearing restorations. This is seen especially in the anterior teeth, where many ceramists tend to flatten the labial surfaces rather than place the proper contour and line angles in the mesial and distal aspects of that surface. Another common fault is lack of critical viewing from the incisal or occlusal aspect.

The ceramist is usually confronted with the problem of matching the contours of adjacent teeth. However, the esthetic appearance of the restoration can usually be improved by first altering the form of the adjacent teeth through cosmetic contouring or interproximal bonded ceramic veneers.

Yuodelis et al. found that correct morphological contours, although a vital part of any esthetic restoration, are of paramount importance during dental procedures that involve full-coverage restorations.[60] It has been suggested that the facial and lingual enamel bulges of human teeth protect the free gingival margin from the trauma of occlusion by deflecting food over the gingival crevice and onto the keratinized gingival tissue. Kramer, however, questions the effect of the curve and the evidence that indicates that crown contours protect tissue.[55]

Since microbial plaque is the principal cause of both caries and periodontal disease, its retention by tooth surfaces is to be avoided. Clinically, plaque retention is greatest in inaccessible areas, particularly the interproximal and the facial and lingual cervical areas of the teeth. To keep these areas plaque free, the relationship of morphology of crown contour and degree of accessibility must be understood. Overcontouring can encourage debris accumulation that may lead to functional and esthetic breakdown of supporting tissues.

In an experiment conducted by Perel that supports these findings, the effect of crown contours on gingiva was clearly demonstrated.[61] The mandibular teeth of mongrel dogs were remodeled by removing tooth structure from the labial, buccal, or lingual surfaces in different parts of the mouth. The labial surfaces of some teeth were overcontoured using self-curing resin. Results showed that supragingival undercontouring caused no apparent gingival pathology, whereas overcontouring caused inflammation and then collection of debris, hyperplasia, and engorgement of the marginal gingiva, scant keratinization, and deterioration of the fibers of the gingival collar.[61]

Thus, it may be seen that this so-called protective function of convex crown contour may in reality trap food and prevent vital stimulation of the gingival margin. In addition, particularly after periodontal therapy that involves osseous resection, a longer-than-normal clinical crown may be left. These lengthened clinical crowns are more difficult to keep plaque free due to the exposed furcations and different root shapes, especially proximal convexities that are much harder to clean.[60] In such cases, for an esthetic long-term result, the final restoration should not follow the original anatomic contour; instead, it should recreate at least the gingival contours of the root portion. This makes the gingival third of the furcation areas more accessible for cleaning. The crown contour debate has been active for years and clearly is real when studying teeth and their gingival relationships. In implant dentistry, where a tighter marginal seal is always present, this debate is of less importance.

While crown contour must establish an esthetic result, it must not compromise the patient's oral health. Although this responsibility lies solely in the hands of the dentist, too many practitioners try to pass it off onto the technician. Tooth preparation is extremely important to guarantee that the laboratory technician has sufficient room to create a well-shaped and contoured restoration. Although the laboratory procedure begins with the technician, it certainly ends with the dentist at chairside. No matter how well the technician has created a crown, some improvement and personalized changes can usually be performed by the dentist at chairside during the try-in appointment. Naturally, the better the technician, the less adjustment is necessary by the dentist. A faithful duplication of the matching tooth in the patient's natural dentition usually gives the best esthetic result, although occasionally an increase or diminution in overall size may be necessary due to tooth movement. The basic curves, angles, heights or contours, contact areas, and general outline form should be duplicated as closely as possible. Areas that need special attention are the mesial and distal incisal angles, the areas of contact, the concavities and convexities at the labial line angles in the gingival third of the crown, and the thickness of the incisal edge labiolingually.

A patient's appearance can be considerably altered depending on the shape of the crowns (Figure 16.33A). Notice in Figure 16.33B how different the smile can look when rounder, softer contours are used.

Another important factor to consider in the contour of the restoration is the shape of the pulp. If the pulp is unusually wide, this may be a contraindication for crowning. When some type of correction is imperative, a wide pulp requires a shallow preparation and a temporary crown for 6 months to 1 year to induce pulp recession through the formation of secondary dentin. The smaller the pulp in height and width, the greater the amount of tooth correction that can be made when necessary.[62]

Final esthetic try-in

The last chance to make corrections is at the esthetic try-in. Staining, final shaping, and contouring to influence personality, age, and sex, and any other improvements, should be done or planned at this time. The ceramist then has to add the necessary final touches to make an attractive and natural-appearing restoration, usually without seeing the patient. These changes must be determined at the chair. When writing the laboratory prescription, include as much information as possible in order to aid the technician.

Figure 16.33 **(A)** This patient presented with a severely worn dentition. She felt that her teeth made her look masculine and wanted softer contours.

Figure 16.33 **(B)** The final delivery shows, in contrast to the originals, that the softer corners and open incisal embrasure can give a youthful appearance.

Figure 16.34 The width of the maxillary teeth in the natural dentition has a definite size variance. These dimensions can be used as a guide to the approximate proportion of anterior tooth width.

Tooth size

Computer imaging can help one in correctly proportioning the teeth. The principles of divine proportion should be built into a software program to give one a better idea of proper relative tooth size for a patient. Beaudreau suggests that the teeth can be proportioned in a general sense.[63] He proposes that when the central incisors are 8 mm wide the cuspids should be approximately 7 mm wide and the laterals should be 6 mm wide (Figure 16.34). Therefore, the lateral should be approximately 25% smaller in width than the central incisor, and the cuspid is approximately 13% narrower than the central incisor.

Long teeth

There are generally two causes of an extra-long tooth. The most common reasons for a long tooth are often caused by a skeletal malocclusion or periodontal disease that caused the teeth to be supraerupted. This problem is especially troublesome in the patient with a high lip line, where tooth symmetry, or lack of it, is all too apparent upon smiling. Periodontal treatment that includes grafting should be instituted before restorative treatment. If the existing restoration is still too long, then the replacement can incorporate gingival ceramic or a shorter root form that may improve the appearance.

Long teeth may be a result of periodontal surgery. A major consideration in crown preparation in these patients is the difficulty in preparing a modified chamfer on the root. Consequently, the resulting thin chamfer or knife-edge preparation does not allow for sufficient marginal depth to accommodate porcelain to conceal the metal or opaque color. In the final analysis, the patient's lip line can make the difference. If the patient has a medium or low lip line, there should be no problem.

When patients have extensive loss of interproximal tissue due to periodontal surgery, there are two solutions that can generally be applied to crown restorations: the addition of pink porcelain to the restoration to simulate interproximal tissue, or, if all else fails, a removable interproximal silicone tissue insert.

The use of gingival ceramics involves raising the gingival contact in porcelain and adding additional material lingually to close the space. One of the problems with this technique is the difficulty in matching the pink tone of the individual patient's gingiva. Request the laboratory to make several shade tabs of different combinations of pink porcelains to provide a range for matching the patient's gingival color, and ideally have the laboratory technician make the color analysis. An alternative to one of the prosthetic solutions to loss of interdental space is the possibility of orthodontic extrusion; this can sometimes work well when there are limited numbers of teeth involved.

Short teeth

If the tooth appears too short, first explore the possibility of lengthening the tooth by periodontal surgery to either apically reposition the tissue or, when there is excesses tissue, by a gingivectomy procedure. If not feasible, then resort to illusions in the crown to give an appearance of greater length. Eliminate horizontal lines and emphasize vertical characterizations and texture. Flatten the gingivoincisal dimension to help emphasize length. Rounding the proximal surfaces will make the tooth appear longer. Use stains to emphasize the length by darkening the interproximal porcelain and lightening the vertical dimension of the crown. Try to create vertical highlights by creating vertical, parallel lines on the labial surface that will reflect light in a vertical dimension.

Correct occlusal registration

An accurate interocclusal registration and the use of an articulator are essential in obtaining a successful esthetic result. As previously discussed, after master impressions and articulation, a dental technician should complete a treatment wax that can be placed in a patient's mouth to determine the correct tooth length, midline position, tooth cant, and the planes of occlusion (see Figure 16.35A–D). It may assist the technician if impressions are made of the provisional crowns to help determine the length of the restorations. Failure to do this may result in the crowns being too long at the try-in appointment. If this is not determined with the patient for their approval, alterations of the porcelain to correct the contour and occlusion may remove or affect ceramic stratification and occlusal or incisal translucency built into the ceramic color. Photographic or computer imaging may aid in this process.

Tooth arrangement

When the arch length to be restored is too small for normally sized crowns, it is sometimes better to overlap the lateral or central incisor crowns, when the patient permits, rather than simply reproducing smaller teeth. Another option is use of slightly larger crowns and elimination of one tooth in the restored arch. The solution should always depend on the patient's facial features, expressions, overall personality, and personal preferences. The intended correction should be made first on study casts and with computer imaging so that both the dentists and their patients can visualize and approve. Then, it is done on the

Figure 16.35 **(A)** This patient had seen an orthodontist for several years. Once the patient was debanded, his teeth exhibited substantial enamel hypoplasia and incipient caries. The anterior maxillary and mandibular six were the most severely affected. Couple that with a virtually nonexistent anterior guidance, so full crowns were indicated.

Figure 16.35 **(B)** The treatment wax is fabricated on the master cast and then transferred to the patient's mouth.

Figure 16.35 **(C)** In the mouth, the treatment wax can be used to allow the patient to freely communicate their esthetic desires. It also allows the technician to align their vision of the case with that of the patient and the restorative dentist.

Figure 16.35 **(D)** After trying in the treatment wax and receiving the patient's approval, the technician can use it as a blueprint and fabricate the final restorations.

temporary prosthesis so that patients can live with it before it is incorporated into the final porcelain restoration.

Tooth color

To deal with the perplexing problems of matching teeth, a thorough understanding of color is mandatory. With this increased knowledge and by applying some of the principles outlined in this chapter, more successful shade matching can be attained.

Culpepper[39] and others have described that one of the weakest links in shade making, regardless of shade guide or system used, is the eyes of the individual dentist. Although there have been many experiments in shade matching, few, if any, could be considered successful. What they did show was not only the tremendous variability in the way different dentists see color, but also the inconsistency in a given dentist's evaluation and judgment of color when tested at different times. Eyesight changes with age, and it also varies day to day, hour to hour, and appointment to appointment. This explains how a dentist or technician can select a shade, then look at this shade several days, or even minutes, later and see a different color. It also helps to explain how, regardless of how much care is taken, shades will sometimes be missed. Also, shade guides are just that: guides. They are rarely made of dental ceramics or the materials that will be used in the restoration. The matching of tooth color must be individualized for each patient.

Texture

After shape and shade selection, surface texture and characterization are important adjuncts to a natural esthetic appearance. An attempt should be made to copy the surface texture of adjacent teeth. Study natural teeth to note how small facets create natural shadows. Figure 16.36A and B shows examples of highly textured and nontextured teeth. Duplicating existing irregularities and heights of contour of adjacent teeth produces realism. Maximum highlights are reflected from the heights of contour, but realize that overprominent ridges and grooves on the labial surface are often associated with false teeth and add little to the esthetics of the restoration. A smooth, unbroken surface gives the impression of a long tooth, whereas texture can give the impression of a smaller tooth. At the try-in appointment, the moistened surface should be compared with adjacent teeth. This is most important when a single crown is to be placed next to a natural tooth.

An alternative method is to use a good color-balanced digital camera that can produce video. These digital images are an excellent method to convey to a technician an actual color representation of the condition of the patient's adjacent teeth, including shade variations.

Light

The light used to take a shade is critical. Since the eyes of the dentist and the laboratory technician are different, using different kinds of light sources can compound an error in color and judgment. For this reason, it is best for both the technician and dentist to use the same color-corrected light source.

The best light source for color selection is the light through a window with a northern exposure. If this is not available, take the patient outside, preferably with an assistant and laboratory technician. Be sure to include a full-face mirror for the patients so that they can participate in the selection procedure. An overcast sky is preferable, since a bright sky has a blue component that enhances the green color of the tooth. Early morning and late afternoon sunlight has a yellow component that enhances the yellow hue in the tooth. Inside, see how the shade may differ in incandescent light and in the lighting of the treatment room.

Even if outside light is available, one should use color-corrected fluorescent bulbs in the treatment rooms. In fact, one

Figure 16.36 **(A)** The amount of surface texture will affect the perception of color. A tooth with minimal surface texture will exhibit a flat, more opaque color.

Figure 16.36 **(B)** In comparison, a tooth with greater surface texture will appear more translucent and have a more vital appearance.

of the best light sources available today is the color-corrected natural daylight fluorescent bulb. Used by major industries concerned with color control, it closely reproduces natural daylight and allows the truest relationship to exist between the shade guide and tooth. Request that the laboratory use them, because they can help achieve the best esthetic color result.

As an alternative, there are several hand-held light sources that one can use to help take a shade (Spectroshade, Vident, or Olympus). Ultimately, one will be using three light sources:

- fluorescent light
- outside light
- incandescent light.

In the event the shade appears different in the various light sources, make sure the patient is aware of this difference. Then ask in which light source he or she will be seen most of the time or in which light condition he or she wants the restoration to best match. *Although the entire dental team may participate in shade selection, the ultimate decision must rest with the patient.* Be sure to have them sign off on this final color selection. Otherwise, the patient may blame you if they become dissatisfied with the color of the final crowns.[64]

A patient's lipstick should be removed before they consider shades. When choosing the gingival shade, the lips of the patient should be raised and the incisal portion of the teeth covered. For selection of the incisal shade, the patient's lips should be in a speaking position to give one a better concept of shade and to eliminate any influence from the gingival third of the tooth. If using lip retractors, avoid drying out the teeth. Keep them wet during the entire process or the existing teeth may dry out sufficiently to change color. When selecting the shade, the patient's head should be erect and at your eye level. The dentist should stand between the patient and the light source. If there is no outside light, and only color-corrected light from overhead fixtures is being used, it may be necessary to tilt the patient back so that the light hits the tooth directly.

What to record

To construct a complete and accurate shade chart of a tooth, it is necessary to be able to see different colors in different sections of the tooth. Although dramatic differences may usually be seen in the broad gingival, body, and incisal portions of the tooth, there are often more subtle variations that occur in smaller areas of the tooth, varying with the angle at which one views the tooth. For example, a translucency may occur at either the mesial or distal line angle. It is rarely straight across or consistent, but often a broken line along the incisal one-third or one-fourth of the tooth and takes different shapes and forms in each tooth.

This should all be recorded on a shade chart that divides the teeth into sections to give the ceramist an understanding of where the colors are located. In this respect, a complete set of felt-tip colored pens is helpful (see Figure 16.37A and B). The different colors in the tooth can be diagrammed easily to give the technician a better understanding. To be as precise as possible, it may be necessary to give the technician several different shade tabs, with only portions of each marked, to correspond with specific sections of the tooth where that specific color is located. This way, the ceramist has a better idea of the hue, value, and chroma to be used. Another technique that can be used as an adjunct to digital photography is manipulation of the digital image. By maximizing the contrast and reducing the exposure of the image, the internal colors, and varying translucencies can be viewed. This technique, which can be seen in Figure 16.38A and B, works best when attempting to mimic an existing natural tooth (e.g., matching centrals). The shade will also depend on the position of the teeth. If central or lateral incisors are tilted lingually, the light is reflected differently than if they were in a marked labial inclination. If the patient is in a Class II or protrusive arrangement, choose a deeper or darker shade, since a lighter shade is more conspicuous and creates the appearance of false teeth. In a Class II patient with a high lip line, it is best to overdramatize the difference between the shades within the tooth. Accentuate the blues, greens, and oranges

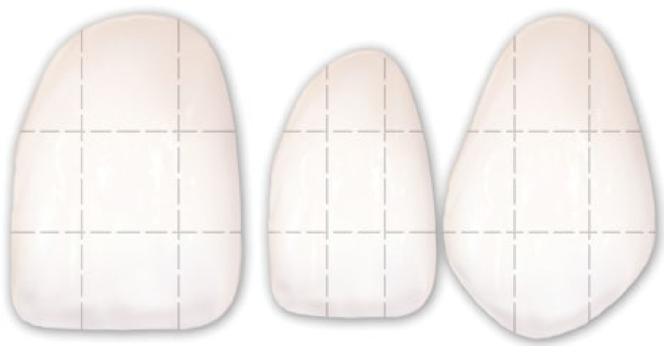

Figure 16.37 **(A)** This is an example how to divide the tooth surface to generate a functional shade chart.The teeth are divided into nine sections each for more exact shade mapping.

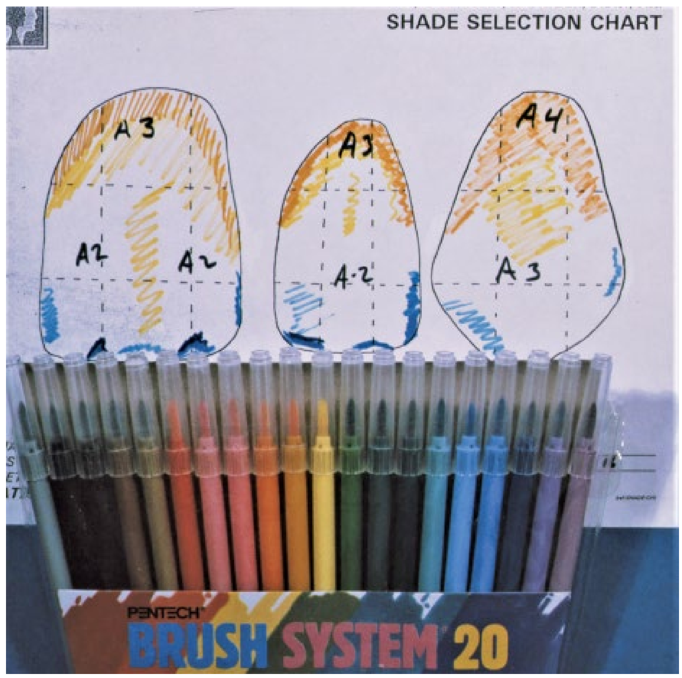

Figure 16.37 **(B)** Note how specifically the gingival intensity and incisal translucency can be designated with a complete set of felt-tip color pens.

Figure 16.38 **(A)** When evaluating the internal coloring and defects in the tooth, a very useful technique is to increase the contrast and decrease the brightness. This will highlight incisal effects that may be difficult to see.

Figure 16.38 **(B)** After modifying the photograph, the technician can clearly see the incisal translucency and halo effect, as well as areas of hypercalcification and cracks.

and include any imperfections that simulate naturalness. Light reflection from a protruding tooth is much greater than from a tooth that is positioned lingually and thus shielded by the lips during smiling or speaking.

Conversely, beware of a dark tooth that is well concealed by the lips. To match this tooth, it is best to do so by choosing the appropriate shade of the basic dental ceramic. Frequently, to match the darker tooth, a mistake is made by using light-colored porcelain with surface stains to darken it. This may result in metamerism, or a tooth that will look different in different kinds of light. In changing light conditions, reflections will make the tooth look darker than it really is. It is critical to take sufficient time to choose the best possible shade and to view it under different forms of light before a final decision is made.

Shade selection should be as accurate as possible because, as shown by Mulla and Weiner, the appearance of the restoration that has been extrinsically stained cannot be precisely predicted. The changes for a particular type of stain, however, appear consistent, and it may be possible to judge the amount of stain to be applied on the basis of prior experience.[65]

McLean notes that custom staining should not be used for alteration of incorrect colors, except in marginal cases, but rather that custom staining be confined only to creating surface defects or colors that are present on the natural tooth surface. If one can narrow the choice of the basic shade to two, the one higher in value should be chosen, because a value can be lowered by staining, but a low value cannot be made lighter.[66–69]

However, there is no doubt that the most esthetic and esthetically long-lasting ceramic crown is one that has been constructed with color incorporated into the porcelain (stratification) internally, rather than by staining the surface. The internal color can come from layers of different shades of porcelain, from inlaid stains, or from special effects included into the building process. Good examples of natural-appearing, internally shaded, all-ceramic crowns are shown in Figure 16.39B.

Areas of stain, hypocalcification, translucency, crack lines, or other artifacts that one wants in the crown should be carefully placed on the shade chart to record their exact position on the tooth. The more accurate the rendition, the better the final result.

For anterior crowns, if there are no adjacent, opposing, or nearby natural anterior teeth to match, evaluate the shape, texture, and shade of the uncrowned, posterior teeth. Note the presence or absence of multiple colors, translucencies, or artifacts. The posterior teeth can serve as a relative guide for the missing anterior teeth. One can also ask the patient to provide photographs that clearly show the anterior teeth when they were unrestored. If there are no photographs or unmarked or undamaged teeth in the mouth, one is free to choose any acceptable shade. Since all these must be done before one begins any treatment on the tooth, a preliminary shade chart should be completed at the first appointment. The tooth should be checked again at the next appointment to confirm or make any necessary changes. Also take color digital photographs of the patient during one of these visits to obtain an accurate guide that may be given to the laboratory technician when the preparations are completed and impressions are made. Make certain that the photograph is an accurate representation of the actual tooth shade. The technician must be able to see the color and any shade differences and to grasp a visual concept of the shape and characterization of the tooth.

There is a definite advantage to having one's own laboratory technician or having an outside technician present at a shade-taking visit. The technician can see the shade as one takes it. Frequently, the technician will suggest certain shades based on their knowledge and experience with porcelain in the laboratory.

Shade guides

It is obvious that whatever manufacturer's product is being used, the corresponding shade guide should also be used. But be careful, because even the shade tabs of one shade number may differ from one supposedly identical shade guide to another. One may also find that there are many times when the only way to arrive at a proper representation of the colors involved is to use different manufacturers' shade guides. One may even use three different manufacturers' shade tabs to delineate separate cervical, body, and incisal parts of a patient's tooth.

Many dentists like to develop their own shade guides. Usually, dentists who have their own laboratory technicians do this. However, an outside laboratory can also do it, if the dentist

Figure 16.39 **(A)** With a large amount of resin composites exhibiting microleakage and recurrent caries, crowns were the best option to provide the patient with an esthetic result.

Figure 16.39 **(B)** With a highly skilled technician, internal colorants, translucency, and surface texture can be employed to create ceramic crowns with a highly natural and esthetic appearance.

requests it. Because of the multiplicity of shade guides (Figure 16.40) and the variety of shades made by individual manufacturers, the exact shade button (or buttons) that was chosen should be sent to the laboratory. If the choice of restoration is metal–ceramics, the metal backing must be the same as routinely employed for the individual dentist's everyday application, including the usual opaque and porcelain thickness.

Probably the most difficult task after the shade has been taken is communicating this to the laboratory so that a reasonably accurate crown comes back for the try-in. Naturally, some correction can be done with staining (provided the required value is higher and the chroma is lower), but the closer the original match, the easier and better the final esthetic result will be. Along with the photographs, which should be sent digitally (including images of the selected shade tabs adjacent to the prepared tooth), send the shade chart, notes on texture and characterization, casts, and anything else that can help. Remember, unless one has an in-office laboratory, the ceramist will most likely never have seen the patient, and they will have to rely totally on the information to create the crown. Again, the more accurate the information, the better the result.

Convey also to the laboratory technician the intensity of the different hues. For instance, in the incisal coloration or translucency, how gray or how blue is a "grayish" or "bluish" tint (Figure 16.41)? Unless some type of shade guide with approximating color can be given to the ceramist, it is mere guesswork as to what shade is being requested.

Review of tips for shade matching

1. Determine the correct hue; different shades within the hue can then be selected (chroma value).
2. Do not look too long at any particular shade, but compare several different ones with the patient in different positions. In addition to observing the tooth directly, try looking slightly away from the tooth so that just a color difference can be seen out of the corner of the eye. The shade that blends most closely with the tooth will usually be the correct one.
3. Make sure the patient is not wearing any brightly colored makeup or clothing. If so, drape the patient in a neutral-colored apron.

Figure 16.40 It is ideal to use the same manufacturer's shade guide as the porcelain selected. However, if one goal is to match an existing tooth, find a shade tab that comes as close as possible to the tooth to be matched (regardless of the manufacturer) and send that to the laboratory.

Figure 16.41 Without a photograph it would be extremely difficult to communicate the color, translucency, and degree of surface texture to the technician. Without this information, fabricating a crown to match this tooth would be highly improbable.

4. Do not be limited by one shade guide. Use shades from different guides to let the ceramist know exactly what color occurs in different parts of the tooth.
5. Use three different light sources: fluorescent, natural, and incandescent. When using outside lighting, avoid direct sunlight. Choose a shaded area that is bright enough to permit visualization of the important differences between teeth. To determine the proper value level, it is best to squint.

To achieve a highly esthetic result in a single crown, meticulous attention must be given to each of the various esthetic considerations. If care is applied to each step, everyone can enjoy the result: an esthetic, harmonious appearance of the mouth and face.

Patient maintenance

Much of the longevity and esthetic success of the crown restoration relies on both maintenance and prevention routines adopted by the patient. However, one can provide them with the best chance for longevity by making sure that one has created the most maintainable restoration possible. This means that one has provided for:

- marginal integrity during the impression, construction, and finishing stages of the crown;
- strong interproximal contact areas;
- restoration contours and materials that resist the retention of plaque and food debris; and
- the complete removal of excess cements and calculus.

Next, it is incumbent upon one to have a strong, comprehensive, and flexible patient maintenance program that focuses on inspiring participation by patients. Promote positive programs with careful professional monitoring. These programs should be tailored to each patient's existing oral condition, as well as to their lifestyle. It is especially important not to overwhelm a patient with too many tasks and devices, particularly with the mobile lifestyle of today's society. As an example, fewer tasks for the patient coupled with more frequent prevention visits to the office may be a better solution. The frequency of these in-office visits with a hygienist can vary from three to six times yearly, or even more in certain situations.

Motivation differs among patients, and not everyone will respond equally. Many patients will follow the esthetic maintenance and soft tissue management instructions to the letter. Others will continue with or fall back on old habits and ignore the prescribed instructions. One can advise that the breakdown and failure of the restoration may cause the patient to need even more drastic restorative treatment, which may include pain, and additional money and time. For these recalcitrant patients, and perhaps for all patients, and quite possibly for one's own protection, it is best to put patient maintenance and prevention instructions in writing, and have the patient sign two copies. Keep one in the patient chart as part of the official record and send the other copy home with the patient. Regardless of the prevention agenda one creates for their patients, the basics in oral hygiene care need to be reinforced:

- thorough brushing on a daily basis, preferably with an electric cleaning device (Oral B Smart Series, Pro Dentec, Rotadent, Sonicare);
- daily flossing regardless of the brushing method used; and
- plaque-reducing rinses.

It is important for the dental hygienist to make a critical evaluation of home care during a prevention appointment for both the patient and dentist. It is equally important for the hygienist to adjust the hygiene procedures for patients with esthetic restorations. Of significant importance in assuring ideal service and longevity of a porcelain restoration is its treatment during routine dental prophylaxis. Jones,[70] Sposetti et al.,[71] and Wunderlich and Yaman,[72] as well as many others, have demonstrated the ability of acidulated fluoride gel to etch a porcelain surface. Therefore, a neutral pH product should be substituted for patients with ceramic restorations. Additionally, never use ultrasonic scalers or air-abrasive polishing systems as they may damage the surface of the restoration.

As a part of follow-up and recall, special attention should be paid to the patient's caries index, and a risk assessment should be made. A risk level of low, moderate, high, and extreme can be assigned based on the following parameters: visible caries or radiographic penetration of caries into dentin, radiographic approximal enamel lesions, enamel decalcification on smooth surfaces, and restorations placed within the past 3 years.[73] Risk factors and protective factors for each patient also need to be assessed and monitored throughout the patient's recall schedule. *Streptococcus mutans* bacterial tests and salivary quantity and quality tests also aid in the risk determination. High-risk patients and extreme-risk patients must be very carefully monitored, and adherence to the established guidelines should be maintained. Jenson et al. have proposed guidelines to recall based on the patient's risk level. Patients who present with one or more carious lesions are assigned to the high-risk category.[74] High-risk patients should have bitewing radiographs every 6–18 months, caries recall examinations every 3–4 months, salivary flow and bacterial test every recall appointment to assess the patient's cooperation, chlorhexidine gluconate 0.12% rinse for 1 week every month, and 1.1% NaF toothpaste instead of regular fluoride paste.[74] Patients who present with one or more carious lesions and hyposalivation are assigned to the extreme-risk category. Extreme-risk patients should have bitewing radiographs every 6 months, caries recall exams should be done every 3 months, salivary flow and bacterial test every recall appointment, chlorhexidine (as per the high-risk patient) and xylitol (6–10 g daily) in gum or candies, 1.1% NaF toothpaste and NaF varnish at the 3-month recalls, acid-neutralizing mouth rinses, and calcium phosphate paste application daily.[74,75] Appropriate caries risk identification and treatment can be vital to the long-term survival of any complex restorative case.

Finally, always attempt to encourage a patient to be part of the "oral care team" that is dedicated to maximizing the investment in their mouth.

Appendix - Zirconium-oxide restorations

Indirect ceramic materials have been developed to higher levels of strength and esthetics, resulting in materials like lithium-disilicate glass-ceramics, aluminum-oxide and Yttrium-stabilized zirconium-oxide. Glass-ceramic materials serve mainly for single unit dental restorations, like crowns, inlays, onlays or veneers. To fabricate all-ceramic framework structures for extended tooth and implant supported fixed-dental-prostheses, monolithic zirconia was utilized to allow for increased mechanical stability and translucency, replacing traditional metal frameworks.[76] Initially introduced zirconia structures were known for their too opaque white appearance. Veneering porcelain needed to be applied to achieve acceptable esthetic results.[77] Multiple international scientific investigations were performed, to understand the early failures of this new material in dentistry, causing high clinical veneering porcelain chipping rates between 20-45%.[78–81] Framework design, veneering porcelain composition,[82] porcelain veneering thickness, coefficient of thermal expansion matching of veneer and core, correct furnace cooling rates and controlling the three-dimensional shrinkage process from the green stage to the final framework of a fixed-dental-prosthesis had to be investigated.[77,82–84] Research of the last 15 years helped to minimize the risk of porcelain chipping of zirconia dental restorations. Yet, based on the practitioners fear of clinical porcelain chipping,[85] and the time and cost consuming process of ceramic veneering dental frameworks, the focus shifted to monolithic pure zirconia dental restorations.[77] Digital workflow in the dental office, interlinked with computer-aided design/computer-assisted manufacture (CAD/CAM) procedures, allow to simulate oral rehabilitation, simplify the production process, and design restorations from single units to full arch frameworks out of zirconia ceramics. To allow for esthetic monolithic zirconia fixed-dental-prostheses, the introduction of dyeing color liquids of different shades was substantial (Prettau Zirconia, ZirkonZahn). The color liquids get applied and absorbed by the green stage monolithic framework under a drying lamp before the final sintering process. The final color becomes indelible through the sintering process.

The progressive development of currently introduced next-generation zirconias, drive toward greater translucency while preserving adequate strength and toughness of monolithic zirconia materials.[86,87] Four examples of current high-translucency monolithic zirconia materials are BruxZir Shaded 16, BruxZir HT, BruxZir, Lava Plus, 3 M, and inCoris TZI C, Dentsply Sirona. It should be mentioned that the enhanced translucency properties are achieved by using different dopants in the starting zirconia powders, for instance 0.2 mol% La_2O_2 into 3Y-TZP, which diminishes mechanical properties of the high-translucency monolithic zirconias, compared to the original Y-TZP frameworks.[86,88] Yet, the residual fracture strength is still considered sufficient to allow for full arch restorations.[77,86]

Current monolithic high-transparent zirconia restorations can generate exceptional esthetic results (Figures 16.42A and B), which have been esthetically matched with lithium-disilicate ceramics in the literature. The initial concern of excessive wear of the opposing dentition through the hardness of monolithic dental restorations was not confirmed, yet the degree of surface roughness should be minimized by surface polishing after occlusal adjustments. Full-contour monoliths are less susceptible to occlusal surface or cementation interface fracture damage. Based on state of the art treatment planning, x-ray and intermaxillary occlusal relation analysis, high-transparent zirconia restorations post an excellent alternative to conventional crown- and bridgework rehabilitations (Figures 16.43A and B).

Figure 16.42 **(A)** This patient presented with chief complaint, “My teeth are worn down, what can be done?”.

Figure 16.42 **(B)** After orthodontics, the patient received crown lengthening, and restoration of vertical dimension with monolithic zirconia crowns (Noritake Katana STML) (Courtesy of J. Londono, G. Chiche, M. Tadros, and S. Bin Im).

Figure 16.43 **(A)** Before: This patient had severe headaches, TMJ dysfunction, jaw pain and difficulty in eating and speaking due to her worn teeth due to bruxism.

Figure 16.43 **(B)** After: Vertical dimension was restored with 12 medium translucency Zirconia full crowns on her maxillary teeth which eliminated all previous symptoms, plus cosmetic contouring and bleaching on the mandibular arch.

Conclusion

Although unique problems occur in the construction of a crown, if properly fabricated this restoration can be as esthetically pleasing as any other type of restoration. Knowing its limitations and providing for and adhering to the basic esthetic principles outlined in this chapter will help ensure successful results. The dentist interested in obtaining predictable results with esthetic restorations is urged to continually study natural and artificial dentitions (Table 16.3).

Table 16.3 Advantages and Disadvantages of Bonding Veneering and Crowning

Procedure	Advantages	Disadvantages
Bonding	No anesthesia required	Can chip or stain
	Little or no tooth reduction necessary	Limited esthetic life
	Immediate esthetic results	May not work if insufficient tooth structure
	Color change possible	Limited ability to realign teeth
	Less expensive than crowning or laminating	Teeth may appear somewhat thicker without enamel reduction
	Can usually be a reversible process	
Veneering	Little tooth reduction required	Can chip or fracture; repairs may be difficult or impossible
	Highly esthetic	More costly than bonding
	Does not stain	Requires two appointments
	Can mask dark color	Irreversible procedure if tooth form altered
	Longer esthetic life than bonding	Limited ability to realign teeth
	Easier to obtain good tooth form and proportion	Teeth may appear thicker unless sufficient enamel reduction is performed
	Less wear than bonding	
	May not require anesthesia	
Crowning	Teeth can be lightened to any shade	Can fracture
	Some realignment of teeth is possible	Requires anesthesia
	Can serve as abutment for fixed or removable restorations	Original tooth form altered
	Longer esthetic life than bonding or veneering	More costly than bonding
	Offers greatest latitude in improving tooth form and proportion	Requires two or more appointments
	Most “natural” results	An irreversible procedure

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PART 3
ESTHETIC CHALLENGES OF MISSING TEETH

Chapter 17 Replacing Missing Teeth with Fixed Partial Dentures

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Although fixed prosthodontics has been greatly enhanced by implant dentistry, there will continue to be situations that require fixed prostheses for the replacement of missing teeth. A fixed partial denture has been described in the "Glossary of prosthodontics terms" as any fixed dental prosthesis that is luted, screwed, or mechanically attached or otherwise securely retained to natural teeth, tooth roots, and/or dental implant abutments that furnish the primary support for the dental prosthesis. This may include replacement of 1 to 16 teeth in each dental arch. If a metallic or ceramic component is included within the fixed dental prosthesis, that component is termed the framework.[1(p.38)] When choosing a fixed partial denture as the restoration of choice for a given edentulous area, a systematic sequence of diagnosis and treatment planning must be followed to achieve a successful esthetic and functional outcome.[2–4]

Diagnosis

In order to establish a positive working relationship and a successful treatment outcome for a patient, there are two critical psychological factors that need to be recognized by a dentist: the patient's attitude toward the dental treatment and prior dental experiences. The patient's chief complaint should be ascertained;

Ronald E. Goldstein's Esthetics in Dentistry, Third Edition. Edited by Ronald E. Goldstein, Stephen J. Chu, Ernesto A. Lee, and Christian F.J. Stappert.

specific esthetic desires, expectations, and needs should also be assessed. Any esthetic shortcomings with previous prostheses and esthetic challenges with the presenting condition should be noted and communicated with the patient. Once all of these elements have been established and a good working relationship exists between the dentist and the patient, the mutually agreed treatment for that patient can be pursued.

Intraoral examination

Whether the patient's presenting condition appears simple or complex in nature, it is recommended that a comprehensive intraoral examination be performed for all patients. The recording of preexisting restorations and any existing pathoses should be a routine procedure. All diagnoses, such as missing teeth, periodontal status, pulpal pathosis, caries, fractures, wear, unesthetic restorations, muscle and temporomandibular joint pathosis, and oral cancer screening, should be documented. A comprehensive evaluation of the patient is necessary to ensure a thorough treatment plan, rather than only addressing the specific edentulous area and adjacent tooth structure. It is of paramount importance that a comprehensive treatment plan be developed to provide appropriate oral health objectives. A complete diagnosis and treatment plan will ensure a successful and sound prosthodontic treatment outcome.[5]

Additionally, the use of an intraoral camera (see figure 2-7A–C in *Esthetics in Dentistry*, Volume 1, 2nd edition)[6,7] or surgical microscope (Figure 17.1) can further assist in the documentation and planning of the presenting condition of the patient.[8] Revelations such as hidden microcracks, defective restorative margins, and other tooth and/or tissue defects can determine if single or multiple retainers are indicated when weakened teeth, thought to be in good condition, are exposed. Each tooth should be individually evaluated and its condition recorded in the patient record for diagnostic and legal purposes.

Extraoral examination

An extraoral evaluation is always important in a comprehensive patient evaluation, and is critical when treating esthetically motivated patients. This evaluation should include assessment of the patient's facial symmetry, muscle hypertrophy, and possible loss of vertical dimension of occlusion. Additionally, a smile analysis that determines the amount of tooth display, smile line, lip line, arch form, and the balance of the hard and soft tissues should be considered.

Radiographic examination

A full-mouth series of radiographs and/or a panoramic radiograph with selected periapical radiographs of the proposed abutment teeth are necessary in the evaluation for treatment with a fixed partial denture. The primary purpose of radiographs

Figure 17.1 The clinical microscope provides enhanced magnification and illumination for better visualization and diagnosis.

is to disclose hidden areas and structures, such as the root morphology, crown/root ratios, pulpal health, periodontal ligament spaces, and existing caries.[9] In some situations, preexisting full-coverage restorations are present that mask the integrity of the underlying coronal tooth structure radiographically. In these instances, an accurate assessment of adequate tooth structure may not be possible without the removal of the existing restorations.

Computerized digital radiographs[10,11] are also an effective way to communicate the observations made to the patient. The ability to colorize the radiographic findings combined with the ability to isolate and enlarge segments of the root or crown in question provides an avenue to enhance the patient–doctor relationship and improve communication.[12,13]

Diagnostic study casts

Diagnostic study casts are imperative during the diagnostic and treatment planning phases. The casts serve as an educational aid for the patient while also providing the dentist with a record of the preexisting condition. Casts mounted on a suitable articulator, at the treatment position, will enable the restoring dentist to evaluate the condition of the patient's mouth. Clinical crown lengths, tipped or rotated teeth, ridge form, and the span of the edentulous area can all be evaluated, thereby helping the dentist in the decision-making process. The interarch space and the occlusal plane can also be evaluated on the diagnostic casts. This may lead to the diagnosis of lost interocclusal space or supraeruption of a segment of the dentition. If these compromised conditions are noted, other interdisciplinary efforts may be required to create a more solid oridealized foundation for the future restorative goals. These treatments may involve crown lengthening, ridge reduction/augmentation, endodontic therapy, orthodontic repositioning of teeth, segmental osteotomy, and/or surgical extraction. Properly mounted, accurate diagnostic casts serve an extremely important role in the comprehensive diagnosis and treatment planning for a fixed partial denture.

The diagnostic wax-up

A diagnostic wax-up of the proposed fixed partial denture can be invaluable in determining the esthetic requirements of a treatment plan. It provides the opportunity to observe the abutment tooth–pontic relationship and the pontic–ridge relationship. The diagnostic wax-up also allows the dentist to evaluate and work within the confines of the edentulous space. The edentulous area itself may be resorbed or reduced in the mesio-distal dimension and require surgical correction with bone grafting, soft tissue, or both. Often, other treatment issues or necessary modifications are more readily visible at this point in the planning process.[14] Frequently, orthodontic treatment is the best solution for limited space, rotated, tipped, and/or malposed teeth. This may be done in place of or prior to fabrication of a fixed partial denture. In some situations, the diagnostic wax-up will indicate the need for endodontic treatment when the required tooth preparations may involve the pulp of slightly malposed or tipped teeth at the time of preparation (Figure 17.2A–D).

Esthetic considerations

A significant part of the complete diagnosis is ascertaining the extent of the patient's esthetic requirements. Understanding the patient's esthetic desires may dictate the type of retainer margin, margin placement in relation to the gingiva, and the type of dental materials to be considered. The dentist should know what the patient's esthetic expectations are before treatment begins, to avoid dissatisfaction and costly retreatment. Although the maxillary anterior region is usually the most demanding area to treat owing to its obvious visibility, certain patients will place just as much esthetic demand in the posterior region of the mouth.

The arch in which the prosthesis is to be placed, the restoration's position in that arch, the amount of display of the prosthesis, and the patient's esthetic desires all have to be considered when designing the elements of an esthetic fixed partial denture. These elements include tooth shape, symmetry, shade, retainer selection, material, amount of tooth coverage, margin location, ceramic–metal junction location on

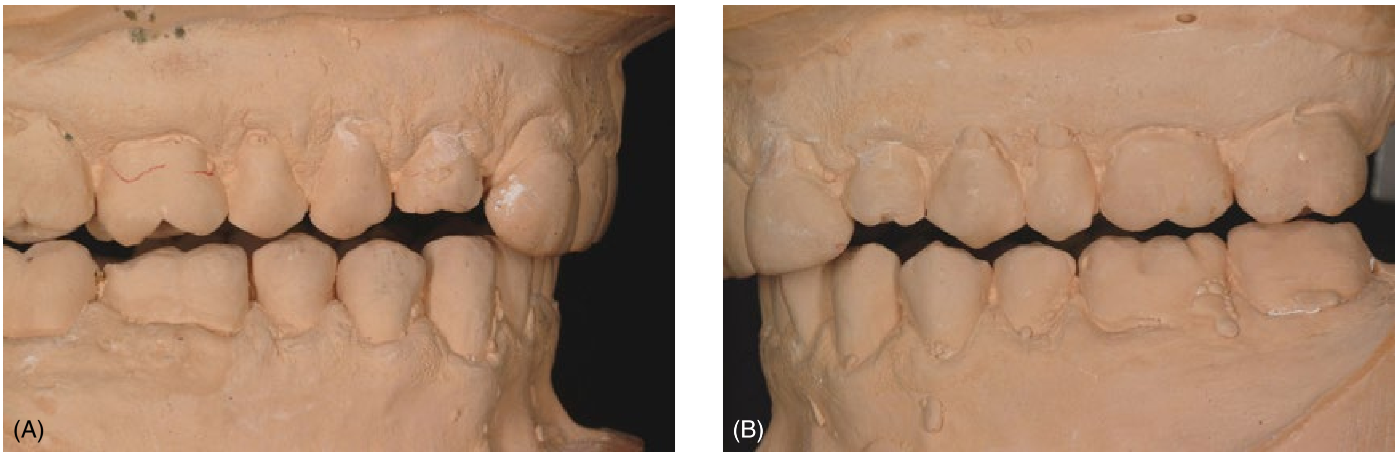

Figure 17.2 **(A)** Right and **(B)** left lateral views of the study casts of a patient who was treatment planned for a complete oral rehabilitation. Clinically, it appeared that an increase in the vertical dimension of occlusion would be necessary to create space for the restorations planned.

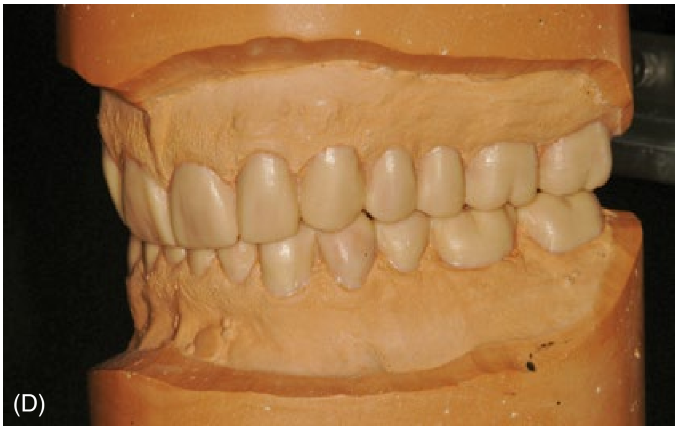

Figure 17.2 **(C)** Right and **(D)** left lateral views of the completed diagnostic wax-up of the proposed treatment at the planned vertical dimension of occlusion.

metal–ceramic crowns, and pontic design. All of these esthetic considerations must be coupled with biologic and functional considerations (such as span length, need for splinting, periodontal support, soft-tissue management, and the use of provisional restorations) and the need for adjunctive care (such as orthodontics, endodontics, periodontics, and oral and maxillofacial surgery).

The anterior fixed prosthesis can often present the most difficult of esthetic challenges, and artistic skill and know-how are important to obtain a pleasing result. Correct functional occlusal schemes and loading characteristics must also be integrated into the final restorations.

Ideally, a pleasing esthetic result can best be achieved when the restorations blend inconspicuously with the patient's remaining natural dentition. An exception to this rule is when the entire dentition is changed. Esthetic templates created from a preliminary diagnostic wax-up can assist the patient to visualize the possibilities of the treatment being recommended (Figure 17.3A–D). Also, thin resin shells of the proposed treatment (Hollywood templates) can be used to help the patient see the proposed results. The form of the lip line will often help to determine the treatment choice. When a tissue disharmony exists, such as excessive or insufficient gingival volume, periodontal plastic surgery may be required to create the ideal environment for an implant or fixed partial denture.

Computer-generated analyses and imaging can also serve as an effective diagnostic adjunct when considering esthetic goals.[15,16] One of the greatest advantages of this technique is the ability to evaluate proposed tooth sizes and shapes before the final restoration is constructed. Although digital imaging can assist in demonstrating the esthetic appearance of the proposed final result, the esthetic elements can be too difficult to clearly visualize on the computer screen. More exacting esthetic analyses before the commencement of treatment provide valuable information for the fabrication of the provisional restorations and subsequently the final restorative design.

Functional considerations

Functional considerations, by their nature, are an integral part of the esthetic evaluation. The type and number of abutments (retainers) utilized for the future fixed prosthesis require

Figure 17.3 **(A)** A study model of patient with advanced wear of her maxillary incisors. The right lateral incisor presented with significant tissue abnormalities after implant placement and a free gingival grafting.

Figure 17.3 **(B)** A diagnostic wax-up was completed to illustrate the treatment objectives with porcelain veneers and connective tissue refinement around the implant at the lateral incisor position.

Figure 17.3 **(C)** The completed diagnostic wax-up was replicated in resin to create a "Hollywood template" or "esthetic template."

Figure 17.3 **(D)** The esthetic template allowed the patient to better visualize the esthetic outcome possible with the proposed treatment.

functional considerations, which in many instances can affect the esthetic result. The use of intracoronal or extracoronal retainers depends on the length of the space to be restored, the functional stresses that will be placed on the prosthesis, and the age of the patient. If extracoronal retainers are chosen, the same considerations apply to the choice of either complete- or partial-coverage crowns that apply to intracoronal retainers.

Patients with deep vertical overlap or those with a history of bruxism or clenching can be at risk for restoration fracture, especially in the anterior region. In these instances, whenever possible, orthodontic intervention should be incorporated to improve the interocclusal relationships and a better occlusal functional scheme.

Interdisciplinary consultations

Interdisciplinary consultations and treatment referrals are important when providing comprehensive care. Multiple treatment modalities and treatment options for the patient should be investigated and presented during the treatment planning phase.[17]

Once the diagnostic process has been completed, treatment options may be selected from the following choices:

I. Retainers
  A. Partial coverage
    1. Cemented
    2. Resin bonded
    3. Porcelain veneers
  B. Complete coverage
    1. All metal
    2. All ceramic
    3. Metal–ceramic
      a. Margins
        - Location
        - Material
        - Metal collar margin
        - Disappearing metal margin
        - Porcelain margin
      b. Porcelain–metal junction
  C. Other considerations
    1. Cantilever fixed partial denture
    2. Implants
    3. Splinting
    4. Use of telescoping crowns as abutments

II. Pontics
  A. Design
  B. Edentulous ridge form
  C. Material.

Retainers

The history of the patient's condition plays a vital role in the treatment planning process. When selecting appropriate retainers for a fixed partial denture, esthetics is only one of three important factors to be considered. The other two are biologic considerations and functional/mechanical considerations. Some biologic and mechanical considerations are the size of the abutment tooth, the amount of remaining tooth structure, the size and type of restoration for the tooth, the status of the pulp, the clinical crown length, the location of the tooth in the mouth, the type of occlusal load, the interocclusal space, the opposing dentition or prostheses, the edentulous span length, and consideration of the insertion path. A patient who presents with a pre-existing fixed partial denture, which has served the patient well for many years, may serve as an indicator of the prognosis if this treatment option is being considered again. This may be an indication that potentially the functional objectives and underlying retainers will provide suitable support for the future fixed prosthesis (Figure 17.4A–F).

Fixed partial denture retainers can be separated broadly into two categories: partial- and complete-coverage retainers. Usually, the most esthetic material the restoring dentist can choose to match the patient's existing dentition is natural tooth structure. This display of natural tooth structure in the esthetic zone is

Figure 17.4 **(A)** This patient presented with an unesthetic fixed partial denture.

Figure 17.4 **(B)** She had become dissatisfied with the appearance of her smile due to the significant wear of the adjacent incisors, ill-matching shades, and black triangles from recession.

Figure 17.4 **(C)** The preexisting fixed prosthesis demonstrates insufficient tooth reductions at the gingival margin that did not allow sufficient room for the restorative materials.

Figure 17.4 **(D)** The abutment teeth were reprepared to allow space for a more natural emergence profile, contour, and enhanced color optics.

Figure 17.4 **(E)** Tissue grafting had been considered and discussed with the patient to correct the black triangles. Owing to sufficient closure of the spaces noted at the time of provisionalization, the doctor and patient decided that an acceptable esthetic outcome could be achieved without tissue augmentation.

Figure 17.4 **(F)** The final esthetic treatment outcome achieved with porcelain veneers and the replacement of a fixed dental prosthesis.

accomplished by way of partial-veneer restorations. As retainers, these are the most conservative and can be the most esthetic treatment option.[18]

Partial-coverage retainers

The most traditional of the partial-coverage retainer designs is the metal inlay, onlay, or three-quarter crown. These are usually made of a gold alloy and cemented with traditional, mechanically retentive cements. Owing to the retention and resistance form necessary to make these retainers successful, it is virtually impossible to avoid some display of metal at the proximal, incisal, and/or occlusal line angles. This show of metal often makes this retainer design unacceptable in the anterior region of the mouth for the esthetically conscious patient. It can be acceptable in less esthetically critical areas of the mouth. The best application is on large and relatively unrestored second premolars and first molars in the maxillary arch.

Currently, the most widely used partial-coverage retainer is the resin-bonded retainer. In its original form, it was described as the "prepless bridge."[19–21] The preparation design is conservative, without resistance form, and relies almost entirely on the resin bond to enamel for retention. This design is especially useful for short-term provisional restorations prior to future implant treatment. The documented success rates for these early restorations varied widely. As a long-term restorative option, the preparation design for resin-bonded retainers has evolved to the classic three-quarter crown preparation. Additionally, parallel grooves can be incorporated to improve resistance and retention form, and can be further augmented with pins or ledges.[22–26] The only modification for esthetics is the lack of the incisal offset and proximal metal display seen in the classic three-quarter crown preparation. This is compensated for by the use of base metal alloys that are relatively rigid in thin sections and the micromechanical retention potential between the cement and metal and between the cement and tooth enamel.[27] These preparation specifics can be challenging to create. For this reason, properly constructed long-term resin-bonded fixed partial dentures have fallen from favor just as traditional partial-coverage retainers.

Resin-bonded partial-veneer fixed partial dentures would be the restoration of choice, particularly in the anterior part of the mouth, if the following conditions are present: the abutment teeth are esthetically acceptable to the patient in their present size, form, and color; the teeth are free of restorations or have only minimal restoration that does not involve the crown margins; and the abutment teeth are of adequate length to afford preparation resistance and retention and of adequate thickness of tooth structure to prevent metal shadowing from the lingual surface. For the best results, the resin-bonded partial-veneer retained prosthesis should only replace one tooth. The teeth should have minimal mobility, as failure rates rise rapidly with increased numbers of pontics and with mobile abutment teeth. The pontic space must be ideal in width, as little widening or narrowing of the edentulous space can be accomplished with partial-veneer retainers. One of the most frequently seen esthetic challenges with this type of retainer is the difficulty of shade matching. If the adjacent retainers are metal, light translucency of the abutment teeth is diminished, resulting in possible shade variance.

A third type of partial-coverage restoration made from traditional crown materials and cemented or bonded to tooth structure is the porcelain veneer. It is one of the most esthetic of all partial-coverage restorations but has limited long-term clinical studies. The connector dimensions are often limited by anatomic configurations, material properties, and esthetic expectations. A connector dimension of at least 3 mm × 3 mm has favorable fracture resistance, based on several in-vitro studies.[28,29] The clinical performance of cantilevered resin-bonded fixed partial dentures has been shown to be superior to the two-retainer designs.[30,31] A 2.5-year follow-up study on zirconia-based resin-bonded fixed partial dentures showed satisfactory functional and esthetic results.[32] In Figure 17.5A, the 17-year-old patient was unable to proceed with implant-supported crowns to replace the congenitally missing upper lateral incisors, and she was seeking an improvement in the esthetics of her resin-bonded bridges. Owing to the thin dimensions of her central incisors, all-ceramic (zirconia) resin-bonded bridges were preferred to avoid the gray show-through of a metal framework (Figure 17.5B). On removal of the pontics, the thin incisal edges were evident (Figure 17.5C).

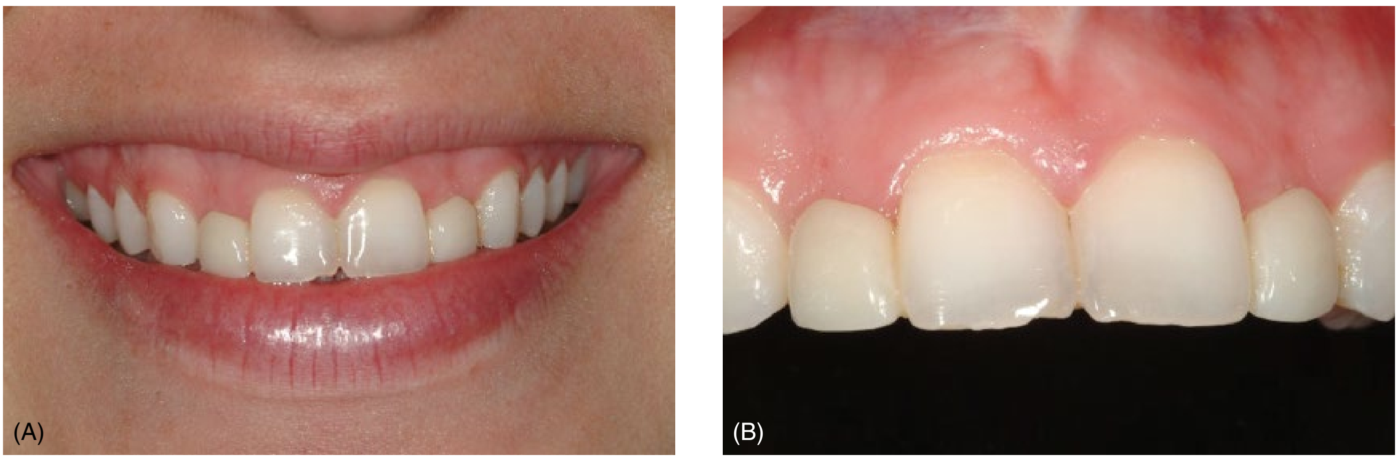

Figure 17.5 **(A, B)** A 17-year-old girl presented seeking esthetic replacement of the congenitally missing lateral incisors.

Figure 17.5 **(C)** Retracted view after removal of resin pontics showing thin, translucent incisal edges that would allow show-through of a metal framework. The phase I treatment included fabrication of partial-coverage adhesive zirconia bridges to replace the maxillary lateral incisors. Phase II treatment would be augmentation of the edentulous ridges and implant crowns to replace both lateral incisors.

Figure 17.5 **(D)** Bonded zirconia framework adhesive bridges with improved pontic contours and more harmonious proportions. The patient was very satisfied with the stronger framework and improved esthetics, providing a more stable restoration while waiting for phase II.

The retracted view of her preexisting bridges shows the unsatisfactory proportions of the pontics. The final bonded zirconia bridges provided improved pontic contours, and more harmonious proportions (Figures 17.5D). A reduction in the framework thickness from 0.5 to 0.3 mm for single crowns on bridge frameworks can reduce the fracture resistance by 35%.[33]

Complete-coverage retainers

Full-veneer retainers are the most popular of all retainers for fixed partial dentures. They generally fall into three categories: all-metal, all-ceramic, and metal–ceramic retainers.

All-metal crowns are not particularly esthetic and therefore should be used only in patients who have low esthetic demands and in esthetically less demanding regions of the mouth. Typically, they are placed in areas of the mouth that virtually cannot be viewed by observers or the patient. They are ideal for maxillary and mandibular second and third molar abutments and for the occasional maxillary first molar in patients with low smile lines that do not expose this tooth. It is fortunate that these areas of the mouth lend themselves to all-metal crowns since it is rare to find second or third molars, particularly mandibular molars, that have sufficient gingivo-occlusal height to allow sufficient reduction for porcelain occlusal coverage. The major advantages of all-metal retainers are less tooth reduction compared with the metal–ceramic or all-ceramic crown preparation, strength, and lack of wear of the opposing dentition. The chief disadvantages are the lack of esthetics and high thermal conductivity.

All-ceramic systems are an esthetic alternative to metal–ceramic systems for fixed partial dentures. Zirconium dioxide ceramics have superior mechanical properties, high flexural strength, and fracture toughness compared with the conventional feldspathic porcelains or leucite or lithium disilicate reinforced ceramics. The majority of zirconia frameworks have been made with yttria-stabilized, tetragonal zirconia polycrystal ceramics[22] which undergo "transformation toughening." Zirconia blocks can be milled at three different stages: green, presintered, and fully sintered. Frameworks milled from the green-stage and presintered zirconia blocks are enlarged to compensate for future material shrinkage (20–25%).[34] Fully sintered zirconia blocks are more difficult and time consuming to mill, but are not subject to the dimensional changes that occur with the green-stage and presintered zirconia materials. Computer-aided design and computer-aided manufacturing (CAD/CAM) technology is used to fabricate most zirconia-based restorations. Precise tooth preparation with rounded shoulder/chamfer margins is recommended to facilitate laser scanning. Sharp axiogingival line angles are difficult to scan, and consequently may result in compromised internal and marginal fit[2,24,35] (Figure 17.6A–G).

The marginal fit of zirconia-based fixed partial dentures can be equal or superior to metal–ceramics, and serve as a viable alternative to metal–ceramic systems.[19] High survival rates (over 95%) has been reported in 5-year clinical studies of zirconia-based posterior fixed partial dentures.[36–38] The most commonly reported complication is chipping of the veneering porcelain. This is often attributed to inappropriate support of the veneering porcelain, although temperature control and ceramic compatibility may play a role as well. A full contour wax-up should be utilized for the zirconia coping design to ensure adequate support for the veneering porcelain[25] (Figure 17.7). The zirconia coping thickness should follow the outback of the wax-up to allow a uniform thickness of veneering porcelain. Future fabrication methods involving pressing to the zirconia coping may improve the clinical outcomes currently seen with traditional layering techniques.[39]

Recent improvements in second-generation lithium disilicate ceramic materials have resulted in smaller and more homogeneous crystals providing improved physical properties such as flexural strength and fracture toughness. Studies indicate that monolithic lithium disilicate ceramic can be used to fabricate three-unit fixed partial dentures to replace anterior teeth and premolars[8,40] When used to replace molars, there were catastrophic failures.[41] The 10-year survival rates ranged from 87.0 to 89.2%, with a rate of ceramic chipping of only 6.1% (similar to that of metal–ceramic fixed partial dentures).[4,42]

Figure 17.6 **(A)** A 15-year-old male was congenitally missing his laterals. He was evaluated as too young for dental implants and the needed ridge augmentation procedure. There was a tooth size discrepancy evident within the maxillary incisors.

Figure 17.6 **(B)** To be conservative, provide stability, allow for growth, and correct esthetic proportions, the two cuspids were prepared for porcelain-fused-to-zirconia cantilever bridges. To correct the size discrepancy, no-prep porcelain veneer pieces were created for the distal of the two centrals, and no-prep porcelain onlays were created for the right and left first bicuspids.

Figure 17.6 **(C)** Right and left CAD/CAM zirconia frameworks seated on the master cast. Note the space created for the partial porcelain veneer that will be used to widen the central incisors.

Figure 17.6 **(D)** Final restorations seated on master cast with corrected tooth contours. Note that conservative restorative choices were provided to allow for growth and additional options in the future.

By far the most commonly used retainer for fixed partial dentures has been the metal–ceramic crown. During the last 30–40 years, this restoration has proven to be very satisfactory. Some of the variables that should be considered with metal–ceramic retainers are the location of the margins in relation to the gingiva, the materials utilized, and the location of the porcelain–metal junction on the occlusal surface.[18]

Margin location

Numerous studies have shown that the biologic acceptance of an artificial crown by the gingival apparatus is generally healthier and more favorable when the artificial material remains supragingival.[43] Supragingival margins are also easier to prepare, impress, and evaluate for accuracy of fit. Although it has been shown that soft-tissue health can be maintained in the presence of subgingival margins,[44] the general consensus is that margins should only be placed into the gingival sulcus when necessary for esthetics, wall height for resistance and retention, or extension beyond preexisting caries or restorations.[30] In one study, it was shown that less than 50% of the population evaluated revealed the gingival third of any of their mandibular teeth during facial expression (without manually retracting their lower lips).[45] A smaller percentage in the same study did not reveal their maxillary gingival margins during facial expression. It was the author's observations that many patients do not show the gingival margin of maxillary molars at all. In general, subgingival metal–ceramic margins should be limited to a patient's visible esthetic zone. In the esthetically critical areas, the equigingival porcelain shoulder butt margin can be utilized to any desired extent of the tooth circumference up to a 360° porcelain margin (see also figure 15–11 in the second edition). For any margin location selected, the restorative objective is to create precise, well-fitting margins that will ensure longevity of the restorations and idealized periodontal health (Figure 17.8A and B).[46]

Figure 17.6 **(E)** Cantilever bridge in place showing size discrepancy for central incisors.

Figure 17.6 **(F)** Right central incisor porcelain veneer (no-prep) expanding width of central incisor to normal proportions. Compare with the unrestored, undersized left central incisor.

Figure 17.6 **(G)** A retracted view of the final esthetic outcome.

Figure 17.7 The zirconia coping thickness should follow a full contour wax-up to allow a uniform thickness of veneering porcelain and provide adequate support and prevent porcelain fracture. The right coping was modified from a typical uniform coping thickness (as seen in the left coping).

Margin materials

Not all subgingival margins result in an esthetic outcome. For patients with a delicate, thin biotype, a metal margin can sometimes show through the thin gingival sulcus. There are three different approaches to a metal–ceramic crown margin. The first is the classic metal collar, in which a small band of metal creates the terminus for the crown with no overlaying porcelain. Historically, the metal collar margin was the technique for all early metal–ceramic crowns and is currently used for posterior restorations or areas with heavy occlusal forces.

The unpredictability of consistently hiding the metal collar subgingivally led to the second approach to metal–ceramic crown margins. This is a compromise variously named the metal–porcelain margin, the covered metal margin, or the disappearing metal margin. This technique involves a thin metal collar with an overlay of porcelain to hide the metal margin. This margin design is contraindicated because the metal is often extremely thin and can often distort during porcelain firing.[38] Second, owing to the thinness of the porcelain overlying this metal, it is almost all opaque porcelain. This opaque porcelain is virtually unglazable and unpolishable, resulting in a rough, plaque-retentive marginal surface that is often overcontoured. Therefore, this marginal design can only produce limited esthetic benefit with potential compromises to the biologic health of the surrounding gingiva.

The third approach to achieving an esthetic metal–ceramic crown margin is the porcelain margin. This is accomplished by cutting back the metal supportive coping to the internal line angle of the shoulder of the preparation as far proximally as is required for esthetics and for the creation of a porcelain shoulder. Some techniques also reduce the metal coping to some distance up the facial surface to further maximize the esthetics of

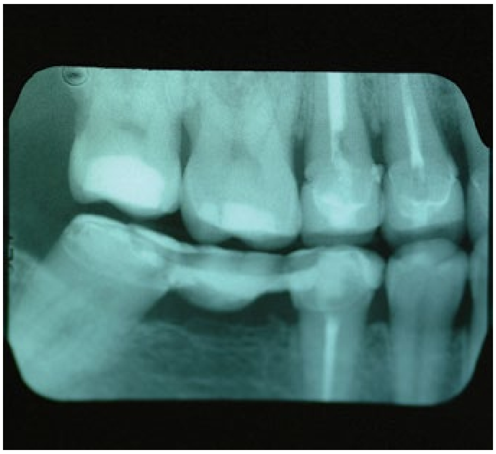

Figure 17.8 **(A)** A radiographic view of ill-fitting restorations and extruded cement. Incomplete marginal closure leads to compromised periodontal health and risk of recurrent caries.

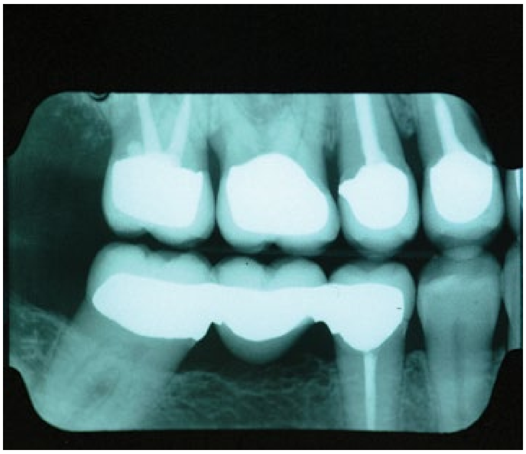

Figure 17.8 **(B)** A posttreatment view of the image in Figure 17.8A illustrating new restorations with well-sealed margins, ideal for the long-term maintenance of periodontal health.

the porcelain and the light-reflective properties of the metal coping.[47] It was originally thought that this technique would not yield sufficiently accurate marginal adaptation to be clinically acceptable. Yet, several studies have shown that margins of equal clinical acceptability as metal margins can be created with this design and by many different porcelain application techniques.[48–50] Historically, ceramic margins were not expected to be strong enough to withstand clinical loads. However, research has indicated that, once cemented on the abutment teeth, all-ceramic margins have equal or possibly greater strength than metal collar margins.[51]

Our recommendation for margin selection for metal–ceramic retainers is to use metal collar margins in esthetically noncritical areas. Porcelain margins should be used in the patient's esthetic zone or for patients with higher esthetic demands, and the combination metal–porcelain margin should be avoided whenever possible (Figure 17.9A–F).

Porcelain–metal junction

The final aspect to consider in the esthetics of the metal–ceramic crown is the location of the porcelain–metal junction. Often, the most esthetic choice is to cover the entire metal coping with porcelain in all areas of the mouth where the abutment retainer is visible. This design is effective as long as the underlying metal coping is of sufficient thickness to provide sufficient rigidity to support the overlying porcelain.[52] Yet, the clinician must make certain there is adequate occlusal reduction for the restorative materials being placed. Otherwise, compromised esthetics or a vulnerability to porcelain fracture can result.[53]

The mandibular arch is also an esthetically demanding area, and complete-porcelain coverage of the mandibular premolars and first molar is often desired. The occlusal and lingual surfaces of these teeth are readily visible when the mouth is open. In some patients, even the mandibular second molar is visible. For many

Figure 17.9 **(A)** A frontal view of the esthetic compromises associated with generalized recession, a constricted maxillary arch, and narrow spaces for congenitally missing maxillary lateral incisors. After an extensive review of interdisciplinary treatment options, periodontal tissue grafting and a comprehensive restorative treatment plan were coordinated to correct the patient's esthetic problems.

Figure 17.9 **(B)** The patient underwent generalized tissue grafting to restore the gingival harmony and balance throughout her dentition. This anterior view with provisional restoration at the cuspid and cantilevered lateral incisor illustrates the graft results.

Figure 17.9 **(C)** A broadened arch form was achieved through the use of a combination of porcelain-bonded restorations, full crowns, and cantilevered fixed partial prosthesis for the replacement of the congenitally missing lateral incisors.

Figure 17.9 **(D)** A maxillary occlusal view of the completed treatment.

Figure 17.9 **(E)** A right lateral view of the completed treatment. The esthetic restorative objectives could be achieved once the preexisting tissue recession issues were corrected with connective tissue grafting procedures.

Figure 17.9 **(F)** An esthetically pleasing outcome was achieved through comprehensive treatment and clear communication on esthetic goals.

patients, the porcelain–metal junction location on mandibular anterior restorations is rarely of importance esthetically or functionally. Biologically, owing to the small size of mandibular anterior teeth, overcontouring of the lingual surface of the restorations is best avoided by locating the junction as far incisively as esthetics will allow.

The delicate balance of porcelain occlusal coverage for esthetics and prevention of wear of the opposing dentition may be compensated for in the posterior occlusion if the patient possesses a mutually protected occlusion in lateral and protrusive excursive movements. Without an anterior disclusive occlusal scheme, porcelain wear of the opposing dentition may need to be addressed with a protective occlusal splint. A well-constructed protective occlusal splint is recommended following any extensive esthetic rehabilitation to ensure protection of the restorations created and longevity of the results. Occlusal splint protection is especially important for patients with nocturnal and daytime parafunctional habits (Figure 17.10).

Figure 17.10 A protective occlusal guard is critical to protect porcelain restorations due to parafunctional activity.

Anterior restorations involving one missing tooth

The ideal choice for the replacement of a single missing tooth is the single-tooth implant. Dental implants have become the standard of care, and it is important to evaluate each patient possessing an edentulous space for the possibility of replacing that space with an implant. The patient has a right to know the potential functional and esthetic success associated with the placement of an implant instead of a fixed or removable prosthesis.

However, there are times when an implant may not be possible or practical. In these instances, a conservative alternative is the cantilever fixed partial denture involving one or more abutment teeth. A cantilever in a mesial location to the abutment tooth is the most favorable functionally as it causes less stress to the abutment tooth. The cantilevered restoration is highly desirable esthetically (especially in areas adjacent to unrestored teeth). This conservative treatment can be an excellent treatment choice for a young patient, where implant surgery is contraindicated until complete growth is achieved. Additionally, for the more mature patient, cantilever bridges can offer an esthetic and conservative treatment where implants are not possible and one of the abutments is not requiring restoration (Figure 17.11A–E).

The question of whether to select an implant prosthesis rather than a tooth-borne fixed partial denture is generally decided by the dentist and the patient after a thorough analysis of the advantages and disadvantages of each treatment modality (Figure 17.12A–I). A thorough discussion of the treatment alternatives must include a conscientious and thorough analysis of the longevity, costs, and esthetic appearance of each proposed treatment.[54]

Splinting

Esthetically, it is much better not to splint the incisors when possible to maintain the individuality of teeth. Either separation or the appearance of separation helps to make a missing tooth replacement appear natural. In addition, the lack of splinting will promote easier maintenance and good oral hygiene. The decision to splint is determined by the mobility patterns of the abutment teeth, support and integrity of the abutment teeth, and potential esthetic challenges that might result when functional requirements indicate splinting.

To achieve a pleasing natural appearance, restorations should appear to have some bilateral symmetry and the maintenance of natural tooth proportions. This may sometimes require the incorporation of some minor crowding of the pontics within the edentulous space. There should also be harmony in the gingival contour and incisal levels to idealize the esthetic appeal of the visible smile.

Use of telescoping crowns as abutments

Advantages

In situations that would often be considered dentally hopeless, the use of telescoping restorations can offer treatment options that will provide an esthetic, functionally stable, and long-lasting result. Numerous benefits exist with this technique. One of the greatest benefits is the ability to ensure complete marginal closure around each of the abutments as they are cemented independently of the splinting suprastructure. This advantage is significant in long-span splinting, especially with periodontally involved abutments. The technique also assures long-term protection of each abutment in case of the intrusion of weak abutments in parafunctionally active patients. Intrusion of a telescoped abutment tooth results in cement failure between the coping and the suprastructure, rather than the abutment and the fixed prosthesis, thereby preventing recurrent decay, potential abutment loss, and the need for a new prosthesis.

Additional advantages focus on the tooth preparation criteria and overall biomechanical advantages for the restorative materials. Telescoping crown preparations do not need to conform to a strict common path of insertion.[55] Only the functional surfaces of the created copings require drawing to a common path. Telescoping restorations also provide the ability to strategically link different segments of fixed partial dentures to limit the length of each segment for better biomechanics, strength, and precision in marginal adaptation. This is particularly useful

Figure 17.11 **(A)** Note deficient tissue in maxillary right lateral incisor pontic site resulting in a food trap and unesthetic appearance.

Figure 17.11 **(B)** A frontal view of the same patient illustrates the thin, chipped, and worn edges of her maxillary centrals.

Figure 17.11 **(C)** Occlusal view postperiodontal surgery with a connective tissue graft to create contours for an ovate pontic.

Figure 17.11 **(D)** A frontal view of the tooth preparations for the cantilevered fixed partial denture and porcelain-bonded restorations. Note the labial view of the ovate pontic site.

Figure 17.11 **(E)** Postoperative view showing the cantilevered fixed partial denture blending with the surrounding dentition and newly created harmonious tissue contours.

Figure 17.12 **(A)** Patient presented postorthodontic treatment, with an upper removable appliance replacing her congenitally missing lateral incisors.

Figure 17.12 **(B, C)** Radiographs of the future implant sites illustrate the limited space for the future implants due to converging roots.

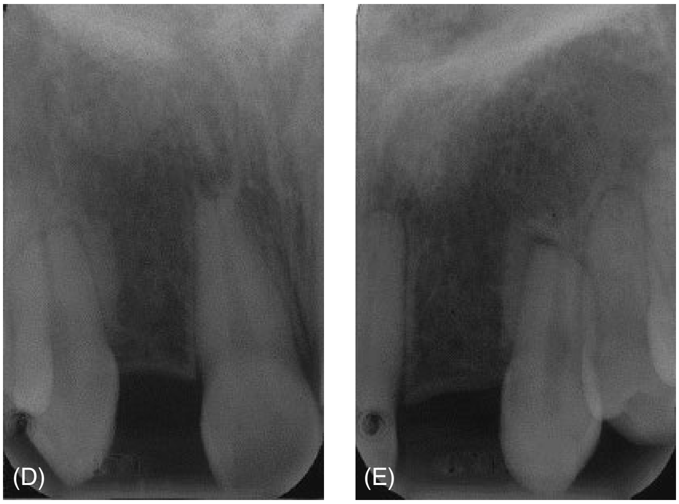

Figure 17.12 **(D, E)** Radiographs of the corrected implant sites following orthodontic retreatment.

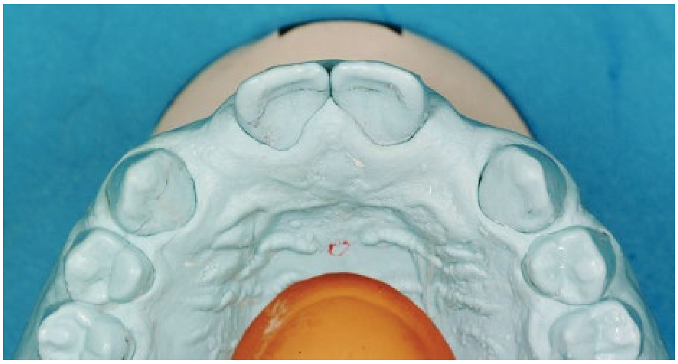

Figure 17.12 **(F)** Master cast prior to tissue augmentation. Note lack of volume in future implant sites due to underdeveloped alveolar ridges.

Figure 17.12 **(G)** Provisional no-prep adhesive bridges, after tissue augmentation and implant site preparation.

Figure 17.12 **(H)** Final results with implants, custom gold abutments, and porcelain-fused-to-gold implant restorations. All of the surrounding teeth are unrestored.

Figure 17.12 **(I)** A 5-year posttreatment view.

when using a metal–ceramic or all-ceramic prosthesis where a long span may produce excessive flexure and, subsequently, increase the possibility of fracture. Smaller spans are less vulnerable to flexure and can be more easily removed for repairs or potential future endodontic procedures.[56]

Telescoped superstructures are delivered with temporary cement providing the benefit of retrievability when future alterations in design are required. For example, in the event of the loss of a posterior abutment, the superstructure may be removed and modified by filling the former abutment retainer with composite resin, turning it into a pontic. This option provides an immediate cost-effective solution, preserves the integrity of the prosthesis, and protects the investment made by the patient. With thoughtful design and engineering of the suprastructure, flexible solutions for future complications can be pre-engineered into the prosthesis.

Owing to the success of endosseous implants, strictly tooth-borne prostheses are limited to the medically compromised patients where implant surgery may be contraindicated.[43,57] Since teeth and implants have different attachment mechanisms to bone, it is not recommended to attach teeth and implants. Otherwise, problems such as natural tooth intrusion can result.[58–60] In complex restorative care, implants and teeth can be combined in the overall treatment plan, but restored in different segments through the use of telescoping abutments, copings, and suprastructures.

An example of this more complex form of treatment is illustrated in Figure 17.13A–H. A male patient referred by his periodontist for restorative retreatment had only seven salvageable teeth in the maxillary arch. The maxillary right first bicuspid to the left cuspid were to be retained, and his posterior teeth would be replaced with implant-supported fixed partial dentures. Owing to the severe periodontal breakdown and structural damage of the anterior teeth, it was determined that periodontal splinting of the remaining natural dentition was indicated. Individual, gold-milled copings and a suprastructure were chosen as the treatment of choice to provide stabilization of the natural teeth, separation of the tooth- and implant-borne segments, and retrievability for potential abutment loss in the future. Figure 17.13B shows the master cast of the milled copings for the anterior teeth and the milled implant abutments for the posterior segments. An intraoral view of the cemented anterior copings is seen in Figure 17.13C. The importance of dividing the tooth-borne and implant-borne suprastructures has been emphasized throughout the literature. Figure 17.13D illustrates the importance of well-designed and contoured connections between the individual segments providing an esthetic natural appearance with seamless transitions of hard and soft tissues while providing

Figure 17.13 **(A)** Preliminary photo of patient's maxillary arch. Only his maxillary right first bicuspid to the left cuspid were restorable. All posterior teeth needed replacement with implant-supported fixed partial dentures.

Figure 17.13 **(B)** Occlusal view of the maxillary master cast showing the milled implant abutments and natural tooth copings. The final prosthesis will be segmented into three separate tooth supported and implant supported fixed partial dentures.

Figure 17.13 **(C)** Anterior view of the custom milled telescopic gold copings for the seven remaining natural teeth. The implant-supported fixed partial dentures are seated in the posterior segments.

Figure 17.13 **(D)** Palatal view of the superstructure on the master cast illustrates the creation of natural-appearing contours. Attention must be paid to create interproximal contours that are easily accessible for adequate hygiene and long-term gingival health.

Figure 17.13 **(E)** All three superstructures seated on the master cast showing the hard- and soft-tissue replacements created in porcelain-fused-to-gold restorations.

Figure 17.13 **(F)** Retracted anterior view of all copings, abutments and superstructures at the clinical try-in appointment.

Figure 17.13 **(G)** Magnified view of the separation between the anterior tooth-borne superstructure and the maxillary left implant-borne superstructure.

Figure 17.13 **(H)** Patient smile with the new restorations in place. Esthetic, mechanical, biologic, and psychologic goals have been accomplished.

easy cleansability. For the patient, correcting hard- and soft-tissue defects through dental bioengineering can help create better self-esteem and a more relaxed smile (Figure 17.13H).

The telescopic copings were cemented with a definitive cement for maximum longevity and stability. Suprastructures were cemented with a provisional cement for retrievability. For this patient, this advantage was realized when a tooth abutment was lost many years later. His superstructure was removed, the failing tooth was extracted, the superstructure was modified with composite resin to create a pontic, and the prosthesis was recemented during the same appointment. The patient was pleased with the minimal expense, preserved esthetics, additional longevity of his prosthesis, and minimal interruption of his daily life. The superstructures need to be designed with exposed metal at the connector site to prevent damage or fracture of the porcelain if a reverse hammer is used to tap off the superstructure.

Disadvantages

The main disadvantage associated with telescopic restorations is increased expense and the three-dimensional (3D) space requirement necessary to accommodate two full-coverage restorations. Even though the expense can sometimes be justified for the many advantages to this procedure, it is still significant. The biomechanical needs of telescoping require careful preoperative planning between the dentist and the dental technician to achieve success. If sufficient interproximal space is lacking, strategic extractions may be required to create more space. Even when the overall spacing will allow for the increased restorative bulk of materials, it is critical that individual tooth preparations be designed to allow for the additional layer of metal, associated cement space, and fuller interproximal contours. Therefore, using telescoping crowns in small, flat teeth should be avoided owing to mechanical limitations.

Another potential esthetic disadvantage with the coping and telescope procedure is the need for a more prominent gold collar at the junction of the coping and the superstructure. Potential treatment solutions for this problem include minimizing the collar heights or the creation of an anterior coping design modification that does not cover the gingival half of the tooth, allowing cross-linkage without the compromise in esthetics.[41,61]

With stronger all-ceramic materials, another possible solution is the use of zirconia copings combined with zirconia superstructures, eliminating the esthetic concerns associated with metal materials. As previously mentioned, recognizing the success of osseointegrated implants today, if contraindications or concerns with salvaging compromised teeth become significant, implants should be considered as an alternative.

Copings are well suited in the patient with a low lip line to mask the esthetic compromises. However, patients' esthetic tolerances vary greatly and it is important that the patient is fully informed of the design and is able to pre-approve the esthetic appearance in a provisional restoration. During provisionalization, the patient can personally experience that the gingival portion of the tooth will not be seen during normal conversation, laughing, or smiling, and may become more accepting of this treatment alternative.

The example in Figure 17.14A–G shows the pretreatment photographs of a female patient who was suffering from severe periodontal disease and was dissatisfied with the appearance of her smile. The patient reported that she wanted to retain her teeth as long as possible. She declined a removable treatment option and was receptive to orthodontic treatment as an adjunct to her restorative treatment. The bone loss in the right and left bicuspid areas would have created severe esthetic and technological challenges. The full mouth series of radiographs shows the severity of the destruction. It was determined that the extrusion of the maxillary right and left bicuspids and the left cuspid would provide esthetic and mechanical advantages for the future implant sites.[9,61] Molar implants were placed and then ultimately used as orthodontic anchorage to extrude the periodontally compromised teeth, bringing the bone and tissue to develop the implant sites. Upon extraction and bone grafting, a full-arch maxillary provisional was placed as an interim restoration to restore esthetics and function. Subsequently, dental implants were placed in the healed extraction sites, and the implants and teeth were restored with gold milled abutments, gold milled tooth copings, and three separate suprastructures. The final results were mechanically stable, functionally ideal, and esthetically improved.

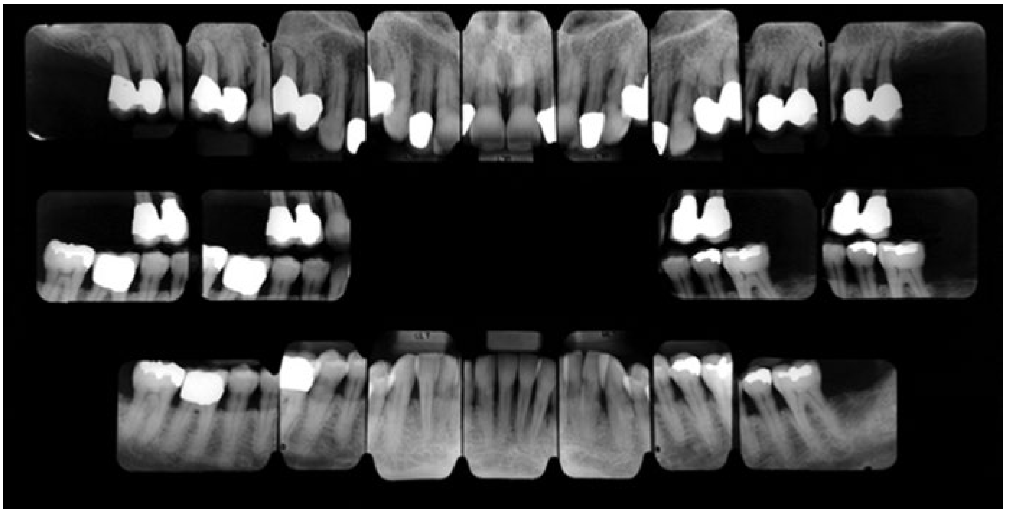

Figure 17.14 **(A)** Radiographs of a patient with severe periodontal disease and terminal posterior teeth and significant horizontal bone loss and mobility.

Figure 17.14 **(B)** To prepare the posterior maxillary bone for implants, the left cuspid and premolars were treatment planned for orthodontic extrusion to bring the tissue and bone levels occlusally. Implant placement was staged so that molar implants were used for leverage to assist in tooth extrusion.

Figure 17.14 **(C)** Postorthodontic extrusion and provisional preparations on remaining maxillary incisors. Note tissue level correction from prior image in Figure 17.14B.

Figure 17.14 **(D)** Maxillary occlusal view of the provisionals on the master cast of the provisional restoration for the maxilla.

Figure 17.14 **(E)** Final radiographs.

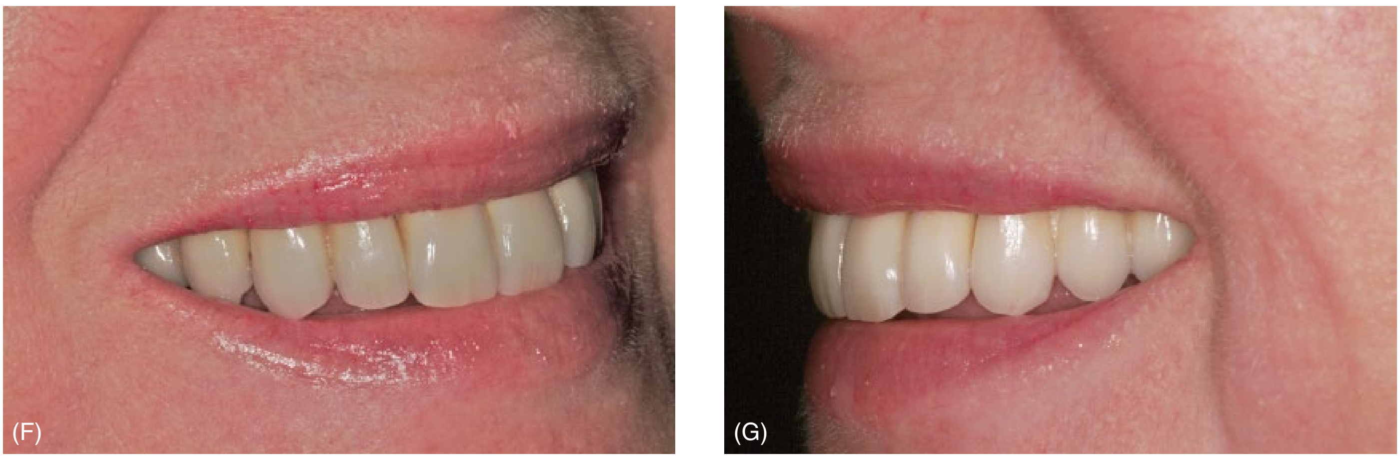

Figure 17.14 **(F, G)** Final photos of completed restorations in place.

An alternative in the posterior region, where vertical height is often restricted, is the open-telescopic technique. The occlusal surface of the restoration is wholly or partially a part of the inner coping, and the outer crown fits around the inner coping. Provision must be made for occlusal seating by incorporating a shoulder in the coping.

It is of paramount importance that the patient be educated on the advantages and limitations of the telescoping and superstructure technique prior to the commencement of treatment.

Evolving technologies

Today's evolving technologies are providing us with exciting new treatment options for the diagnosis and treatment of missing teeth. These new diagnostic and technological breakthroughs have provided the clinician with improved data for the 3D diagnosis of pathology, virtual 3D treatment planning capabilities, including placement of dental implants, virtual diagnostic wax-up, and design of abutment support and superstructure frameworks, and the final actual CAD/CAM prosthesis ready for the technologist's final esthetic customization. The new materials available, if utilized properly, are stronger, have potentially more accurate marginal fit than traditional techniques, and can provide excellent esthetic results.

The patient in Figure 17.15A–H reported esthetic dissatisfaction with her severely worn 18-year-old implant-supported hybrid denture. She was 88 years old and required disassembly of her prostheses every 3 months for hygiene maintenance as the implants were inaccessible for cleaning due to the large ridge lap design of the prosthesis. She routinely required chronic repairs to the maxillary prosthesis, and the bilateral zygomatic implants were failing, probing over 20 mm with suppuration. The previously placed pterygoid implants were unloaded owing to the patient's inability to keep them clean and were painful due to their position in the unattached buccal mucosa.

The treatment plan was to submerge the pterygoid implants, shorten and submerge the remaining zygomatic implants, use cone beam computed tomography to plan additional implants for

Figure 17.15 **(A)** A patient presented with a traditional, 20-year-old, maxillary hybrid prosthesis that was in chronic need of removal for repairs and proper hygienic access on recall visits.

Figure 17.15 **(B)** An intraoral view of the prosthesis in place illustrates the challenging implant position that resulted in unhygienic contours and impingement into the patient's tongue space.

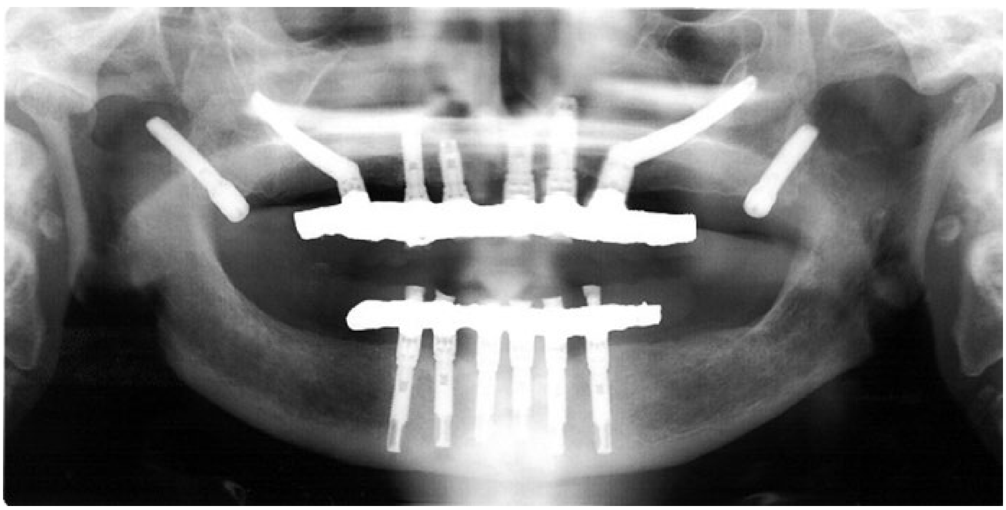

Figure 17.15 **(C)** Before treatment: panoramic radiograph demonstrates preexisting prosthesis with failing zygomatic implants.

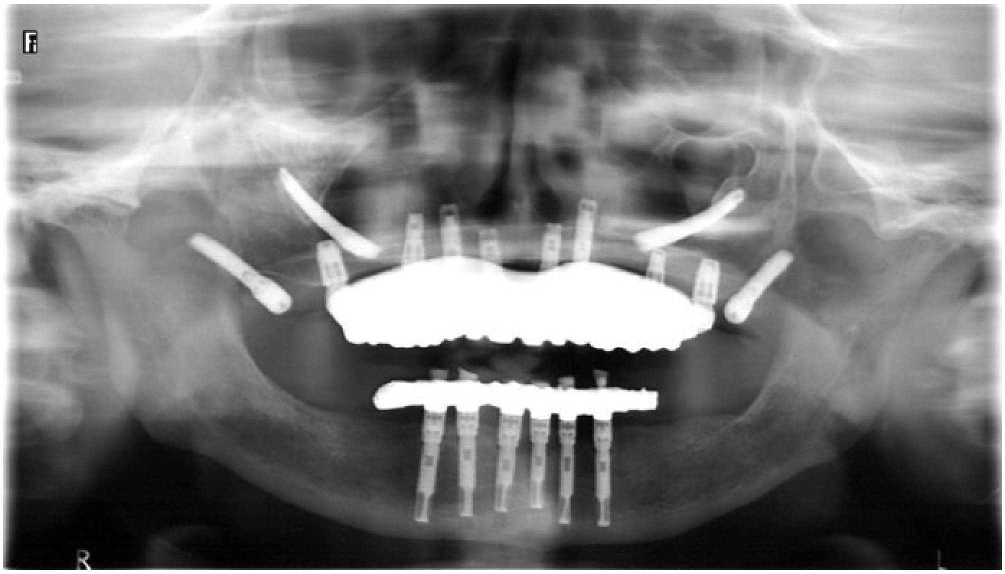

Figure 17.15 **(D)** After treatment: panoramic radiograph demonstrates new prosthesis in place with four new implants for fixed retention and unloading and submersion of the zygomatic implants.

Figure 17.15 **(E)** Intraoral occlusion view of maxillary supportive (substructure) titanium bar in place.

Figure 17.15 **(F)** Intraoral view of maxillary zirconia preliminary suprastructure in place for esthetic try-in.

Figure 17.15 **(G)** Retracted view of final esthetic outcome. Note pleasant esthetic outcome achieved with zirconia prosthesis conservatively veneered with feldspathic porcelain for the six anteriors.

Figure 17.15 **(H)** Patient's posttreatment smile.

required support, and then design a new CAD/CAM maxillary prosthesis. Four new implants were planned and placed to augment the preexisting, still serviceable dental implants. The newly placed implants enabled a reconfiguration of the maxillary superstructure design with a reduced ridge lap for hygiene access.

The infection was eliminated by the debridement and submersion of the zygomatic and pterygoid implants. The patient had improved access for oral health maintenance, improved esthetics, and improved biomechanics. The patient was elderly and medically compromised, and the elimination of infection was of critical importance to her health. On completion of the restoration, the patient reported an improvement in her overall health and was very pleased with the improvement in esthetics.

Radiographic examination/cone beam computed tomography

Three-dimensional analyses and visualization are critical to accurately and safely perform the surgical plan and execution of treatment. This is especially critical when there is a deficiency of bone or critical anatomical structures. The ability to transfer the surgical plan into a surgical guide/stent and a preoperative model on which the restoration can be fabricated has increased the efficiency, cost, and accuracy of implant-supported prostheses. Historically, conventional two-dimensional radiographic analyses were challenging and supplemented by direct visualization at the time of surgery. Computerized tomography can assist the evaluation of regional anatomy but is costly and also exposes the patient to a higher dosage of radiation.

All-ceramic/zirconia fixed partial dentures

There is increasing use of zirconia (yttria-containing tetragonal zirconia polycrystal) not only for single crowns, but also for short-span fixed partial dentures and full-arch zirconia frameworks.[62,63] Zirconia's high flexural strength (900–1200 MPa) and high fracture toughness (9–10 MPa m$^{1/2}$) enable its use in full-arch restorations.[64] Milled, partially sintered zirconia is popular for the fabrication of fixed partial dentures owing to their consistent fit, reliability, and reduced labor and material costs.

The phenomenon of low-temperature degradation is when water penetrates a surface crack, resulting in propagation of the microfracture, grain pullout, and surface roughness.[65] Currently, there is no definitive relationship between low-temperature degradation and the clinical failure of zirconia fixed partial dentures.[66] There are very few studies on the clinical performance of implant-supported zirconia fixed partial dentures and single crowns, or long-term clinical trials.[67–70] Catastrophic fractures of fixed partial dentures through the zirconia core after 2–5 years were 1–8% and were 7% for single crowns after 2 years. Occlusal overloading in bruxers resulting in fractures through the zirconia core were also attributed to insufficient framework thickness <0.3 mm, especially through the connector in long-span fixed partial dentures.[71,72] Higher rates of fracturing of the veneering porcelain were reported for implant-supported single crowns (8%) than for tooth-supported single crowns, where there was a 2–9% failure of the veneering porcelain after 6 months–3 years. Implant fixed partial dentures had porcelain veneer fracture rates of 53% after 1 year compared with 3–30% for tooth-supported fixed partial dentures after 1–5 years.[62] To minimize failure of the veneering porcelain, a full-contour wax-up and cut-back is recommended to control the thickness of the zirconia coping and support the overlying porcelain. Careful adjustment of the zirconia is critical to minimize the formation of surface microfractures and roughness, and avoidance of postsintering modifications is recommended.[73,74]

Use of precision attachments

When it is not advisable or feasible to use a one-piece superstructure, interlocking suprastructure segments can assist in creating cross-arch stabilization in a segmented superstructure. Precision attachments that have an open rod and sleeve design can be preferable compared with the dictated sequence of removal required of the male/female attachments.

Semiprecision or precision internal attachments in fixed partial dentures may improve the quality of the prosthesis significantly. Precision attachments can eliminate parallelism problems, interlock smaller segments to avoid lengthy spans of porcelain-fused-to-metal restorations, and provide splinting of periodontally mobile segments. Additionally, they can provide a stress breaking protection in cases of cuspid abutments attached to posterior fixed partial dentures (Figure 17.16A–C).

Figure 17.16 **(A)** Intraoral occlusal view of a hopeless mandibular natural dentition. All remaining teeth were planned for extraction and replacement with endosseous implants. **(B)** Impression copings in place for the final impression for the fabrication of an implant-retained complete mandibular rehabilitation. The superstructures were planned for solderless joint connections distal to the cuspids for retrievability and improved accuracy for fabrication. **(C)** Occlusal view of the completed implant-retained prosthesis in place. Note the solderless joints placed distal to the cuspid restorations.

Pontics

Pontic design

The overall objective in pontic design is to achieve esthetics, function, and cleansability. Additionally, the tooth substitute should be in harmony with the abutment teeth and the remaining dentition. Concealing the pontic as an artificial replacement is accomplished with attention to its outline form, size, alignment, embrasure form, contour, surface texture, and color. In addition, it must function with the opposing occlusion and provide comfort and support to the adjacent tissues (Figure 17.17A–F).

There are several pontic designs available for fixed partial dentures. The choices include ridge lap (saddle), modified ridge lap, conical or bullet, hygienic (sanitary), and the ovate pontic (Figure 17.18A–E). Esthetics, phonetics, edentulous ridge anatomy, and the patient's ability to maintain adequate hygiene must be considered during pontic design. Hygienic pontics are relegated to the posterior, nonesthetic zone and act to restore occlusal function while preventing the drifting of adjacent teeth. Conical or bullet-shaped pontics are indicated for thin mandibular ridges; however, they may have larger embrasure spaces, resulting in a tendency to collect debris. The ridge-lap pontic is the least favorable design owing to the patient's inability to maintain adequate oral hygiene and is not recommended.

To optimize esthetics and create a natural-appearing emergence profile, the modified ridge lap[75] and the ovate pontic[35,76] are the preferred pontic designs. Certain conditions are required to accomplish a favorable esthetic outcome. The pontic must have the proper incisogingival or occlusogingival length in relation to the abutment teeth. Excessively open interproximal embrasures or "black triangles" must be avoided in the anterior

Figure 17.17 **(A)** Final bridge preparations of the maxillary right cuspid to central with ovate pontic site preparation utilizing connective tissue grafts for tissue augmentation.

Figure 17.17 **(B)** Contralateral tooth preparations illustrating symmetry of natural contours with the grafted pontic site.

Figure 17.17 **(C)** Occlusal view of the maxillary arch demonstrating tooth-specific preparation designs ranging from porcelain veneers, inlays, veneer onlays, to full-coverage restorations.

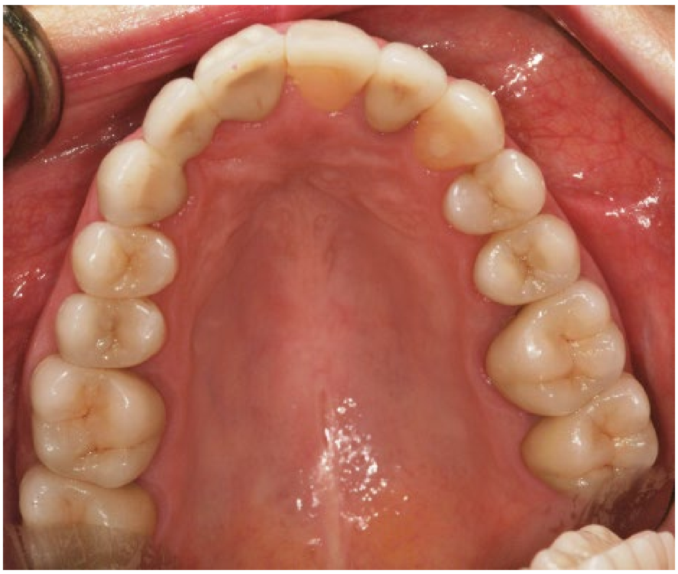

Figure 17.17 **(D)** Occlusal view of maxillary arch.

Figure 17.17 **(E)** Posttreatment smile.

Figure 17.17 **(F)** Anterior view of final restorations.

Figure 17.18 **(A)** Pontic design: total ridge lap.

Figure 17.18 **(B)** Pontic design: intaglio surface of modified ridge-lap pontic.

region, and a proper labiolingual or buccolingual relationship with the abutment teeth should be obtained for a natural emergence profile. To accomplish these three requirements, ideal edentulous ridge form is imperative. Preprosthetic surgery is often required to enhance the edentulous ridge to achieve the desired esthetic goals.

Preparation of tissue

A diagnostic wax-up of the planned fixed partial denture will aid in assessing the pontic–ridge relationship to determine whether the three design requirements are met.

The edentulous ridge with ideal dimensions both buccolingually and occlusogingivally can be treated with a modified ridge-lap pontic design, meeting all three esthetic design requirements. Ridge contour for the modified ridge-lap pontic should be slightly convex in a labiolingual direction and gently concave mesiodistally.[77] Modified ridge-lap pontic contours should not extend lingually past the middle of the edentulous ridge. For the edentulous ridge that has excessive hard or soft tissue, surgical reduction can be performed. If the soft tissue is thick, scalloping of the tissue may create a favorable pontic site. If the hard tissue is excessive with a minimal soft-tissue covering, osseous recontouring or resection may be necessary.

Ovate pontic designs are generally used in two types of clinical situations: the healed edentulous ridge and new extraction sites. When a healed edentulous ridge exists, the recipient site requires a surgical procedure of hard tissue, soft tissue, or both to provide proper emergence from the tissue. In a new extraction site, the abutment teeth can be prepared and the fixed partial denture provisional fabricated. Then, the ovate pontic provisional can be placed so that it emerges from the immature extraction site. This type of procedure quite often leads to a highly acceptable esthetic effect, but requires an adequately wide labiolingual ridge dimension.[32]

Frequently, a deficient edentulous ridge involves adjunctive soft- and/or hard-tissue augmentation. Deficient pontic areas may occur as a result of trauma, periodontal disease, root or buccal plate fractures, periapical lesions, or developmental

Figure 17.18 **(C)** Pontic design: clinical view of modified ridge lap.

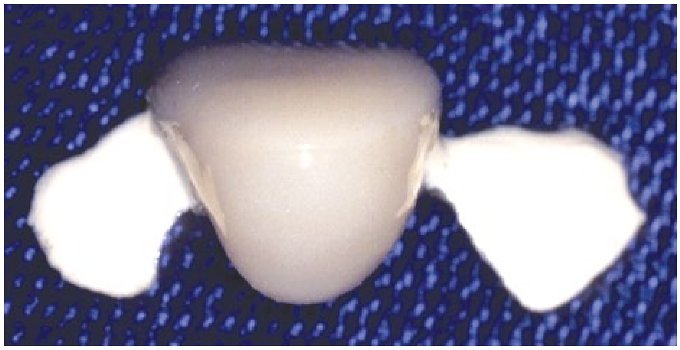

Figure 17.18 **(D)** Pontic design: intaglio surface of ovate pontic.

Figure 17.18 **(E)** Pontic design: clinical view of ovate pontic site.

defects. The edentulous area may be deficient in height, width, or both, depending on the individual situation. The classification system by Seibert describes: (1) buccolingual loss of tissue with normal ridge height (Class I), (2) apicocoronal loss of tissue with normal ridge width (Class II), or (3) combined loss of ridge contour in both the buccolingual and apicocoronal dimensions (Class III).[78] For the deficient ridge, adjunctive treatment involves surgical augmentation, which can be accomplished using an autogenous or allogenic bone graft, placement of subepithelial connective tissue grafts, rolling a pediculated flap buccally, an alloplastic graft, or a combination of these techniques depending on the amount of donor tissue needed to repair the defect of augmentation required.[38,76,77,79–81] The volume of donor tissue needed to repair the defect and the availability of such tissue will affect the selection of the graft material.[82] Larger augmentations quite often involve multiple surgeries to achieve optimal results. For sites that can be augmented with soft tissue alone, esthetic results can often be obtained with one surgical grafting procedure.[83] If the deficient site cannot be augmented, for reasons that may include cost, medical history, or too severe a defect, another modality such as a removable partial denture should be considered or tissue replacement with the use of a pink restorative material (Figure 17.19A–H).[84]

The goal of the pontic site tissue preparation procedure is to provide a ridge in which the pontic displays a natural emergence profile and is harmonious with the surrounding dentition. Although the hard tissue gives the augmented site the necessary structure and support, proper soft-tissue contours and thickness provide the illusion of a natural tooth emergence in an edentulous site. Tissue thickness over the edentulous ridge areas can vary depending on the location. In Stein's study of 50 anterior ridges and 50 posterior ridges, he found that, regardless of the degree of ridge atrophy, the mean tissue thickness of the posterior regions was 2.05 mm. The mandibular anterior region was similar to the posterior regions, whereas the maxillary anterior regions showed a mean tissue thickness of 4.13 mm.[85] This study and many others have shown that a certain thickness of tissue needs to be maintained, and encroachment on the tissue by the pontic may lead to an inflammatory process. If additional tissue thickness is generated over the ridge, soft-tissue modification can be performed.[75] Seibert Class I category defects can be treated with a soft-tissue augmentation procedure buccally to improve esthetics. This is a highly successful and fairly predictable procedure. Seibert Class II and Class III defects are much less predictable and quite often require multiple surgeries to increase the likelihood of a successful esthetic result.

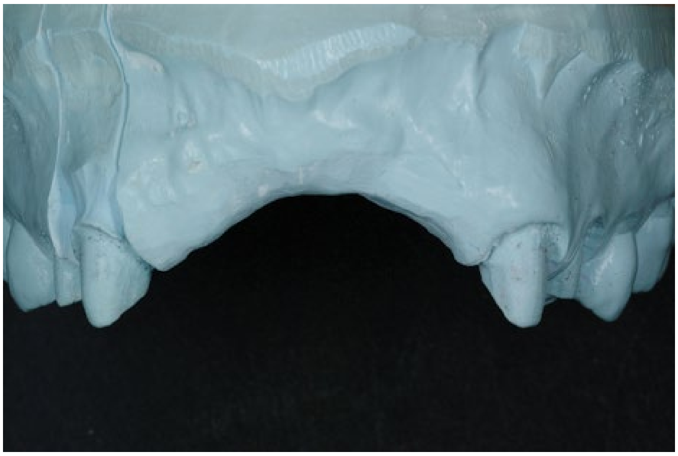

Figure 17.19 **(A)** A patient had experienced extensive bone loss in the anterior maxilla. After two failed attempts at dental implants and bone grafting, a conventional tooth-borne fixed prosthesis was determined to be the most suitable treatment option.

Figure 17.19 **(B)** The fixed prosthesis was created to simulate the replacement of both the teeth and the osseous and gingival tissues.

Figure 17.19 **(C)** The elaborate pontic made to fill the tissue deficiency was ovate in form for ease of proper hygiene and overall longevity of the restoration.

Figure 17.19 **(D–F)** Retracted views of the completed treatment with the fixed partial prosthesis cemented into place.

The future pontic site often has a nonrestorable tooth with deficient attachment apparatus, resulting in a soft-tissue defect. Orthodontic extrusion before extraction may be an alternative that can help modify the ridge and benefit pontic site design by bringing down the bone as the tooth erupts, thus eliminating or reducing any preexisting defects.[78]

Prosthodontic preparation prior to ridge augmentation is necessary in order to facilitate a successful esthetic outcome (Figure 17.20A–G). Prior to ridge augmentation, the abutments are prepared and a provisional acrylic resin fixed partial denture is fabricated. The proper form and function of the prosthesis are created in the provisional, and the pontic intaglio surface (the tissue-borne surface) is designed to simulate the position and contour desired in the final prostheses. At the surgical appointment, the provisional is removed and the ridge is augmented. The surgeon uses the intaglio surface of the pontic as a reference

Figure 17.19 **(G)** A lateral view of the patient's completed smile illustrates the efforts made to create natural tooth contours and alignment that complement the patient's facial profile and lip contours.

Figure 17.19 **(H)** An esthetic outcome was achieved in all facial expressions.

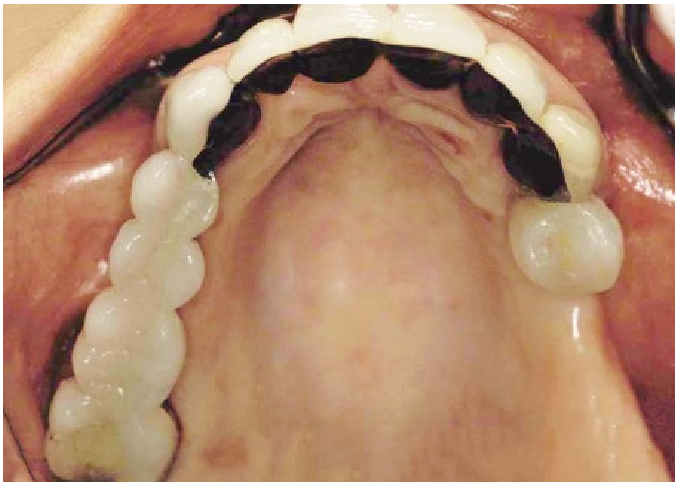

Figure 17.20 **(A)** Preexisting failing fixed prostheses with leakage and recurrent decay.

Figure 17.20 **(B)** The maxillary stone cast of the remaining abutments. Bone/ridge augmentations were required to allow implants to be placed in the posterior regions and improve tissue architecture in the anterior region where a tooth-borne fixed prosthesis was planned.

Figure 17.20 **(C)** A view of the maxillary arch wax-up following completion of the augmentation procedures. **(D)** An occlusal view of the maxillary arch illustrates the augmented ridges and implant placement compared with the prior configuration seen in Figure 17.20B, created for the support of the future restorations. **(E)** An occlusal view of the completed treatment. The tooth-borne and implant-borne prostheses are cemented independent of one another for biomechanical reasons.

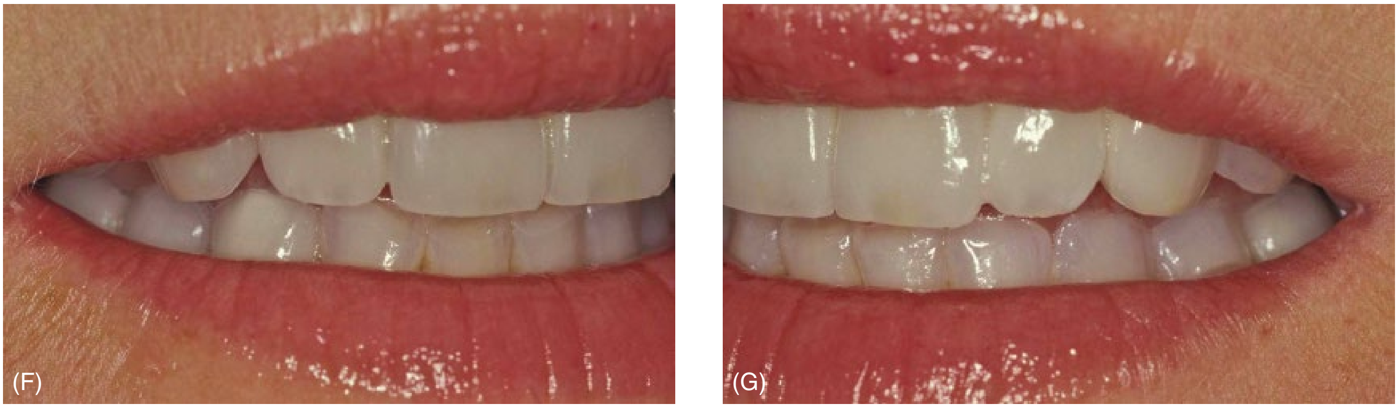

Figure 17.20 **(F, G)** The final esthetic outcome of the treatment combining both tooth-borne and implant-borne final prostheses for the rehabilitation of the maxillary arch.

point for the amount of augmentation, making sure to compensate for tissue shrinkage. The intaglio surface of the pontic is then modified prior to recementation, ensuring little to no tissue contact. The surgical site is allowed to heal for 6–8 weeks, depending on the location (longer period for anterior esthetic areas). Once adequate healing has occurred, the provisional fixed partial denture is removed and the pontic intaglio surface is modified by forming acrylic resin to the ideal shape. At this point of healing, the soft tissue is modified either by electrosurgery, a surgical blade, laser surgery, or rotary instrumentation to a contour adaptive to the provisional. The highly polished provisional is temporarily cemented and the area allowed to heal for an additional 6–8 weeks prior to making the final impression for the definitive prosthesis. "Scalloping" the soft-tissue site and adapting the fabricated provisional to the scalloped site affords the clinician the opportunity to shape the tissue, creating an esthetic prosthesis. The tissue scalloping allows the pontic to closely mimic the emergence of the abutment teeth. The pontic–ridge relationship will look natural, and the three requirements for an esthetic pontic/edentulous ridge will be met.[86]

If attempts at surgery are unsuccessful or even only moderately successful, resulting in small black triangles, then esthetic masking must take place in the fabrication of the prosthesis. This can take the form of either fixed or removable tissue inserts. The fixed tissue insert can be fabricated from tissue-colored ceramic or composite resin material. Great longevity should be expected if ceramics are used to replace the interdental tissue. Gingival porcelain replaces the lost hard and soft tissue and may prevent food impaction and allow for better phonetics by preventing percolation of saliva during speech.[35] Alternatively, some patients use a removable tissue insert fabricated from acrylic resin.

Pontic materials

The type of material utilized for the pontic depends on the esthetic result required and potentially the materials utilized for the adjacent areas. Pontic material types can be all metal, metal–ceramic, all ceramic, or metal with acrylic resin. Porcelain covering all exposed areas is the most esthetic. Metal with acrylic resin is occasionally used today in the posterior regions when retainer

Figure 17.21 **(A)** A right lateral view of a patient's presenting condition. The patient was unhappy with the presenting fixed prosthesis and surrounding restorations. Limiting the tooth size to the contours of the limited edentulous space, often associated with tooth loss, creates and aged/"denture look" to the restorations.

Figure 17.21 **(B)** A frontal view of the patient's smile illustrates the irregularities in the occlusal plane and the lack of symmetry and balance in relation to the patient's natural smile line.

design dictates type III gold. The length of span of a fixed partial denture can influence material choice. Many failures associated with the fixed partial denture can be related to the choice of materials.[87] For longer span fixed partial dentures, a more rigid (higher modulus of elasticity) predominantly base-metal alloy such as Rexillium III (Jeneric/Pentron, Wallingford, CT) may be the alloy of choice to minimize flexure.[88]

Proper pontic–tissue contours and surface finish are the key to healthy tissue response. Pontic design has been found to be the foremost factor in obtaining inflammatory-free pontic–ridge relationships.[85] Surface smoothness and polish are critical factors; there is no observable advantage with porcelain, acrylic resin, or gold. However, Stein also found that modification of the pontic outline form without attention to the surface smoothness did not prevent gingival inflammation.[85] Other studies have found that glazed porcelain and highly polished gold are the preferable materials for tissue contact[45,55] (Figure 17.21A–S).

Figure 17.21 **(C)** The patient underwent several periodontal plastic surgeries, connective tissue grafts, crown lengthenings, and pontic site developments to idealize the overall tissue harmony.

Figure 17.21 **(D)** An occlusal view of the final tissue harmony and the gingival symmetries established sites for the future fixed prosthesis.

Figure 17.21 **(E, F)** The provisional restorations for this patient were adjusted over a few separate visits. The occlusal plane, vertical dimension of occlusion, and tooth esthetics were all refined to achieve an esthetic template for the final restorations.

Figure 17.21 **(G–I)** The completed final prostheses on the master model.

Figure 17.21 **(J, K)** Pink porcelain papilla added to the prosthesis created a more natural tissue harmony with sharp papilla interproximally. The addition of papilla was first tested in the provisional restoration to ensure patient approval and hygienic contours.

Figure 17.21 **(L)** A close-up view of the pink porcelain papilla added to the fixed partial prosthesis to maximize the esthetic outcome of the patient with a moderately high lip line.

Figure 17.21 **(M)** Three tooth abutments (retainers) were utilized to retain this fixed prosthesis.

Figure 17.21 **(N)** Some slight tooth crowding of the pontics and abutment crowns creates natural tooth dimensions that will assist in creating a natural esthetic outcome.

Figure 17.21 **(O)** Ovate pontic designs with contours created for good hygiene access and maintenance.

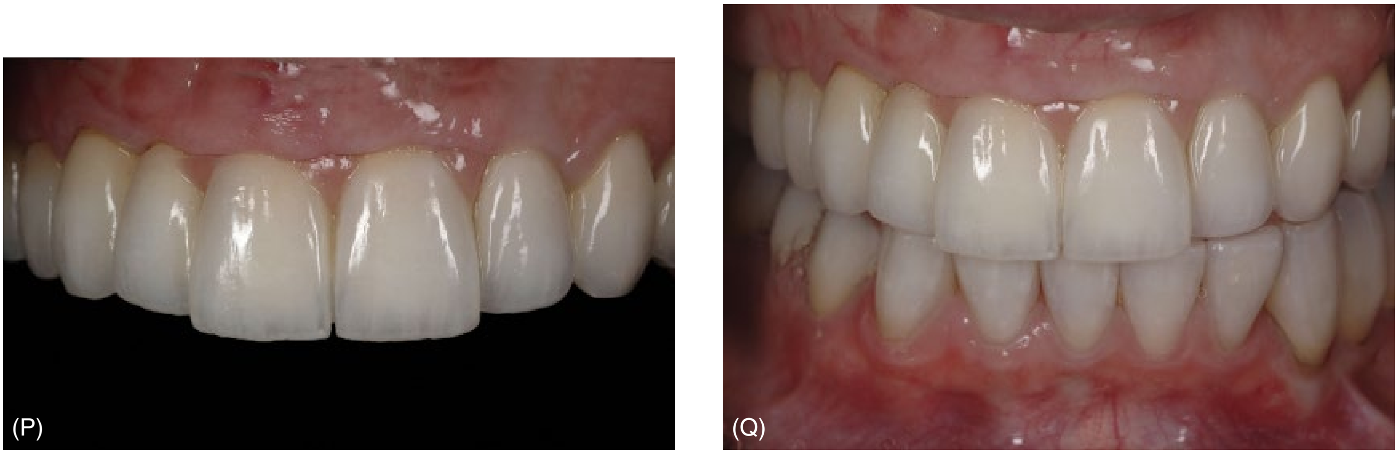

Figure 17.21 **(P, Q)** The retracted view of the final result.

Figure 17.21 **(R, S)** The full and relaxed smile.

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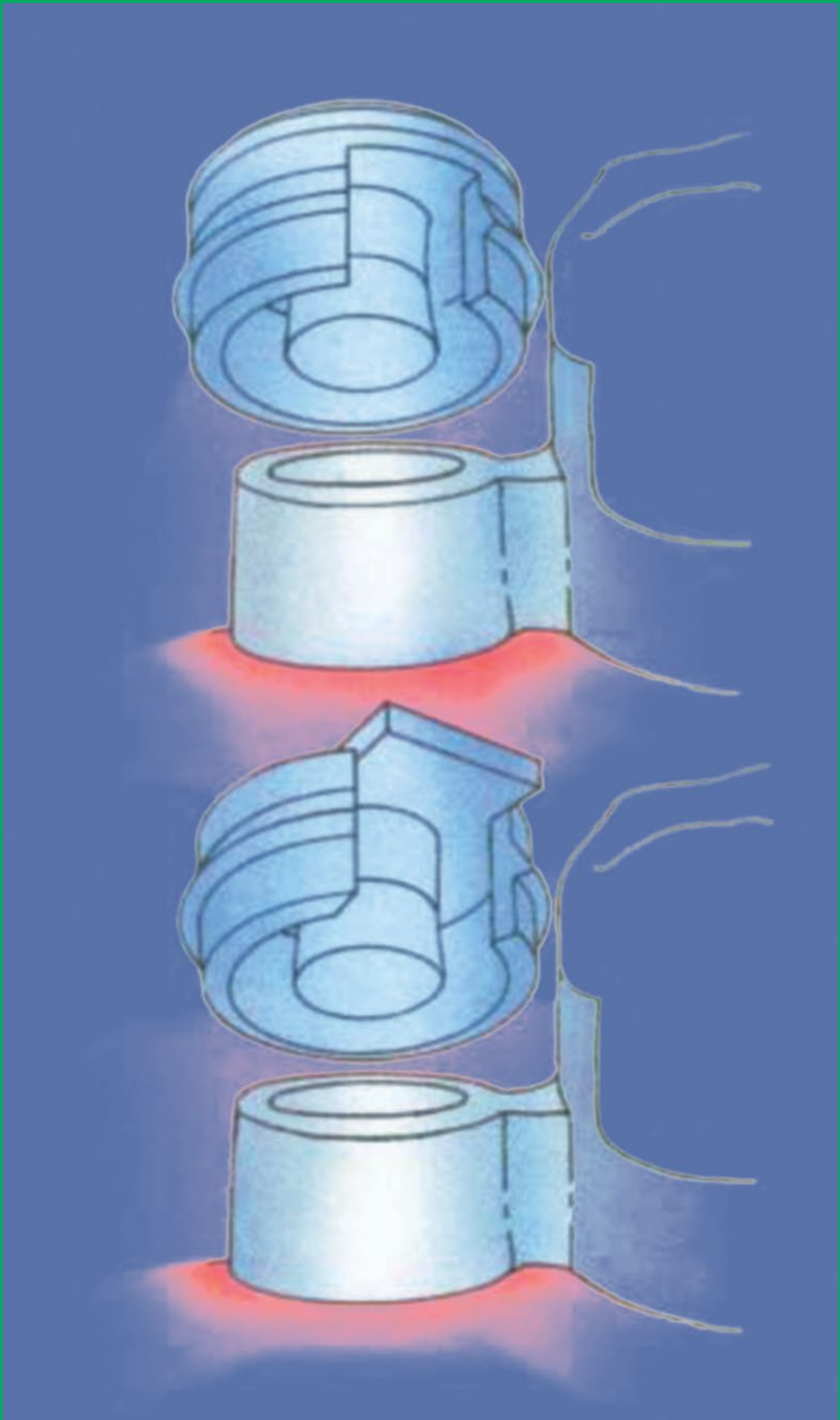

Chapter 18 Esthetic Removable Partial Dentures

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Chapter Outline

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The patient who has lost a number of teeth has several treatment alternatives. The patient may remain partially edentulous until esthetics or function is compromised, or treatment in the form of a fixed partial denture (FPD), removable partial denture (RPD), or implant(s) may be pursued.

The highly esthetic demands of contemporary dental patients compel dentists to satisfy their requests. RPDs designed without prudence and skillfulness may result in functional or esthetic insufficiency. Esthetic deficiencies may be shrouded by functional criticisms. Patients may present with frequent functional complaints of unaccountable pain or inability to chew when, in fact, they are discontented with the appearance. Unesthetic RPDs can be avoided with appropriate diagnosis and design using conventional clasping or attachment-aided prostheses.

Ronald E. Goldstein's Esthetics in Dentistry, Third Edition. Edited by Ronald E. Goldstein, Stephen J. Chu, Ernesto A. Lee, and Christian F.J. Stappert.

Classification overview

Universal classification systems for the partially edentulous arch have been devised to enhance communication and aid in design. Although numerous classification systems exist, the most widely accepted is that proposed by Kennedy[1] and further modified by Applegate.[2] There are four classes in the Kennedy classification system (Figure 18.1). The Kennedy Class I consists of bilateral edentulous areas located posterior to the remaining natural teeth and is the most common of the partially edentulous situations.[3] The Kennedy Class II has a unilateral edentulous area located posterior to the remaining natural teeth. The Kennedy Class III consists of a unilateral edentulous area with natural teeth remaining both anterior and posterior to it. The rarest class of the Kennedy classification is the Kennedy Class IV, which is a single, bilateral (crossing the midline), edentulous area located anterior to the remaining natural teeth. Edentulous areas other than those determining the classification are termed modification spaces.

Principles of design

The prudent treatment plan embraces a comprehensive analysis of the patient's dentition and supportive soft tissues. The health and distribution of the teeth will influence partial denture component selection and the anticipated esthetics. Likewise, the quality of the supportive soft tissues dictates the measure of force transferred to the abutments and guides the component selection for the tooth-tissue-supported RPD. The greater the tissue support required, the more likely it is that the forces imparted to the abutment teeth will increase. The most destructive force is that of torque in the distal extension design. Minimization of torque should be considered of paramount importance in the design of the RPD.

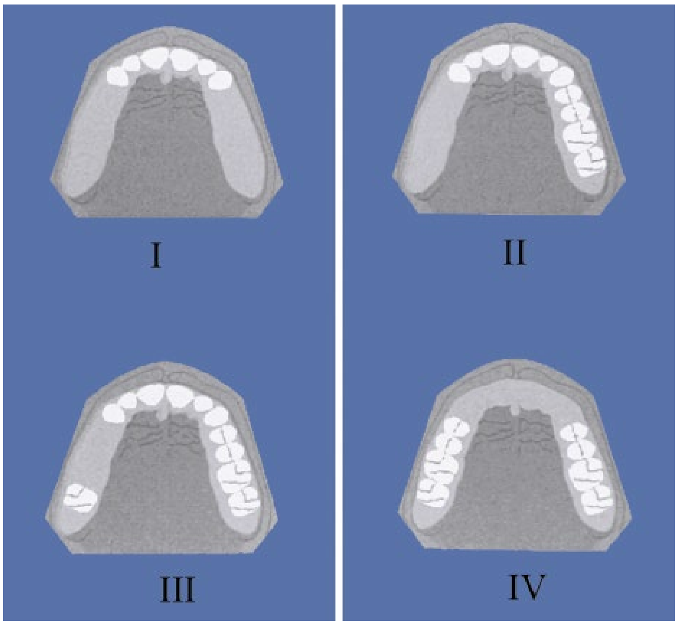

Figure 18.1 Kennedy classification: Class I, bilateral distal extension; Class II, unilateral distal extension; Class III, unilateral edentulous area bounded by natural teeth; and Class IV, single bilateral (crossing the midline) area located anterior to the remaining natural teeth.

Therefore, RPD design should be based on the available support. Kennedy Class I, II, and large IV RPDs are considered tooth-tissue-supported. In general, flexible direct retainer assemblies, mesioocclusal rests on posterior distal extension abutments, and indirect retainers to limit rotation are indicated for tooth-tissue-supported RPDs.[4]

Kennedy Class III and small IV arches are considered tooth-supported RPDs. In these situations, no additional support from the tissue is generally needed. For these designs, clasp assemblies may be more rigid, and indirect retainers are usually not indicated.

Examination of the patient requires clinical and radiographic diagnosis of the teeth and soft tissues for judgment of the support available for the partial denture. Radiographic interpretation should include (1) periodontal status, (2) responses of the teeth to previous stress, (3) vitality of the remaining teeth, and (4) pathosis. The quantity or height and quality of bone support often predict the prognosis of an abutment tooth or may influence the design of an RPD component. Proper diagnosis necessitates high-quality radiographs, devoid of angulation errors. Vertical bone heights will provide a measure of clinical crown : root ratios. A clinical crown : root ratio greater than 1 : 1 should be considered an endangered abutment with a poor prognosis for RPD support. Stress-breaking direct retainers and contingency planning should be included in the design of RPDs to use an abutment with marginal support.

Bone indices have been described;[5] however, they may be difficult to discern on some radiographs. A 25% error in actual bone calcification levels may be found with normal radiographs. Optimum bone qualities are expressed as normal-sized interdental trabecular spaces that tend to decrease in size slightly near the coronal portion of the root. Normal bone responds favorably to stresses within clinical limits. Favorable reaction to stresses from an existing RPD may be considered indicative of a future reaction to stress. Teeth that have experienced previous heavy stress from RPD support or in conjunction with abnormal occlusal forces and demonstrate normal to slightly condensed trabeculation, a dense lamina dura, and a heavy cortical layer are designated as having a positive bone index or factor. Abnormal stresses will be evidenced as a reduction in the size of the trabeculae being most pronounced adjacent to the lamina dura. The reduced trabeculae size may be termed bone condensation and may be indicative of aberrant forces that could result in bone loss if the patient becomes less resistant. A compaction of trabecular spaces and significant alterations to the cortical layer or lamina dura may be considered a negative bone index or bone factor.

Lamina dura is considered a radiographic measure of abutment tooth health. The structure is hard cortical bone lining the tooth sockets with a primary function of withstanding mechanical strain. The lamina dura should be intact and cross interdental spaces to adjacent teeth as a fine, radiopaque white line.

The supportive elements will generally respond to build support where needed and predict the degree of future response. Mechanical insults from poorly designed RPDs may overload the remodeling capacity of the body, resulting in tissue destruction. Bone is approximately 30% organic and stores little protein; therefore, any alterations in body health will be reflected in the ability to maintain support. Systemic diseases that alter the reparative capacity of the body should be strongly considered with RPD design. The patient's future health status and manifestations of aging should be considered in the selection of abutment teeth for loading.

Use of a surveyor

The dental surveyor is a fundamental instrument for RPD design and treatment planning. Additionally, the dental surveyor is indispensable for the dental laboratory technician to fabricate an RPD and fabricate supportive elements such as surveyed, telescopic, or attachment restorations.

The surveyor may be used for diagnostic cast analysis, contouring abutment tooth restorations, placement of attachment retainers, and milling internal rests and reciprocal elements. Survey objectives include: (1) determination of an acceptable path of insertion to eliminate interference with placement or removal of either hard or soft tissues; (2) identification of proximal tooth surfaces to be made parallel to act as guiding planes for placement and removal; (3) location and measurement areas of teeth for undercut and suitable esthetic clasp placement; (4) delineation of heights of contour; and (5) recording of cast position, or tripod, for future reference.[5,6]

An esthetic determinant of the survey is establishing one path of placement to minimize the retentive element and acrylic resin or denture base display. Retentive areas may influence the placement of retentive elements, so areas of retention should be selected to enhance the esthetic value of the RPD. When an anterior modification space is present, a path of placement should be selected to minimize excessive modification of adjacent abutment teeth and eliminate placement interferences. Anterior tissue undercuts may dictate a posteriorly directed path of placement to avoid excessive need for tissue blockout and inherent lip fullness from the overcontoured denture base flange. Restoration of highly esthetic anterior regions should be accomplished through fixed prosthodontics whenever possible or when the path of placement required for accomplishment of esthetics might limit the functional efficacy of the partial denture.

Biomechanics

The design of an RPD must value the mechanics and the biologic considerations. Maxwell stated that "Common observation clearly indicates that the ability of things to tolerate force is largely dependent upon the magnitude or intensity of the force."[5] The structures supporting a partial denture, teeth, and residual ridges are "living things" subjected to forces. The attributes, frequency, and magnitude of the force will foretell the success or failure of the RPD and remaining dentition.

Forces applied to an RPD are generally classified into three cranial planes: vertical, sagittal, and coronal. However, it should be recognized that functional forces are a summation of individual vector forces in the three cranial planes. Therefore, the actual force encountered by an abutment may be the result of two differing planar vector forces of varied intensity. Knowledge of the functional movements patients generate should be considered in the selection of abutment teeth, retainers, and partial denture design. Widely distributed abutment teeth with poor periodontal support in a patient with a parafunctional bruxism habit whose native diet includes nuts will obligate the dentist to develop a different design than for a patient with sound periodontal support and few other potentially damaging functional considerations.

A lever is a rigid rod supported somewhere between its two ends at a point, termed a fulcrum, which allows movement around that point.[5] The lever system allows magnification of force applied at one end of the rod proportional to the length of the rod from the fulcrum. Consequently, a small magnitude of force remote to the fulcrum will amplify to potentially destructive levels, depending on the design of the prosthesis. This is most apparent in distal extension designs, where the length of the lever arm predicts the degree of force applied to the abutment teeth. Likewise, the dissimilar characteristics of support from the teeth and soft tissues yield rotation in three cranial planes.

The tooth : tissue dissimilarity of support is a preeminent concern in distal extension and Class I, II, or large IV partial denture designs. Class I, II, or large IV partial dentures derive most of their support from the residual ridges and a limited amount from the abutment teeth. These types of RPDs generate the most potentially destructive lever forces. The fulcrum is generally established through a line connecting the most distal abutment teeth or the rests on those teeth. The Class III or small IV partial denture design is generally tooth supported with the fulcrum positioned between the abutment teeth bordering the edentulous space.

The residual ridge has a fibrous connective tissue covering the bone and underlying the mucosa. The thickness of subepithelial tissue defines the displaceability of the tissue overlying the residual bone. The displaceability and the amount of keratinized mucosa overlying the residual ridge will distinguish the amount of support anticipated from the edentulous regions. The periodontal ligament is composed of collagenous fibers, blood vessels, and interstitial fluid to act as a shock absorber for the dentition. This ligament or membrane may vary in composition or thickness depending on the amount of force applied to the tooth. However, the compressibility of the residual ridge tissues and tooth ligament is not comparable. In fact, a tissue : tooth ratio of approximately 13 : 1 exists in healthy tissues.[5] This phenomenon requires careful deliberation when designing and fabricating a distal extension RPD.

Occlusion is of primary interest in the distal extension prosthesis. Accentuated occlusal forces or aberrant, parafunctional occlusal forces on the most remote portion of the distal extension base will impart a greater degree of leverage force to the supportive elements. Formation of a precise occlusal scheme will ensure harmonious function and enhance the prognosis of the abutment teeth.

Tooth morphology should be considered when evaluating potential abutment teeth. Clinical crown contours and occlusion will often dictate direct retainer, major and minor connector selection, and rest seat placement.[7,8] Root anatomy is frequently overlooked as a critical component of the supportive element for a removable prosthesis. In general, single-rooted teeth are less favorable abutments than multirooted abutments. Divergent roots render more support than fused roots. Circular roots offer the least resistance to rotational forces than do oblong root contours. For this reason, premolars, particularly mandibular premolars, are poor choices to serve as solitary abutments for distal extension RPDs. Ideally, an FPD or implant should be provided from the second premolar to the canine to avoid using the second premolar as a solitary abutment. Periodontally weakened roots provide disproportionately less surface area for anchorage owing to their conical shape.

Problem situations

Perhaps the most difficult situation is the distal extension RPD. This is complicated when the missing teeth are located unilaterally, since functional requirements make it more difficult to esthetically mask the abutment attachments. However, if the entire arch is to be restored, then the situation becomes amenable to either an overdenture, precision attachment, or implant-retained prosthesis. If this is not the case, then the determination of the lower lip when smiling will help determine the type of attachment or clasp assembly to use.

Specific clasp types and esthetic considerations

The use of conventional clasping in esthetic regions of the mouth can present difficulties with patient acceptance. Proper surveying and mouth preparation may circumvent complications. Clasps may approach undercuts from a suprabulge or infrabulge region. Proper abutment tooth selection for clasps and placement of the clasps far enough into the infrabulge or distal region will maximize the esthetic benefit. Ideally, suprabulge clasps should be placed in the middle one-third of the tooth in the region of the proximal plate. The retentive tip should be located in the gingival one-third but not encroach on the free gingival margin (Figure 18.2). Placing the suprabulge clasp in this manner will improve the esthetic result and diminish the torquing forces applied to the tooth by the clasp. Infrabulge clasps will generally provide more enhanced esthetics, although they may have limitations to their use owing to anatomic considerations. The height of the vestibule, position of frena and soft tissue, or bony prominences may limit their application or necessitate preprosthetic surgery.

Circumferential clasp

Owing to its rigidity, this suprabulge clasp is generally reserved for tooth-supported abutments in posterior regions of the mouth. It is a cast clasp of either a round or half-round configuration, both of which provide little flexibility. When serving as a retentive element, the clasp should only engage a 0.25 mm undercut to avoid excessive torquing of the tooth. This clasp may also serve as a bracing or reciprocal element and is positioned above the height of contour. Owing to the relative size (thickness and diameter) of this clasp, use of the clasp above the height of contour for reciprocation should be limited in esthetic regions of the mouth. In situations where increased flexibility is necessary, but there is no place to remote solder a wrought wire clasp, such as the tooth-supported side of a Kennedy Class II arch, a cast round clasp may be used. A 20-gauge cast round clasp has been shown to have the same flexibility as a 19-gauge wrought wire clasp.[9]

I-, Y-, T-, or modified T-bar clasp

The infrabulge approach of this clasp optimizes esthetics for patients with reasonably high lip lines or in situations where clasping of maxillary first or second premolars is indicated (Figure 18.3). It is generally cast as part of the framework and

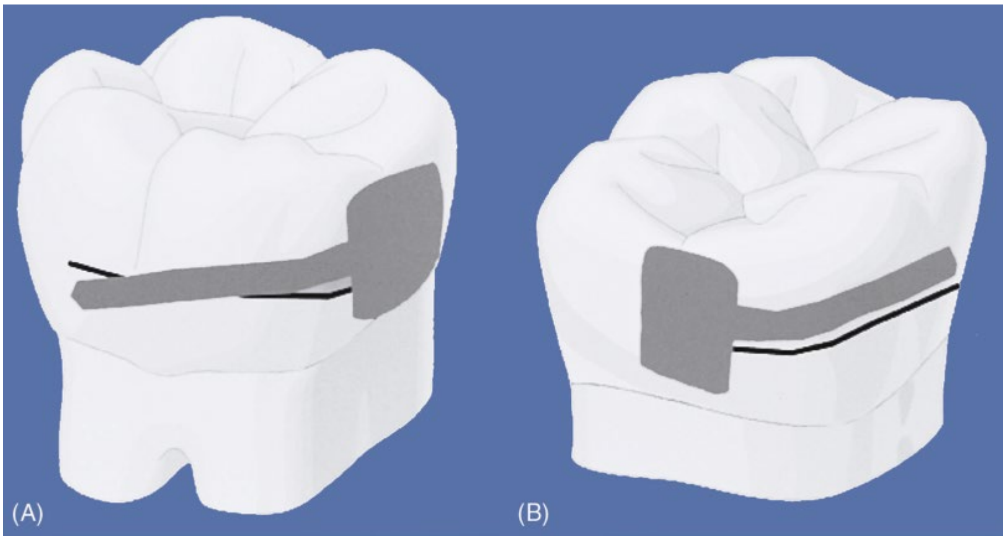

Figure 18.2 Proper placement of the retentive and reciprocal arms. **(A)** The retentive arm exits the abutment tooth in the middle one-third and terminates in the gingival one-third; only the retentive tip (terminal one-third) is placed below the height of contour. **(B)** The reciprocal arm exits the abutment tooth in the middle one-third and remains completely above the height of contour.

Figure 18.3 The use of the infrabulge bar (I-bar) clasp optimizes esthetics, particularly in the maxillary arch.

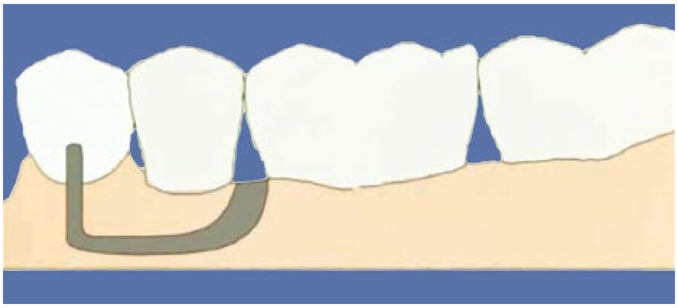

Figure 18.4 The approach arm of the I-bar is placed approximately one tooth distal to the abutment tooth. It exits the meshwork in the interdental area between the replacement teeth to minimize grinding of the replacement teeth.

should exit the meshwork approximately one tooth distal to the abutment tooth. This allows for optimal tooth positioning without excessive grinding of the replacement tooth, which would reduce the esthetic value of the denture tooth. In Figure 18.4, correct positioning of the approach arm of the I-bar allows the clasp to traverse from the framework through the interproximal embrasure region of the first and second replacement tooth. This minimizes the need to shorten the most anterior denture tooth to allow for the clasp to traverse from the framework more anteriorly.

The T- or Y-bar configuration achieves undercut engagement of 0.25 mm on either the mesial or distal surfaces of the tooth. A common error is to place both tips of the T- or Y-bar clasp into an undercut (Figure 18.5A and B). The esthetic value may be diminished if the anterior arm of the T- or Y-bar remains while using a distal undercut. Removal of the anterior arm should be considered, and a modified T-bar clasp should be selected (Figure 18.6A and B). A functional advantage of the modified T-bar is elimination of the mesial arm, limiting mesial undercut engagement of the clasp during a seating movement of the denture base toward the residual ridge. This will reduce the torque and distal tipping of the tooth. As a general rule, clasps should disengage during denture base movements toward the residual ridge and become active only on dislodging movements away from the residual ridge. If the height of contour is located in the incisal or occlusal one-third of the tooth, this clasp design should not be used because of the space created under the approach arm.

Rest–proximal plate–I-bar clasp

The rest–proximal plate–I-bar (RPI) clasp, described by Kratochvil1[10,11] and later modified by Krol and coworkers,[12,13] consists of the following components: (1) mesioocclusal rest, (2) proximal plate, and (3) I-bar clasp. The retentive tip of the I-bar should engage a 0.25 mm midfacial undercut (Figure 18.7). As for the T- or Y-bar clasps, the approach arm should traverse from the meshwork approximately one tooth distal from the abutment tooth. Esthetically, the RPI clasp fulfills all requirements of a conventional clasp yet demonstrates minimal tooth coverage, relatively limited metal display, and an infrabulge approach. The mesioocclusal rest stabilizes the tooth and resists distal tipping. The design is indicated for distal extension situations and allows for disengagement of the clasp under occlusal force to the denture base. As with the T- or Y-bar, this infrabulge approach may not be desirable if adequate vestibular height is not present or anatomic structures, such as frena, are present. Infrabulge clasps may be more esthetically pleasing for patients with a low lip line.

Mesial groove reciprocation clasp

The mesial groove reciprocation (MGR) clasp, described by McCartney,[14] is indicated for maxillary distal extension RPDs when canines serve as the abutment teeth (see Figure 18.3). Facial bracing is important because, unlike premolars, the mesiolingual contour of the canine does not usually present enough surface to resist distal movement. Adequate bracing is necessary to resist distal movement that would disengage the retentive portion of a distally placed clasp from the surface of the canine and result in a loss of retention.[15]

When necessary, the labial surface should be prepared so that its height of contour is at the same occlusogingival level as that of the lingual surface. A distal guide plane is not prepared. A 1 mm depression is prepared in the center of the distal half of the labial surface, gingival to its height of contour (Figures 18.8, 18.9, and 18.10). Retention is attained with a 19-gauge cast or wrought wire I-bar engaging a 0.25 mm undercut on this surface. The MGR clasp incorporates a prepared mesial groove to provide reciprocation. A vertical mesial groove guiding plane 1–2 mm in length is prepared in the mesiolingual surface within the mesial marginal ridge enamel. To complete the abutment modification, the mesial reciprocation groove is extended over the mesial marginal ridge to terminate in a spoon-shaped mesial rest seat. Occasionally, a small amalgam restoration may be required when dentin is exposed while preparing sufficient depth for lateral force resistance.

Ring clasp

This clasp is used for inclined maxillary or mandibular molars with natural undercuts on the mesiobuccal or mesiolingual surface respectively. The ring clasp should never be used as an unsupported ring, known as a back-action clasp, as it cannot

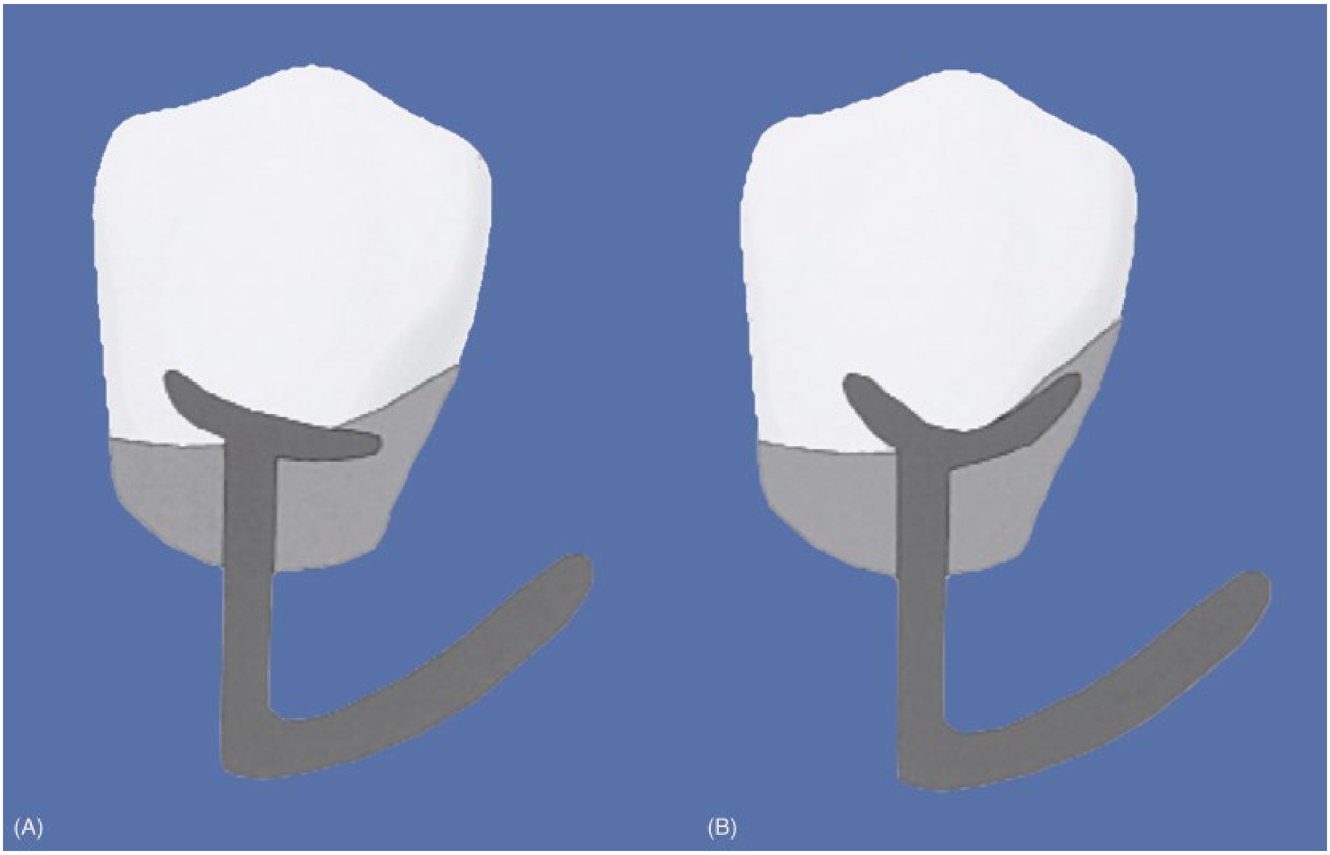

Figure 18.5 **(A, B)** Only one tip of the T- or Y-bar clasp should be placed in the retentive undercut. The other tip provides support only.

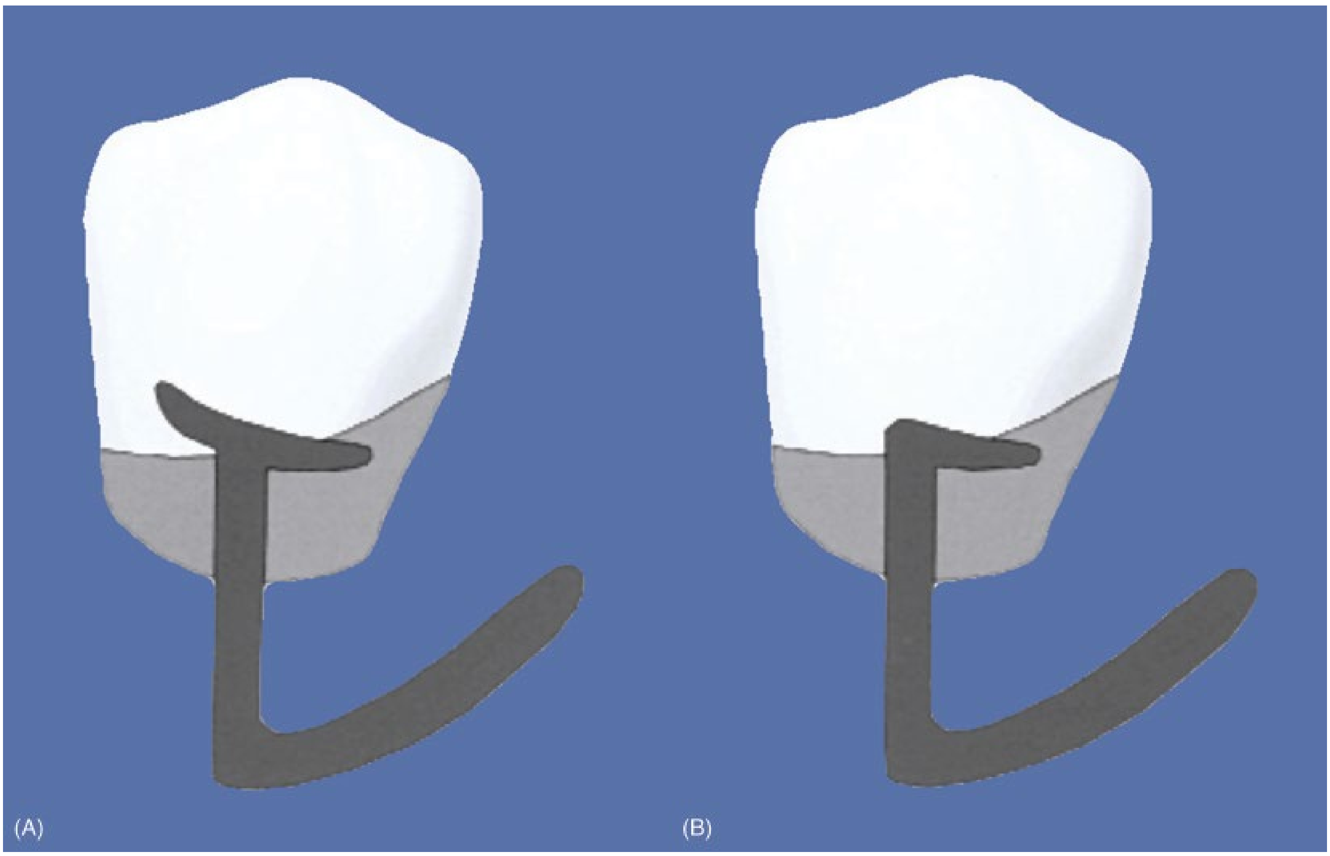

Figure 18.6 **(A, B)** The anterior tip of the T-bar clasp may be eliminated, producing the modified T-bar clasp.

Figure 18.7 The RPI clasp design consists of a mesioocclusal rest, proximal plate, and midfacial I-bar clasp. *Source:* Courtesy of Dr John R. Ivanhoe.

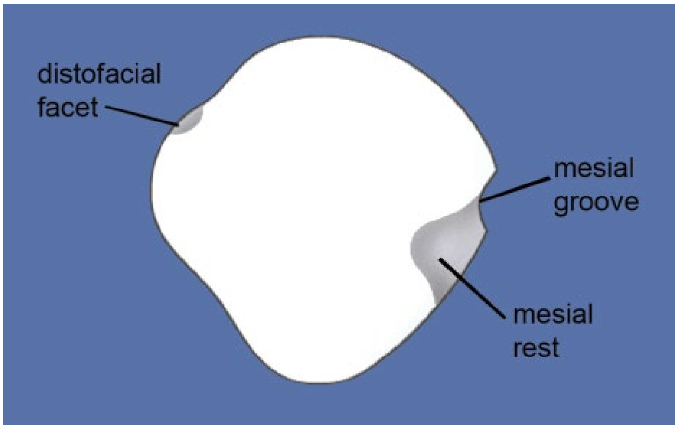

Figure 18.8 MGR clasp natural tooth preparation. A distal guide plane is not prepared. A 1 mm depression is prepared in the center of the distal half of the labial surface, gingival to the height of contour. A mesial groove that provides reciprocation extends over the mesial marginal ridge to a mesial rest seat.

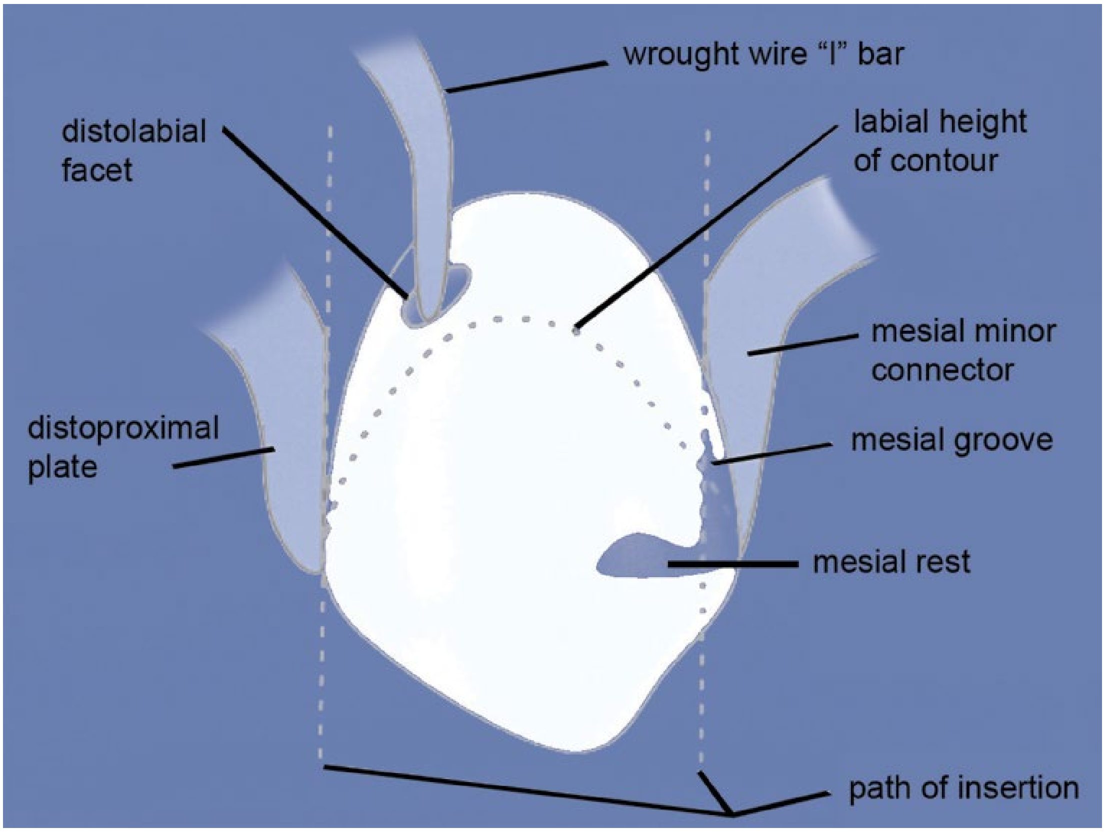

Figure 18.9 MGR clasp framework design. An I-bar engages a 0.25 mm undercut in the prepared depression on the distal surface. The mesial minor connector contacts the mesial groove and terminates in the mesial rest seat.

provide both reciprocation and stabilization.[5] It is usually designed with an additional bracing arm to prevent excessive flexing. An additional rest seat placed on the opposite side of the tooth enhances the rigidity of the clasp assembly and may aid in resisting further mesial migration of the tooth. The entire clasp assembly, except for the retentive tip, must lie above the height of contour. Consequently, it is not an esthetic clasp assembly and is reserved for molar abutments.

Embrasure clasp

This clasp will be used in posterior regions of the mouth in the quadrant without an edentulous space, as in Class II situations. This clasp avoids excessive distal extension of the major connector. The embrasure clasp is a suprabulge clasp that should have an adequate sluiceway prepared through the embrasure of the abutment teeth to allow for proximal rests and emergence of the suprabulge clasp arm elements near the height of contour (Figure 18.11A and B). Adequate sluiceway depth will also provide for proper metal thickness to ensure rigidity and avoid occlusal interference from the opposing dentition.

Combination clasp

The combination clasp consists of a wrought wire clasp arm and cast reciprocal arm (Figure 18.12).[16] It is most frequently used adjacent to a distal extension base to promote stress-breaking characteristics to the abutment tooth. The wrought wire, being more flexible (less brittle), may be used in smaller diameter with less danger of fracture. A 19-gauge wrought wire in a 0.5 mm mesial undercut is generally indicated for canine and premolar distal extension abutments. Remote soldering of the clasp to the framework provides increased flexibility.[17] Owing to its round form, light refraction is decreased, making the metal display less noticeable than with the broader surface of a cast clasp.

Retention enhancement

Traditionally, enamelplasty or a cast restoration has been indicated for an abutment tooth with an inadequate undercut. The improvements in composite resins have made them a conservative, cost-effective, and minimally invasive method for enhancing retention. However, variable results have been reported from the studies using composite resin to enhance retention. In-vitro studies have shown that cast I-bars produced wear of the composite resin,[18] whereas stainless steel round clasps did not cause a noticeable loss of retention.[19] The use of a partial-coverage porcelain laminate bonded to a tooth to enhance retention is a viable alternative.[20]

Rest seats

In general, mesioocclusal rest seats are indicated for posterior distal extension abutments when the occlusion permits.[10,21] For tooth-supported RPDs, rest seats are placed on either side of the

Figure 18.10 The MGR clasp is indicated for maxillary teeth where esthetics is a concern.

Figure 18.12 The combination clasp consists of a wrought wire retentive arm with a cast reciprocating arm or plated surface. *Source:* Courtesy of Dr John R. Ivanhoe.

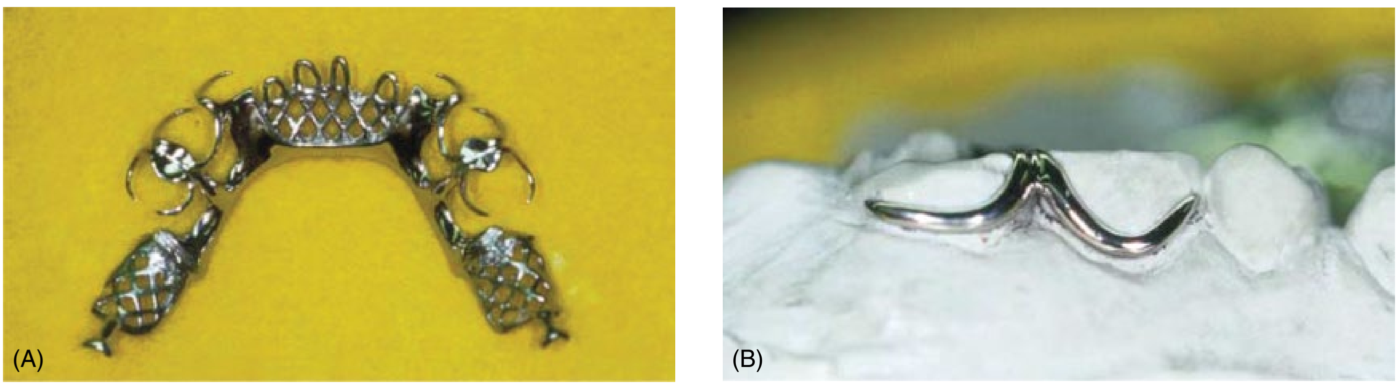

Figure 18.11 **(A, B)** The embrasure clasp is used on posterior teeth where no modification space is present.

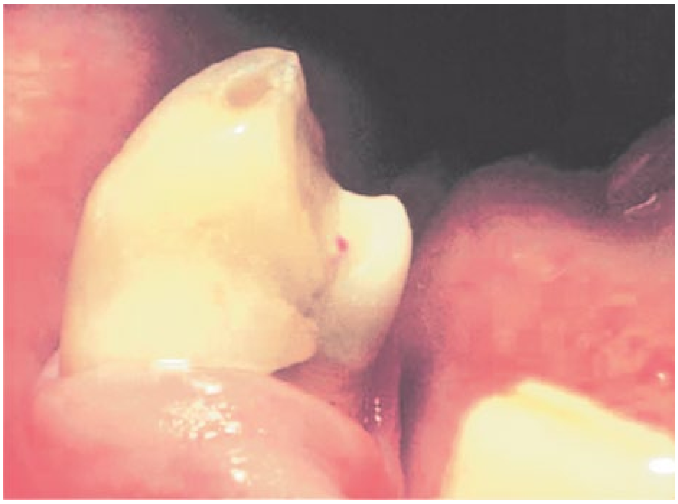

Figure 18.13 Bonded composite resin rest seat.

modification space to prevent tissueward movement of the RPD and for ease of fabrication. Cingulum rest seats are indicated for anterior teeth. However, the lack of adequate enamel often precludes placement of a positive cingulum rest seat on the mandibular anterior teeth. Traditionally, incisal rests have been advocated for mandibular anterior teeth. Unfortunately, they are unesthetic, may interfere with the occlusion, and may increase torquing forces on the teeth. Bonded composite resin or metal rest seats have been shown to provide a satisfactory and esthetic alternative to the incisal rest (Figure 18.13).[22,23]

Flange design

A labial flange in the anterior region is indicated when residual ridge resorption has occurred and additional lip support is needed. The flange should extend to the junction of the attached and unattached mucosa and should be contoured to blend in with the adjacent teeth. Also, the flange should not extend into an undercut apical to the adjacent teeth.[24] Occasionally, tinting of the denture base to match the pigmentation of the patient may be indicated.[25–27]

Replacement teeth

Teeth should be selected to match the size, shape, shade, and contour of the adjacent teeth. In some instances, it will be necessary to contour the tooth, and, occasionally, it may be necessary to stain the artificial tooth or place a restoration in the tooth to match adjacent teeth. A technique to modify the shade, contour, and occlusal contacting surfaces of denture teeth with light-polymerized composite resin has been described.[28] Microfilled resins for veneering facial surfaces are advocated because these are more easily polished and provide an improved esthetic appearance. These changes are most easily accomplished when the artificial tooth is fabricated from acrylic resin. The acrylic denture base resin should be contoured to match the size and contour of those of the adjacent teeth. The artificial teeth should be positioned to simulate the position of the natural teeth. If natural teeth remain, they may be used as a guide for placing the artificial teeth in a harmonious arrangement.

Other esthetic considerations

The patient should be assessed in totality rather than as an aggregate of singular entities. The potential consequence that one treatment has on another region of the mouth and the overall result requires careful appraisal. Although it is the intent of most clinicians to maximize the esthetic value of treatment for the patient, the esthetic awareness and desire of the patient merit consideration. The implementation of complex components that potentially increase the cost, maintenance, or difficulties with hygiene for a patient unconcerned with esthetics is not prudent. However, the assessment of patient awareness needs to be bona fide. The apathetic patient can create postinsertion obstacles if a genuine esthetic concern is not detected. This type of patient will frequently respond to queries of esthetics with "Do whatever you think would look good, doctor," or "I don't care about the appearance, as long as I can chew." Caution should be exercised when managing the prosthetic care of these patients.

Skeletal anomalies that may affect esthetics should be brought to the patient's attention prior to treatment. Any discussion following the completion of care may often be interpreted as an excuse. Particular examples would include patients who believe that the RPD will correct skeletal discrepancies, overt facial wrinkling, or other esthetic concerns normally requiring surgical intervention. A skeletal Class II patient or a patient with vertical maxillary excess will be particularly aware of a maxillary anterior modification space for the RPD. The excessive acrylic resin display or lip displacement justifies consultation prior to RPD fabrication, allowing the patient the opportunity to consider alternative treatment options to meet their esthetic needs.

Tooth morphology and anticipated placement require evaluation of presurgical diagnostic casts. Most patients will request replacement of the missing dentition to maintain their previous esthetic situation. This should be readily accomplished, although if a suitable replacement is not feasible the limitations should be discussed with the patient prior to commencing treatment. Encumbrances may be due to tooth size or shape limitations or positioning difficulties, which may detract from the function of the partial denture. Examples may include the patient with natural anterior teeth that were much larger than the commercially available artificial dentition or the request to maintain the anterior tooth display in a patient demonstrating an excessive vertical overlap of the maxillary incisors. Clearly, esthetic and functional concerns may create the need for investigation of alternative treatment options or acceptance of the limitations by compromising either the esthetics or functional design. Any of these situations should remain well documented and explained to the patient completely.

Alternative treatment modalities

In situations demanding maximal esthetics, alternatives to conventional RPD design must be in the clinician's armamentarium. Alternative treatment modalities will often produce a result in prudent design with function and esthetics. The use of dental attachments is discussed in this chapter; however, finances, as

Figure 18.14 **(A)** The maxillary anterior teeth were lost as a result of a traumatic injury. The bone loss in the anterior maxilla is significant.

Figure 18.14 **(B)** The rotational path RPD allows the elimination of anterior clasp arms to improve esthetics.

well as dexterity or the ability to complete or maintain complex care, often dictate the need for conventional alternatives.

Adjunctive mechanisms for minimizing metal display

Camouflaging of RPD clasps, including the addition of acrylic or composite resin, has been reported in the literature.[29,30] The difficulty with the use of acrylic or composite resin to veneer to RPD metals lies in the differences between their abilities to flex and their coefficients of thermal expansion. Non-noble metals possess strength and resist significant flexure. However, resins are subjected to greater deformation from physical and thermal conditions. The composite resin matrix also tends to be brittle beyond its elastic limit. As a result, the abilities of the metals and resins to deform plastically are incompatible. Other concerns include the effect of the intraoral forces of mastication, the adjustability of veneered clasps, and the additional bulk of the clasp created by the addition of the veneering material. Excessive shortening and thinning of the clasp should be avoided to ensure rigidity and minimize the breakage potential of the clasp.[31]

Rotational path removable partial dentures

The rotational path RPD is a relatively uncomplicated method that eliminates the use of esthetically objectionable clasping in the anterior region of the mouth (Figure 18.14A and B).[32–35] It uses an anterior rigid portion of the framework and a conventional flexible posterior retentive clasp as the retentive components. The primary advantage of this design is the minimal use of clasps. The esthetic result is enhanced, and the tendency toward plaque accumulation is reduced. However, both the clinical and laboratory procedures required for the rotational path RPD are technique sensitive.

The rotational path RPD should be limited to tooth-supported situations to prevent torquing of abutment teeth. This design also requires that positive rest seats be used. Cingulum and extended occlusal rest seats are indicated for canine and premolar abutments respectively (Figures 18.15A and B and 18.16). For premolars, the rest seats should be extended to 1.5–2.0 mm deep occlusogingivally with nearly parallel facial and lingual walls. A restoration may be indicated to adequately contour the rest seat.

The cast is first surveyed at a 0° tilt to determine the adequacy of undercuts on the mesial surfaces of the anterior abutments and the distofacial surfaces of the posterior abutments (Figure 18.17). The amount of undercut needed for the anterior teeth is 0.25–0.5 mm. This position is registered using tripod marks. The cast is then tilted until the undercuts of the anterior abutments are eliminated. The analyzing rod is then used to determine whether access exists for the rests to be seated. There must be no interferences for the anterior segment to go to place (Figure 18.18). If it is satisfactory, the second cast tilt should be registered on the cast with a second set of tripod marks (Figure 18.19A and B). Major connectors with minimal palatal or lingual tooth contact are indicated to avoid interferences to seating of the framework. It is important that, during the framework trial insertion appointment, there is minimal adjustment of the anterior proximal plate; otherwise, the anterior retentive component may be lost. The rotational path RPD is not indicated for distal extension RPDs, arches with lingually inclined teeth, severely tapered arches, and arches with multiple edentulous areas.

Attachments for removable partial dentures

Diagnosis and treatment planning

The demands for highly esthetic dental restorations provide the catalyst for the attachment RPDs. The esthetic expectations of a patient should be the primary directive for attachment use. The psychological component of treatment planning of the RPD remains crucial to the success or failure of the rehabilitation. Meeting the patient's esthetic and functional expectations while not exceeding the biomechanical attributes of the supportive structures will result in successful therapy. The anticipated

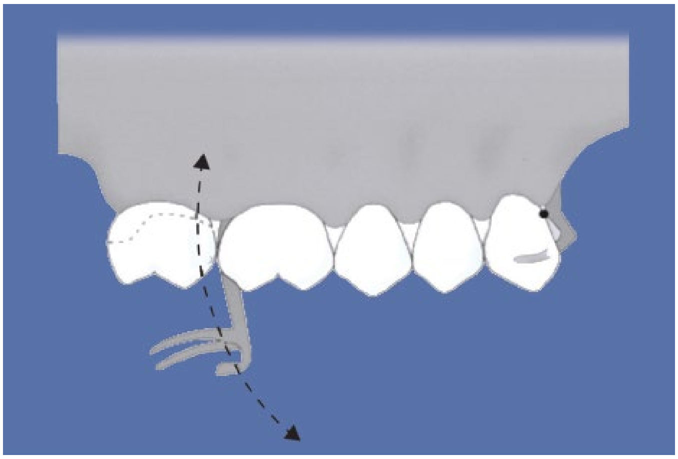

Figure 18.15 **(A)** The rotational path RPD uses an anterior rigid portion of the framework that engages an undercut and a conventional flexible posterior retentive clasp. After engaging the anterior undercut, the prosthesis is rotated into the fully seated position along an arc.

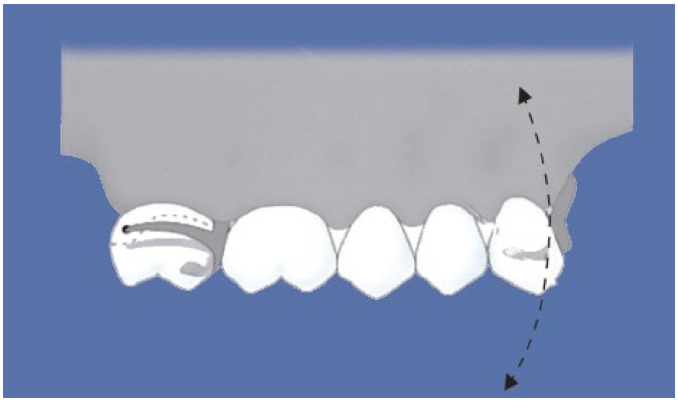

Figure 18.15 **(B)** This arc demonstrates the arc along which the anterior rigid retainer would have to move for the prosthesis to be dislodged.

Figure 18.16 The rotational path design uses extended rests on the anterior abutments.

function of the prostheses by the patient must not exceed the physiologic capacity of the teeth and tissues.

Proper treatment planning of the attachment RPD encompasses similar concepts to the conventional RPD. Fundamental biologic tenets must be adhered to for successful treatment. The components of guiding planes, rigid major and minor connectors, and indirect retention remain important in the philosophy of design. Suitable tissue preparation, accurate border extension, and tissue coverage without impingement are important adjuncts. Correct prosthetic planning will reduce the possibility of tissue abuse and enhance the prognosis for success.

Definition

An attachment is a connector consisting of two or more parts.[36] One part is connected to a root, tooth, or implant and the other part to a prosthesis. Attachment RPDs have been empirically termed "precision attachments" for years. The terminology of precision attachment partial dentures is frequently misused. Attachment partial dentures should be classified by the nature of the attachment fabrication, location, and biomechanical properties. Attachments used in RPDs are most commonly classified as (1) precision, (2) semiprecision, (3) intracoronal (nonresilient and resilient), and (4) extracoronal (nonresilient and resilient).[36–38]

Attachments are subdivided into two general categories: precision and nonprecision.[36,39] Precision attachments consist of machined components of special alloys under precise tolerances within 0.01 mm. The metallurgic properties of the alloys are controlled to minimize the intra-attachment wear and are designed in a manner that affords most wear to occur on interchangeable elements. The intra-abutment portion of the attachment will generally evidence little to no wear, allowing accurate replacement while maintaining the specific tolerances designed. These systems allow ease of replacement interchangeability of the standard components.

Semiprecision attachments require the direct casting of plastic, wax, or refractory patterns. They are considered semiprecision because they are subject to inconsistent water : powder ratios, burnout temperatures, and other variables. The resulting components may dimensionally change and reduce the preciseness of their accuracy of fit. The primary advantages of the semiprecision attachments are economy, ease of fabrication, and ability to be cast in a wide variety of alloys without the problem of coefficiency differences between the casting alloy and the attachment alloy.[36,39]

General considerations for attachments

The variability in the circumstances for use of attachments and the variety of attachments available preclude the establishment of a standard model. Selection should be based on the functional and physiologic requirements of the restoration. Consideration of the laboratory expertise in using particular attachments must be contemplated. Selection of an attachment with specific biomechanical and functional attributes may be finalized by the dental laboratory technician's ability to use the attachment and fabricate the prosthesis.

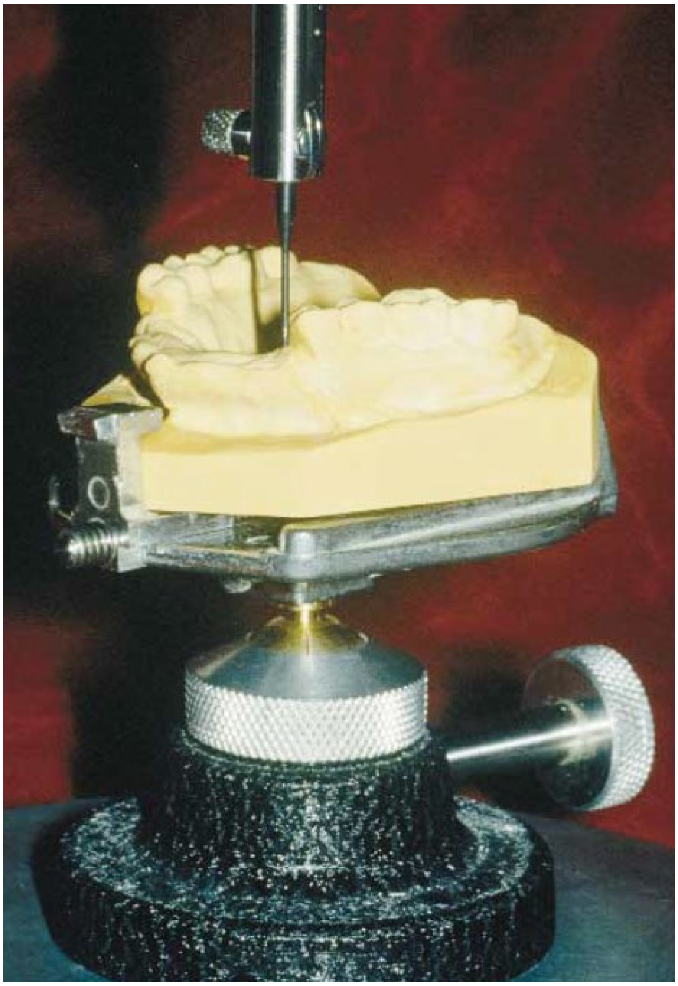

Figure 18.17 The cast is first surveyed with a 0° tilt to determine the adequacy of undercuts on the mesial surfaces of the anterior abutments and on the distal facial surfaces of the posterior abutments. This position is registered using tripod marks.

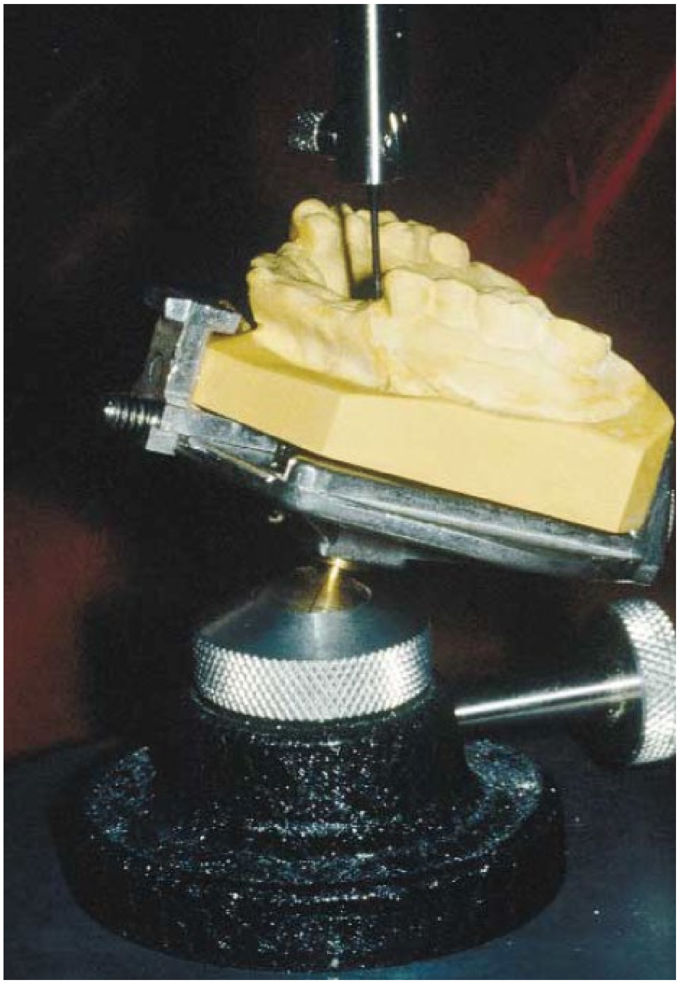

Figure 18.18 The cast is then tilted to eliminate the undercuts of the anterior abutments. This tilt is registered with a second set of tripod marks.

Attachment use

A significant consideration in the selection of an attachment should be the long-term maintenance. Retrievability should be regarded with equality to function in the design and selection of an attachment for the esthetic RPD. Repeated use of similar attachments increases the knowledge of the clinician and dental laboratory technician alike. This repetition will prove beneficial for efficacious delivery of care, management of difficult situations, and postoperative maintenance. The dental team should limit the application of dental attachments to a selection that meets the functional and esthetic requirements of the majority of patients and the level of expertise of the team. Other attachments may be considered periodically; however, use of other attachments may prove to be the rarity rather than the norm. This self-imposed limitation will ensure correct fabrication of the partial denture, untroubled delivery of care, and unrestricted maintenance of the prosthesis. Periodic planned or unplanned maintenance of the attachment prosthesis will be required. Consistent use of an attachment selection may safeguard adequate supply of replacement parts in the event of accidental breakage.[40]

Indications and contraindications

The overwhelming indication for the attachment RPD is esthetics. Numerous skillfully designed conventional RPDs are not worn simply because the patient does not like the appearance. Elimination of the buccal or labial direct retainer or clasp arm is a key factor in establishing an esthetically acceptable design. Once the need for an attachment-assisted RPD is established, the selection of the attachment type should be based on the biomechanical, physiologic, and functional attributes of the patient or technical expertise of the dental team.[39,41]

The contraindications to the use of attachments in RPDs are numerous. One must consider anatomic, biomechanical, personal, and physiologic factors in determining the selection of attachments. The health and morphology of the abutment teeth remain a significant factor in the selection of an attachment. Short clinical crowns prove to be the foremost contraindication to the use of attachments in the fabrication of RPDs. The tooth must have adequate clinical crown height to house the attachment components and effectively offset the leverage forces exerted on the tooth and supporting apparatus. The leverage forces are most often observed in distal extension RPDs.

Figure 18.19 **(A, B)** The heights of contour made at the two paths of insertion. The superior height of contour is made at the 0° tilt. The inferior height of contour represents the path of insertion whereby the undercuts of the anterior abutments are eliminated. The area between the two lines represents the undercut into which the anterior rigid section of the framework is seated. Care must be taken during finishing and fitting of the framework in this area; otherwise, retention may be lost.

In addition, adequate height must be present for the corresponding attachment components to be housed within the RPD framework or supportive acrylic resin while allowing proper artificial tooth placement.[36–41] Too little vertical height will preclude the use of attachments or require modifications to the attachment thereby reducing its strength or functionality; this also may result in insufficient space for replacement teeth and resin on the RPD, resulting in reduced esthetics, reduced function, or unanticipated fractures in this area.

Adjunctive procedures

Gingivectomy, or crown-lengthening procedures, may overcome the clinical disadvantage of short clinical crown height. This preprosthetic procedure will generally improve fixed prosthesis retention and resistance form and may increase the effective undercut, thereby enhancing the retention for a conventional clasping mechanism. This may avoid the need for placement of a surveyed crown when attachments are not a feasible treatment modality. Gingival crown-lengthening procedures may be required to provide adequate occlusal cervical space for attachment positioning while maintaining the functional attributes of the selected attachment to be used.

Orthodontic therapy should be considered with the presence of tipped or malpositioned teeth. The orthodontic correction of malpositioned teeth will avoid excessive tooth preparation, enhance vertical loading, avert the need for endodontics, and provide easier development of a common path of placement for the attachment partial denture. A particular degree of parallelism is required of all attachments. Orthodontic correction of malpositioning will allow proper attachment orientation. A nonresilient precision attachment requires the higher degree of parallelism.

Teeth with large pulps will not allow for incorporation of an internal box within the crown preparation to accommodate certain attachments.[37,39,41] The result of improper preparation would be an excessively overcontoured tooth resulting in a periodontal compromise. Endodontic therapy may be required in certain instances for the use of attachments. Endodontics should also be considered when preparation of a tooth with a large core restoration might provide little resistance to fracture. The placement of an intraradicular core might offer enhanced resistance to fracture under the functional loading of an attachment RPD.

The placement of attachments in pontics is an option that can avoid possible violations of biologic principles during tooth preparation or the need for adjunctive procedures (Figure 18.20). The use of attachments lingually positioned in a traditional pontic or distally located in a cantilevered pontic has been described.[42]

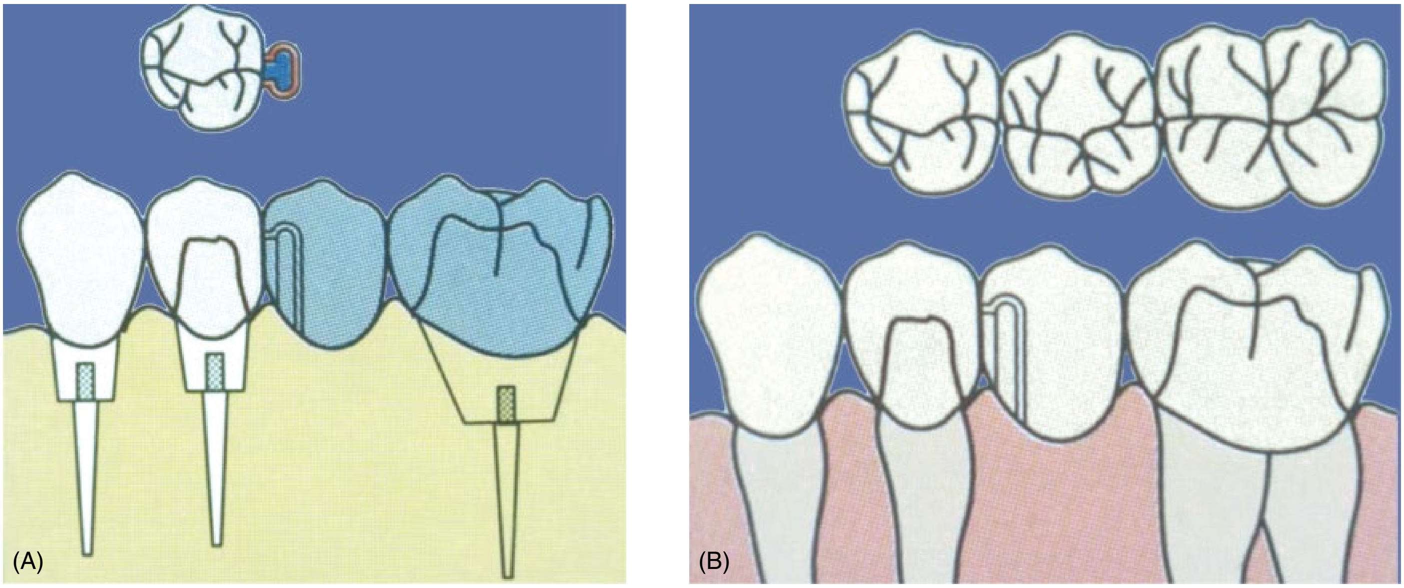

Figure 18.20 Intracoronal attachment types, such as the Score-BR, PDC, Omega-M, Beyeler, and others (Attachments International, San Mateo, CA). **(A)** The matrix is placed upside down and cast to the anterior abutment. The patrix is waxed over the matrix, and the waxing of the FPD is completed. **(B)** The FPD is invested, cast, and finished. *Source:* Reproduced with permission from Staubli.[36]

Dexterity

Poor patient dexterity remains a strong contraindication for the placement of an attachment RPD. Patients lacking adequate hand coordination may encounter significant difficulty manipulating the prosthesis intraorally. For some, it may be a virtual impossibility. While the average life expectancy increases, more patients become potential candidates for RPD treatment. Debilitating diseases affecting neuromuscular control and joint mobility are likely to correspondingly increase. Arthritis, Parkinson's disease, cerebrovascular accidents, and other situations that influence fine motor skills might preclude efficacious attachment partial denture use or, at least, direct the attachment selection. Consequently, dexterity should remain a strong diagnostic consideration with all potential attachment RPD patients. Patients demonstrating average dexterity will generally be able to manipulate placement and removal with relative ease over time. A resilient attachment will generally be more easily accommodated rather than a rigid intracoronal attachment with a precise path of placement.

Cost

The design and fabrication of the complex attachment RPD treatment are costly. Cost in terms of time, effort, and resource commitment can be anticipated. The economic factors may predict the feasibility of using attachments. The prudent clinician should anticipate an increased amount of diagnostic effort, laboratory expense, chair time, and maintenance in this form of therapy. These factors should be explained to the patient. The patient should anticipate charges for periodic attachment maintenance or replacement. Subsequently, these considerations support the use of a limited number of different attachments for efficacious delivery of care and reduced chair time.[40]

Oral hygiene maintenance

A final factor to be considered in the possible exclusion of attachment use for patients is the long-term maintenance of the prosthesis. It must be anticipated that periodic evaluation, adjustment, or replacement of attachment components will be required. The inability of patients to travel or return on a regular or periodic basis should be considered contraindications to the use of attachments. Oral hygiene may also be considered a parameter of attachment selection. Attachments will accumulate plaque and calculus, limiting the effectiveness or intended function of the attachment. Additionally, attachment use implicates the fabrication of full- or partial-coverage castings. Patients with high caries rates may experience a diminished prognosis with rehabilitations consisting of multiple fixed restorations.

Biomechanics and support

Once a decision has been made to restore a region with an attachment prosthesis, the manner in which the vertical and horizontal forces are to be supported requires consideration. A partial prosthesis may be tooth borne or tooth–tissue borne. The forces imparted to the prosthesis and its supportive elements should be as widely distributed as possible.

The periodontal health and support of the natural teeth should be considered in the selection of an attachment design. The forces should be equitably distributed over as many teeth as possible within the biologic and physiologic capacity of the supportive dentition. The denture bases should offer the broadest support possible for mucosal coverage.

Distal extension situations raise the dilemma of load distribution between the teeth and mucosa. The amount of soft-tissue compressibility over the distal extension residual ridge remains disproportionate to the abutment teeth. This phenomenon will create unharmonious movement of the partial denture, imparting leverage forces to the abutment teeth, possibly resulting in harm to the abutment teeth, mucosa, and residual ridge, if not considered in the selection of an attachment. Only teeth with suitable clinical crown height and periodontal stature should be considered for attachment use. The presence of excessive tissue compressibility or unsupported tissue might prescribe the need for preprosthetic surgical intervention.[37–39,41]

Path of insertion

With the aid of a surveyor, the anticipated path of insertion must be considered to develop appropriate guiding planes and attachment placement within the confines of the natural dentition. A less resilient attachment will generally dictate a smaller degree of tolerance or more parallelism relative to the path of insertion. Rigid and intracoronal attachments must closely accommodate nonsurgically correctable tissue/anatomic limitations or undercuts. For example, distal extension situations may require a distally inclined path of placement to accommodate extension into the retromylohyoid fossa, whereas an anterior modification space may require a labially inclined path of insertion and attachment orientation.[37,38]

Knowledge of the anticipated path of insertion may guide the attachment selection to a more resilient, universal design that can offer a greater tolerance to the path of placement. The path of insertion of the abutment crowns may be determined at this time and may indicate the need for preprosthetic endodontics or surgery.

Once a prosthesis has been placed along its path of insertion, anterior, posterior, and lateral forces alone or in combination influence the stability of the prosthesis. The tendency of the forces to dislodge the prosthesis must be counteracted through direct and indirect retainers. Direct retention may occur through friction of the attachment components, framework components with the teeth, or mucosal coverage of the denture bases. The forces of adhesion, cohesion, and surface tension between the base, saliva, and mucosa cause a pressure reduction on compression and further inhibit denture base movement.

Indirect retention

Resistance to lateral displacing forces must be provided through rigid bracing components and the vertical height of the residual ridges. Bilateral distal extension bases use the mucosa and teeth of both sides of the dental arches for resistance to lateral forces. A force on one side of the arch is resisted by the components or tissue/base integrity of the contralateral side. This supports the increased stability usually found in bilateral distal extension bases compared with unilateral designs. The design of certain attachments will provide indirect retention; however, the effectiveness of the indirect retention will vary. In attachment systems that offer little or no indirect retention, it must be incorporated in the framework design. In general, the more precise or rigid the attachment design is, the greater is the degree of indirect retention inherent in the design. Additionally, the more widely spaced the retainers are, the greater the support and stability are when compared with a design with retainers placed closely together.[36–41,43]

As attachment designs increase in the degree of indirect retention, a generally greater amount of force to the supportive elements will be generated. Because of this increase in leverage forces transferred to the abutment teeth by the prosthesis, many teeth treated with castings incorporating attachments must be splinted to adjacent teeth. This concept safeguards the functional and biomechanical overloading of the supportive elements.[44–47]

Tooth preparation

Preparation design should anticipate an increased degree of the forces to be applied to the teeth by the attachment mechanism. Avoidance of excessive taper, replacement of suspicious or weakened core restorations, and adequate axial wall height will reduce the risk of tooth fracture or decementation of the restoration. Therefore, most teeth will require full crown coverage for adequate retention and resistance form.

The preparations should consider the morphology of the tooth as related to the attachment selection. Adequate tooth structure must be present in all dimensions to allow incorporation of the attachment pattern yet retain the emergence profile and clinical crown contours of the tooth. Buccolingual, incisocervical, and mesiodistal space must be considered before a bur is placed to the tooth tissue. Alternative attachment selection or adjunctive procedures should be planned prior to preparation to allow for completion of the intended restoration and to enhance the functional and periodontal success of the restoration.

Attachment selection considerations

Proper attachment selection requires evaluation of five factors: location, function, retention, available space, and cost. Location can be subdivided into intracoronal, extracoronal, radicular, and bar types of attachments.[36]

Location

Intracoronal attachments are incorporated entirely within the contours of the cast crown for the tooth. It is imperative that adequate space exists in all three dimensions for both incorporation of the attachment and the maintenance of natural tooth contours to ensure proper use of the attachment and a positive prognosis of the restoration and the tooth. If it is not possible to place a box in the preparation to accommodate the matrix component of the attachment, an alternative attachment selection should be made. The advantage of the intracoronal attachment is that the forces exerted by the prosthesis are applied more closely to the long axis of the tooth. All intracoronal attachments are nonresilient and may require double abutting or splinting of the adjacent teeth. This form of attachment offers indirect retention and a more precise path of placement. Most wear will occur on placement and removal. In situations with diminished attachment length as a result of reduced interocclusal height, milled lingual bracing arms should be considered (Figure 18.21A–C). Careful consideration should be given to the amount of reduction in attachment length that will also allow for maintenance of the

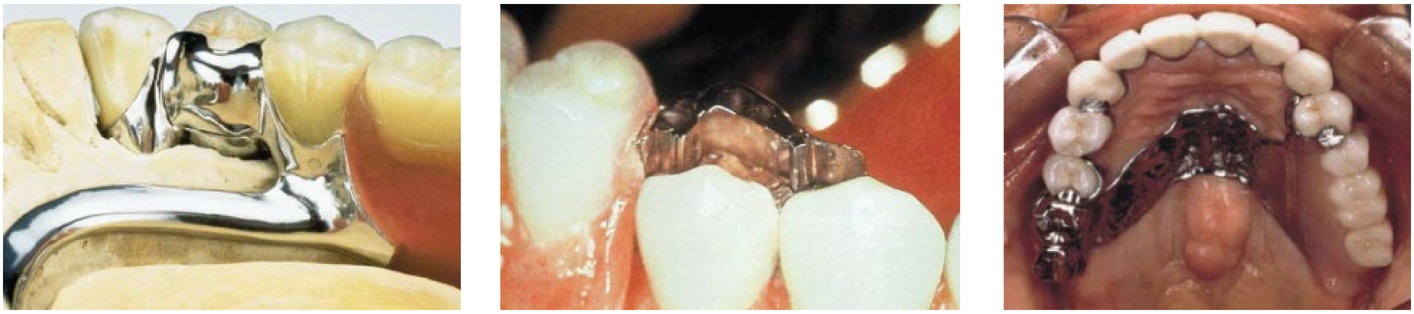

Figure 18.21 **(A)** Milled lingual bracing arm on an RPD framework. The design allows development of normal crown contours with placement of the RPD. **(B)** The Biloc and Plasta attachment (Attachments International) allows the bracing arm to be incorporated into the crown contours. **(C)** A traditional lingual bracing or reciprocal arm may create bulk or result in tongue irritation.

functional aspects of the attachment. Most manufacturers state the optimal and minimal lengths of the attachment.

Extracoronal attachments are situated external to the developed contours of the crown. Normal emergence profile and tooth contours may be maintained while minimizing the amount of tooth structure preparation. The more conservative preparation reduces the risk of or need for devitalization.

The majority of extracoronal attachments have resilient attributes. This will improve the ability of patients demonstrating dexterity problems when inserting the prosthesis. However, the extracoronal positioning will increase the likelihood of hygiene difficulties. Patients will require fastidious hygiene instruction using floss and adjunctive periodontal aids to prevent food entrapment and calculus accumulation. Inadequate hygiene will generally result in hyperplastic tissue inflammation subjacent to the attachment apparatus.

Function

The functional attributes of an attachment require differentiation between the intention of the prosthesis as being solid or resilient. Kennedy Class III and small to moderate-size (replacement of less than seven teeth) Class IV tooth-supported prostheses should be considered solid, whereas large Class IV and distal extension I or II prostheses are increasingly tissue supported and should be considered resilient.

Rigid attachment mechanisms may include locking pins. Locking and nonlocking attachments allow for virtually no movement between the prosthesis and the abutment tooth. Resilient attachments allow for a spectrum of movement ranging from limited uniplanar to universal. Staubli has categorized rigid and resilient attachments into six classifications, from rigid to universal resiliency.[36] The higher classification number correlates with a greater degree of resiliency and suggests less torque transfer to the root or implant abutment. The classifications are shown in Table 18.1.

Retention

Retention of the attachment components may be based on frictional, mechanical, frictional–mechanical, magnetic, and suction characteristics. Frictional retention is developed by the resistance to the relative motion of two or more surfaces in contact. Greater intimate surface contact will usually correlate with an increase in the amount of retention. Mechanical retention implies the resistance to relative motion by means of a physical undercut. The degree of undercut and the ability to adjust the physical component will predict retention. Frictional–mechanical retention combines parameters previously discussed and should be considered in situations necessitating increased retention with appropriate abutment support. Magnetic retention is created by attraction of certain materials to a surrounding field of force produced by the motion of electrons and atomic alignment. This type of retention is not largely used and may be diminished by corrosion of the elements. Suction is created by a negative pressure similar to the intaglio surface of a denture to the supportive residual ridge.

Space

Space is a principal consideration for the selection of an attachment. Vertical space is measured from free gingival margin to the marginal ridge of the abutment. Avoidance of tissue impingement and maintenance of a proper emergence profile is paramount at the cervical region. Cautious placement of the superior aspect of the attachment will circumvent occlusal interferences. The length of attachments that rely on frictional retention should be maximized to maintain resistance to dislodgment. Placement of the attachment should be as low on the tooth as possible to reduce the tipping or leverage forces applied. Buccolingual space is equally important to avoid overcontouring the crown. Additional bulk will be required buccal and lingual to the attachment for the casting alloy. Proper analysis of mesiodistal

Table 18.1 Classification of Attachments

Class 1a	Solid, rigid, nonresilient
Class 1b	Solid, rigid, lockable with U-pin or screw
Class 2	Vertical resilient
Class 3	Hinge resilient
Class 4	Vertical and hinge resilient
Class 5	Rotational and vertical resilient
Class 6	Universal, omniplanar

Source: Reprinted with permission from Staubli.[36(p.5)] measurement ensures proper proximal contour and will provide an indication of a need for boxes in the development of the preparation. The largest attachment possible should be selected. This requires careful prepreparation analysis that includes the arrangement of denture teeth in a diagnostic waxing. This will help ensure the highest functional and esthetic value to the reconstruction.

Cost

Cost is related to the complexity of the attachment and the material components. In general, precision attachments are machined from noble alloys. The accuracy, manufacturing, and precious nature of the composition will demand a higher cost. Semiprecision attachments are made of plastic or other refractory materials subject to variables in the casting procedure possibly resulting in inaccuracies in the preciseness of fit; however, the materials and processes significantly reduce the cost of using these attachments.

Intracoronal attachments

Advantages

Intracoronal attachments, if used correctly, are incorporated entirely within the contours of the crown. This is advantageous for maintenance of tooth dimension and morphology. The positioning of the attachment near the long axis of the tooth allows force direction to be located along the long axis of the tooth. This creates a more advantageous biomechanical loading and force transfer to the tooth with a reduction in adverse leverage forces. Maintenance of natural tooth contours and the ability to properly place an adjacent replacement tooth without excessive recontouring or alteration for adaptation around an external attachment generally make intracoronal attachments more esthetic. Less possibility of food entrapment near the gingival tissues will enhance long-term prognosis and comfort.[36–39,41,43]

Disadvantages

A disadvantage of intracoronal attachments is the more excessive tooth reduction required for proper positioning of the attachment. Teeth with large pulps or young patients often contraindicate the use of intracoronal attachments or necessitate endodontic therapy for attachment use. The three-dimensional size of the tooth will predict the functional or biomechanical success with this attachment. Large clinical crowns (at least 4 mm) are usually required for intracoronal attachments. Decreasing the length by half reduces the retention by a factor of eight. This may be overcome by using a mechanical type of retentive element. The cost and precision of intracoronal attachments may be a limiting factor. Patient dexterity, maintenance, and repair are disadvantages or possible contraindications to the use of this type of attachment. Attachment alignment is critical owing to the limited resilience and finite path of placement possible. This creates a limited path of placement for the prosthesis.[36–39,41,43]

It is the authors' intention to present commonly used attachments that meet the considerations previously described. However, it is recognized that other attachments similar in design and meeting the functional and biomechanical criteria for use may be prescribed. The intracoronal attachment obligates a sound abutment tooth and demand for high esthetic value. A clinical crown of greater than 4 mm is generally required with a similar faciolingual width. The preparation depth of the internal box is approximately 2 mm. The frictional retention attachments must maximize clinical length to offer the greatest degree of retention. Generally, in situations where the clinical crown will be 3.5 mm or less, a mechanical retention attachment type should be considered.

Types of intracoronal attachments

The Stern G/A, Stern G/L, and Stern Type 7 are intracoronal precision attachments providing frictional retention and allowing for some degree of adjunctive mechanical retention.[43] The Stern G/A attachment may be considered for segmenting an FPD, which may require modification to an RPD in the future. The gold alloy patrix offers an expansion slot on the gingival edge for enhancement of frictional retention. The Stern Type 7 does not offer conversion from an FPD to an RPD, although it has similar adjustment of the frictional retention through the use of expansion slots. The Stern G/A expansion slot design (Figure 18.22) allows for the patrix faceplate to remain flat against the matrix wall, thereby reducing wear. The Stern G/L employs a gingival latch mechanism to provide mechanical retention in addition to the frictional retention of the similar Stern G/A and Type 7 (Figure 18.23). The Stern G/L patrix is produced in two designs: the flat-back and the "tail" on the back of the patrix (ESI), and in two faciolingual widths, 0.70 and 0.96 inches. The width characteristics are axiomatic, although the shape characteristics predict the method of attachment to the RPD framework. The flat-back design requires soldering to the framework or casting a retentive arm to the attachment for acrylic resin retention within the denture base. The ESI offers greater versatility, allowing soldering, electrosoldering, and acrylic resin attachment to the RPD framework (Figure 18.24). Owing to the presence of the mechanical gingival lock, this type of attachment allows one of the shortest clinical crown height requirements of 2.7 mm.

The Stern McCollum (Sterngold) attachment (Figures 18.25 and 18.26) offers an adjustment slot on the face of the patrix that allows access when the slot is situated lingually for cross-arch stabilization.[43]

The Biloc and Plasta attachments (Attachments International, San Mateo, CA) offer conversion possibilities from FPDs to RPDs.[36] The Biloc and Plasta attachment, an intracoronal semiprecision attachment, offers a machined patrix in two alloy possibilities and a castable plastic matrix. A lingual bracing arm is recommended and is indicated in fixed Kennedy Class I or II situations (Figure 18.27). The patrix portion of the attachment types described are either similar in metallurgic properties or possess characteristics allowing a greater degree of wear when compared with the matrix. Consequently, the frictional wear of the patrix reduces retention and supports the adjustment capacity of the components. When the amount of wear or loss of retention exceeds the adjustment capacity, replacement of the patrix component is necessary. This clarifies the advantage of a

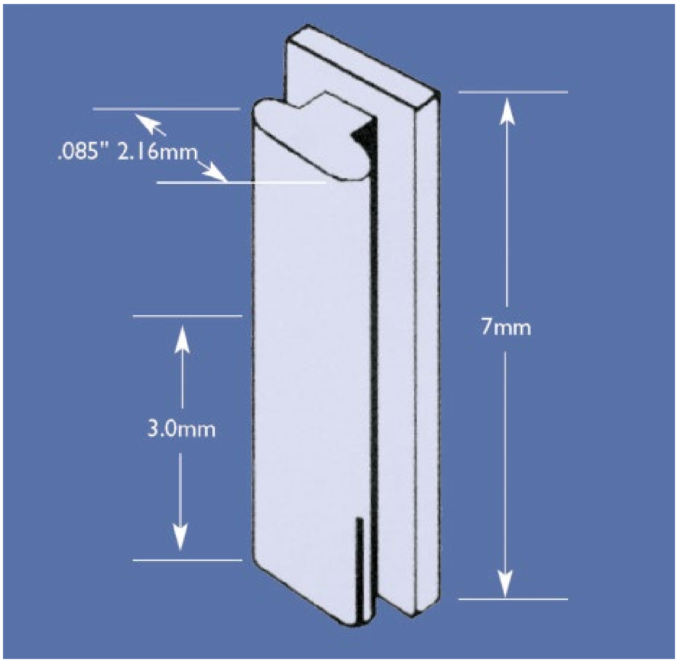

Figure 18.22 Stern G/A dimensions and illustration of expansion slot to allow for frictional retention adjustment. *Source:* Reproduced with permission from Sterngold, International.[43]

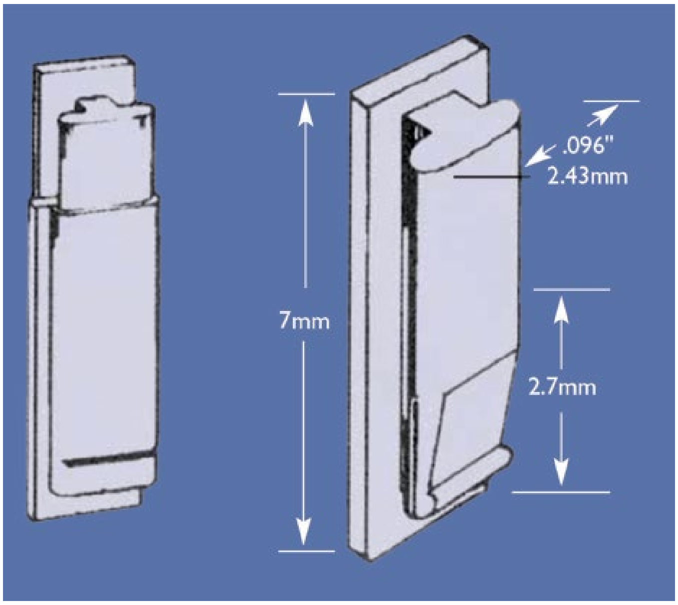

Figure 18.23 Stern G/L dimensions and illustration of an expansion slot to allow for frictional retention adjustment and gingival latch component. *Source:* Reproduced with permission from Sterngold, International.[43]

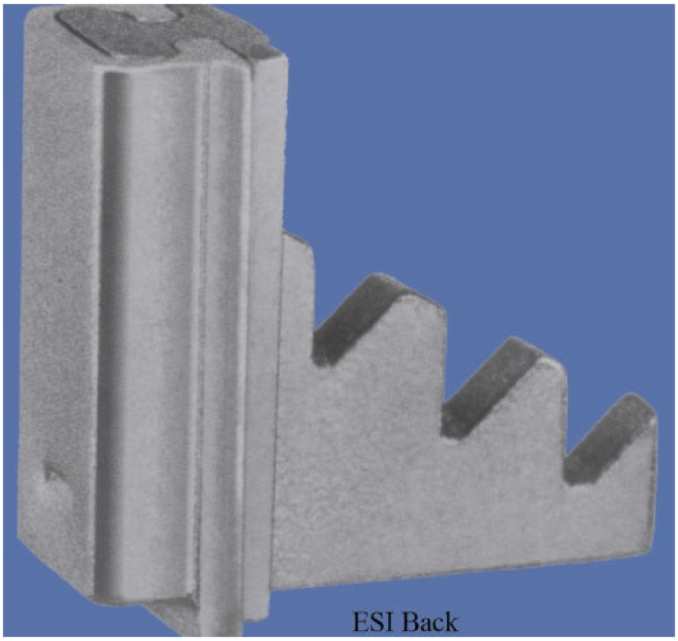

Figure 18.24 Stern G/L ESI back allows for acrylic resin retention to the RPD framework during attachment relation. Acrylic resin retention allows for retrievability of the attachment for ease of maintenance. *Source:* Reproduced with permission from Sterngold, International.[43]

precision-milled component. For replacement, a new patrix is purchased and replaced into the RPD without concern for casting inaccuracies or difficulties retrofitting the patrix portion to the abutment matrix, as might be experienced with semiprecision attachments.

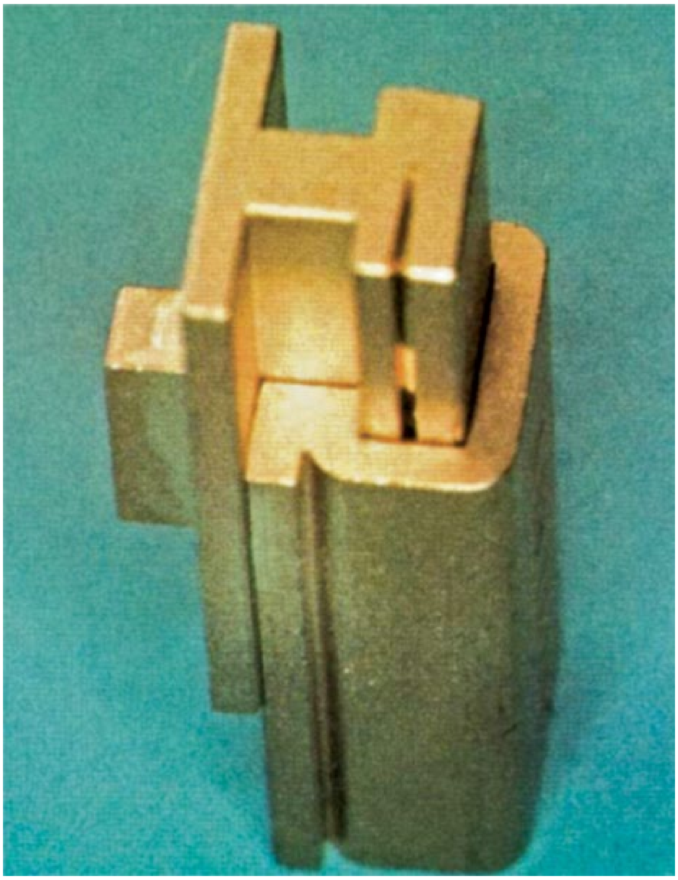

Figure 18.25 Stern McCollum attachment (Sterngold). Note that the expansion slot must be positioned to face buccally.

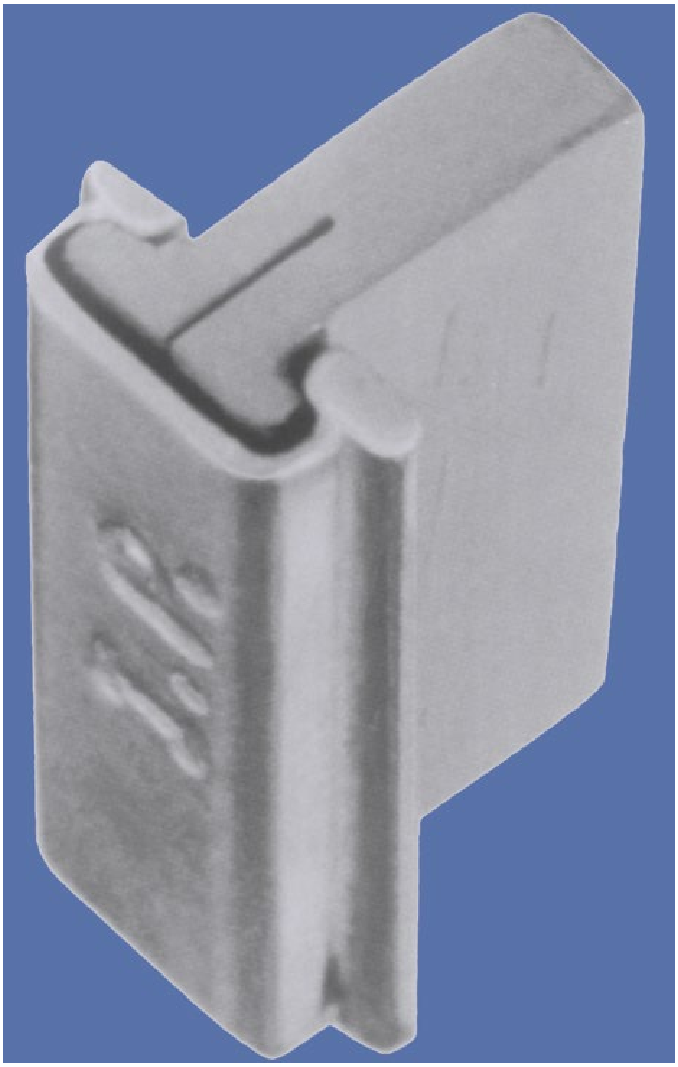

Figure 18.26 Stern McCollum (Sterngold) attachment. Note that the expansion slot is positioned on the face of the attachment oriented along the ridge crest. *Source:* Reproduced with permission from Sterngold, International.[43]

Figure 18.27 The Biloc and Plasta attachment (Attachments International) allows for fabrication of an intracoronal attachment with a milled bracing arm. This design offers incorporation of the RPD bracing arm into the proper clinical crown contours. The mesial portion of the bracing arm is similar in orientation and function to the intracoronal portion of the attachment on the distal of the crown.

Attachment connection to the RPD may be accomplished in a variety of ways, as previously described. Soldering to the framework remains the most permanent and possibly the most common method. However, acrylic resin attachment of the patrix or patrix portion of the attachment to the RPD provides the highest degree of retrievability. In acrylic resin attachment patrices, the worn patrix component is retrieved from the RPD, and the new patrix is luted into place with autopolymerizing acrylic resin, often without disturbing the artificial teeth (Figure 18.28). The disadvantages of this technique are the discoloration and potential weakness of the acrylic resin. However, this technique remains more time and resource efficient than rebasing the RPD to retrieve a soldered-to attachment. A soldered technique requires artificial tooth removal and replacement owing to the excessive heat generated from the retrieval and resoldering of the patrix to the framework.

Extracoronal attachments

Advantages

The advantages of extracoronal attachments include resiliency in certain designs and less abutment tooth preparation. The conservative nature of the preparation required would suggest less harm to the pulp and reduced risk of potential endodontic intervention. The resiliency in design provides advantageous stress-breaking characteristics in distal extension situations (i.e., Class I or II arches). Attachment alignment is not as critical in highly resilient extracoronal attachments due to the omniplanar motion possible. This creates the advantage of multiple paths of placement for the prosthesis. Patients with biomechanical limitations not withstanding a rigid attachment apparatus or anatomic limitations precluding a finite path of placement are strong candidates for resilient attachments.[36–39,41,43]

Disadvantages

The adverse aspects of extracoronal classification include the potential for torque imparted by the attachment to the tooth and hygiene maintenance. Careful recall evaluation is necessary to

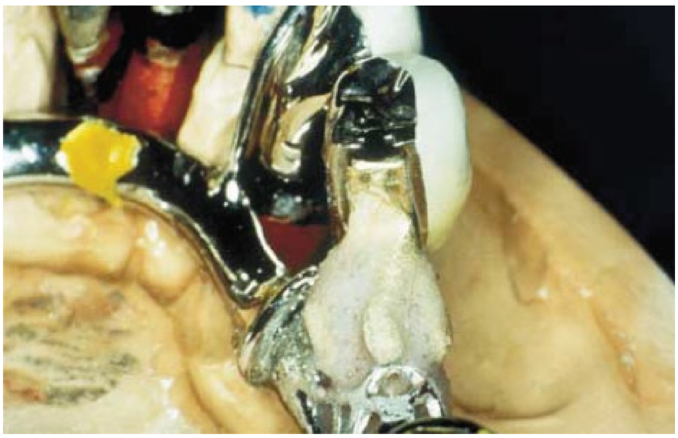

Figure 18.28 Patrix attachment with autopolymerizing acrylic resin to the RPD framework allows for easy retrievability and attachment replacement. This type of patrix placement increases the accuracy of the framework relation to the tissues and the abutment teeth.

ensure proper base–tissue relationships and fastidious oral hygiene. Tooth positioning around the attachment apparatus is often difficult and diminishes functional or esthetic value if adequate space is not available. Some resilient extracoronal attachments do not allow for "locking" to a rigid state. This may create difficulties with relining and rebasing procedures. Indirect retention and bracing are not incorporated into most extracoronal attachment designs and will necessitate the addition of components to provide these functions.[36–39,41,43] As with intracoronal attachments, it was our intention to present commonly used attachments, while understanding that other attachments similar in design and meeting the functional and biomechanical criteria for use may be prescribed.

Types of extracoronal attachments

Dalbo attachment system (Cendres & Métaux SA)

This attachment is one of the oldest and most successful extracoronal attachments and is classified as an adjustable, directed-hinge distal extension attachment.[36,43] This system features lateral stability, vertical resiliency, and hinge movement (Figure 18.29A–D). The advantages of the Dalbo system are the intrinsic direct retainer and excellent stability owing to the vertical beam. The attachment may be used in unilateral or bilateral applications (Figure 18.29E–J). The unilateral configuration provides a larger vertical bar for enhanced lateral stability. The attachment is offered in two sizes, although the mini version lacks vertical resiliency (see Figure 18.29D). The vertical resiliency is rendered through the presence of a spring and found only in the standard unilateral and bilateral designs. The difference between the standard and the mini is approximately 2 mm in clinical crown height requirement, 1.7–2.0 mm in preparation depth, and 1 mm in faciolingual width requirement. As in all extracoronal attachments, the amount of space required in the denture base is approximately 5.5–6.0 mm. This often creates difficulty with tooth placement and inadequate strength for the acrylic resin. The minimum amount of acrylic resin recommended should be strictly adhered to so as not to compromise the strength of the denture base in the region of the attachment. This extracoronal retainer offers a mechanism to "lock" the attachment for reline procedures.

Octolink

The Octolink system (Attachments International), an extracoronal precision/semiprecision attachment, provides a large degree of movement and is classified as a universal hinge with vertical resiliency (Figure 18.30A–D).[43] The patrix button is adjustable and is screwed into a metal keeper, or retention nut, which is retained in the acrylic resin or may be spot-welded to the RPD framework. The matrix becomes incorporated into the crown through either a cast-to technique or a castable plastic technique (Figure 18.30E–I). A minimum of 4.0 mm of vertical abutment tooth height is necessary, although a minimum of 6.0 mm of space is mandatory for the retentive keeper and patrix component in the denture base.

Stern ERA-RV, ERA-RV offset and micro

The Stern ERA and Stern-RV (reduced vertical) (Sterngold) are commonly used semiprecision attachment providing universal hinge and vertical resiliency (Figure 18.31A–E).[43] Retention may be varied through use of four color-coded nylon patrices indicating four levels of retention (Figure 18.31F and G). An optional metal jacket serves as a keeper for the patrix retentive element, which may be alternatively retained within the acrylic resin (Figure 18.31H). However, this is more difficult to change once retention is diminished. Patrices may be easily changed without the use of acrylic resin. The Stern ERA requires a minimum of 4 mm of vertical height, whereas the Stern-RV requires 3.5 mm of vertical space (Figure 18.32). No additional preparation depth is required for matrix incorporation to the crown restoration. A large space of 6.5 mm is required within the denture base for the patrix component and an additional 0.3–0.5 mm for the optional ERA metal jacket. The manufacturer recommends an additional 1.0 mm of acrylic resin for patients demonstrating parafunction or "habitually strong occlusions." The patrix component is the variable between the Stern ERA and the Stern-RV. Both patrices fit with the selected matrix.[43,48]

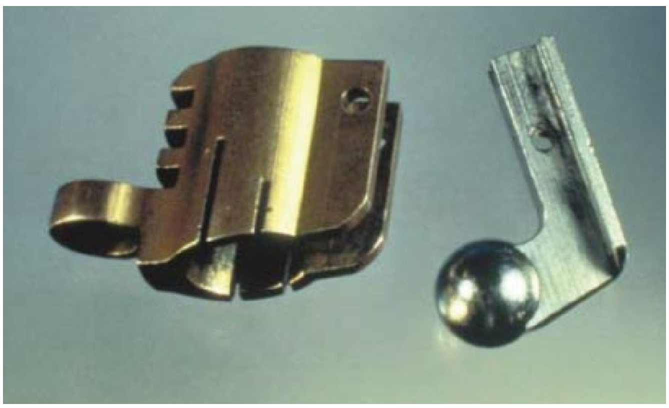

Figure 18.29 **(A)** Dalbo attachment (Cendres & Métaux).

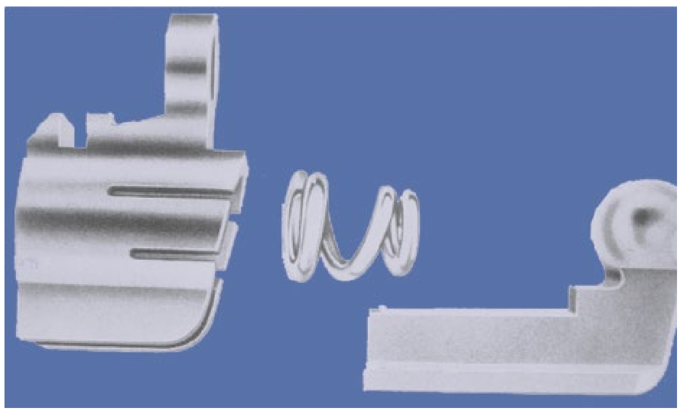

Figure 18.29 **(B)** A spring allows for vertical resiliency, and a ball allows for horizontal rotation.

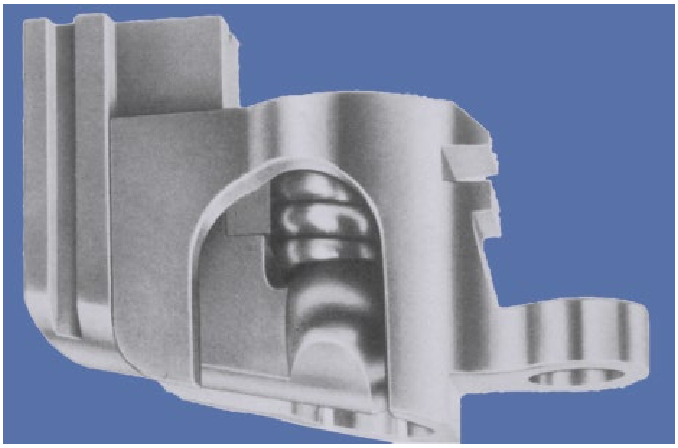

Figure 18.29 **(C)** A compressed spring allowing for vertical resiliency.

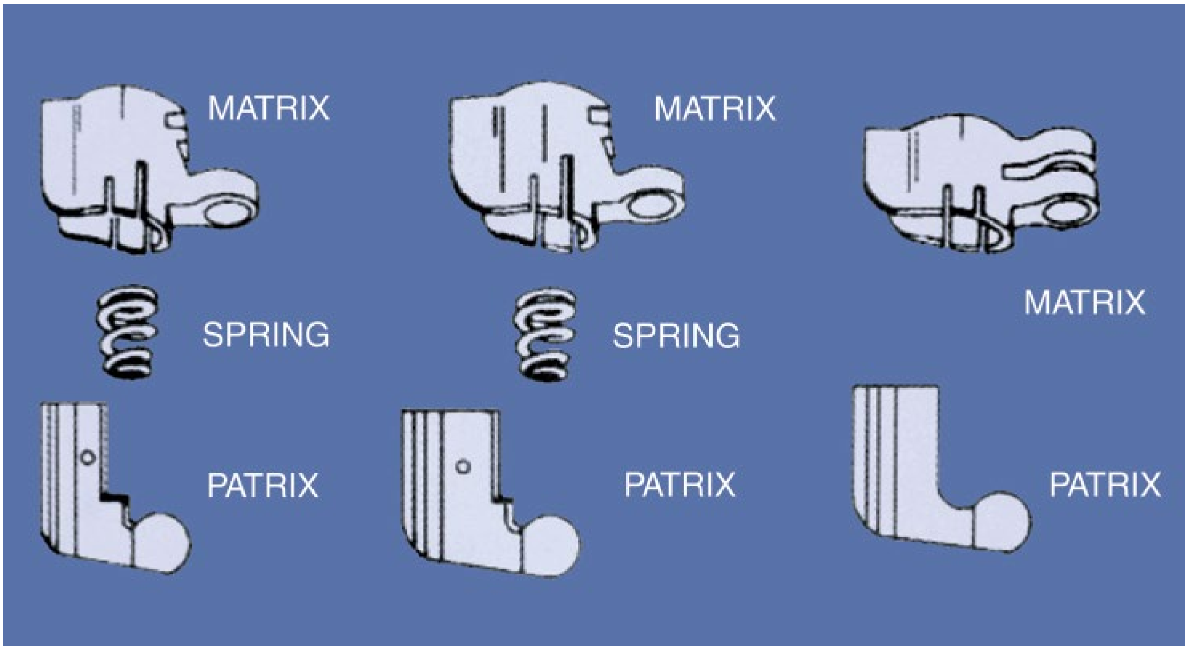

Figure 18.29 **(D)** Bilateral application, unilateral application, and mini (left to right).

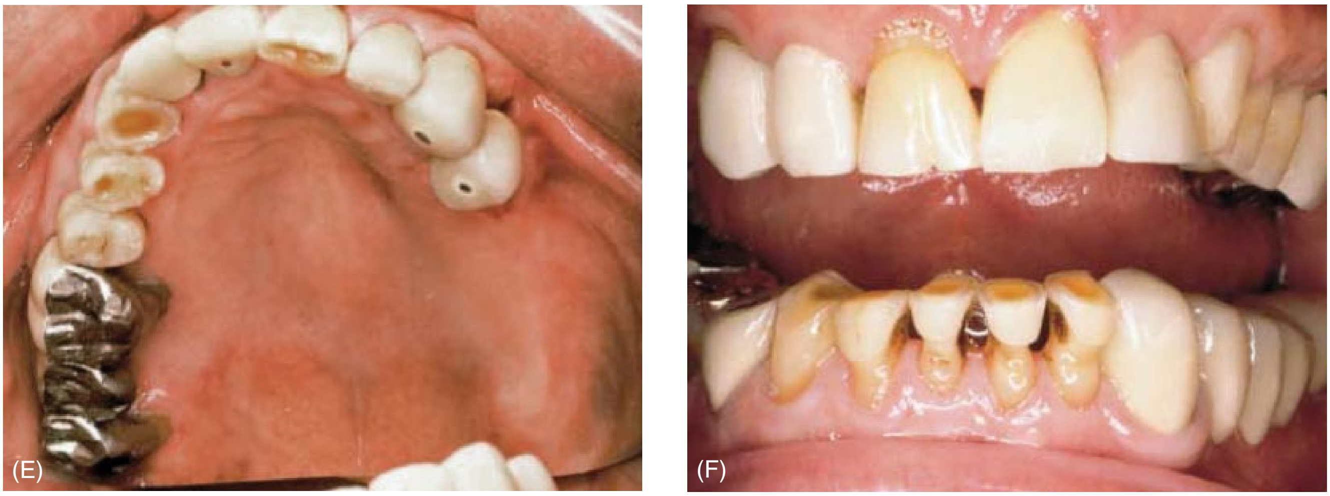

Figure 18.29 **(E, F)** This 75-year-old man wanted to improve both function and esthetics. Note the considerable wear in both the maxillary and mandibular dentitions.

Figure 18.29 **(G)** A removable prosthesis with Dalbo attachments in place.

Figure 18.29 **(H)** The metal–ceramic framework is easily fixed to the Dalbo attachments.

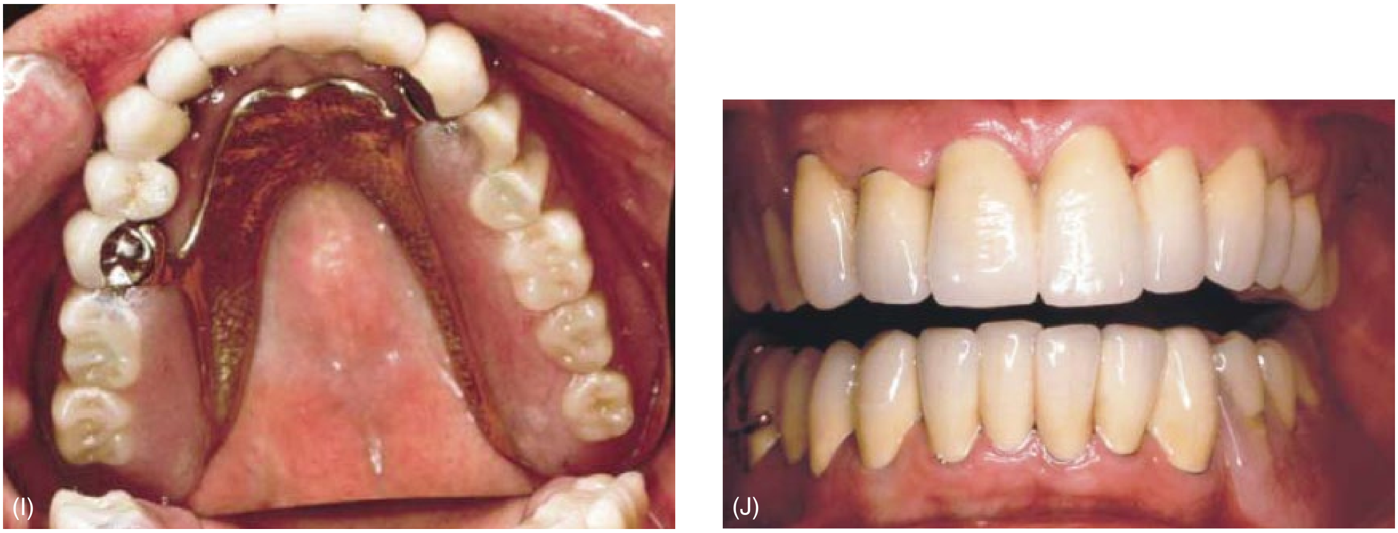

Figure 18.29 **(I, J)** Fixed metal–ceramic prostheses combined with Dalbo attachments provided maximum function and esthetics and were easy for this patient to insert and remove.

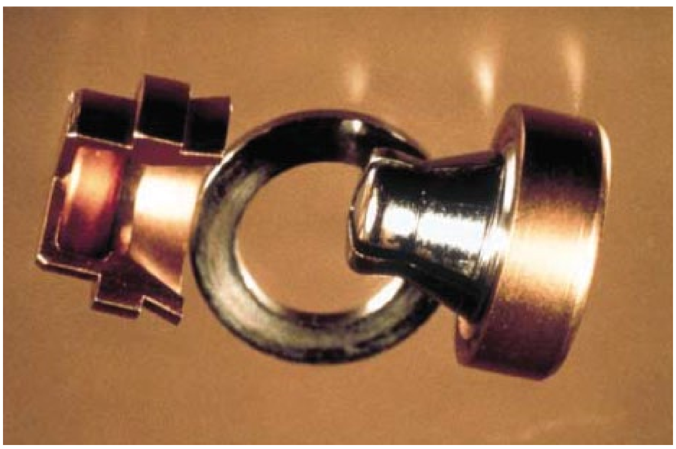

Figure 18.30 **(A)** Octolink attachment (Attachments International).

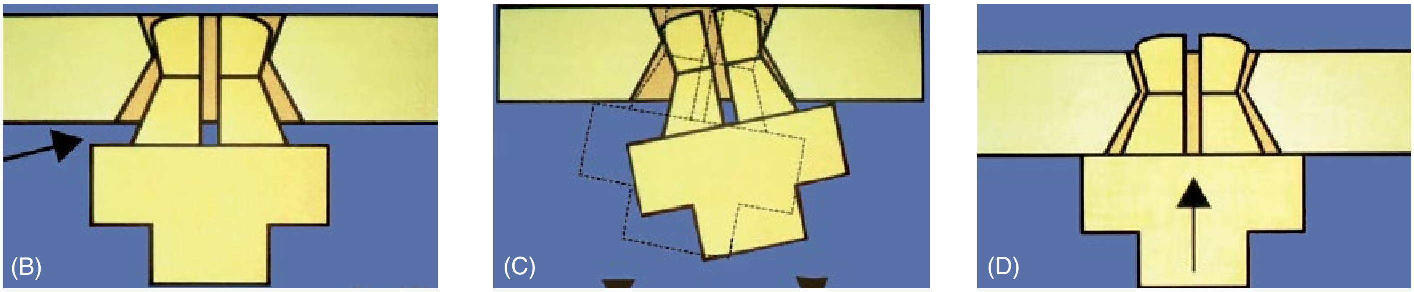

Figure 18.30 **(B)** Spacer used to allow for vertical resiliency. (C, D) Note the vertical and omniplanar resiliency of the attachment.

Figure 18.30 **(E)** This 30-year-old man was embarrassed because the clasps of his removable prosthesis showed when he smiled.

Figure 18.30 **(F)** A four-unit metal–ceramic splint combined with an Octolink (Attachments International) framework would better support the removable prosthesis.

Figure 18.30 **(G)** This frontal view shows the adaptation of the metal framework to the alveolar ridge.

Figure 18.30 **(H)** This view shows how the Octolink (Attachments International) attachments will fit into the removable prosthesis.

Figure 18.30 **(I)** The final smile shows the esthetic improvement offered by the combination of a secure attachment and a natural-looking acrylic flange.

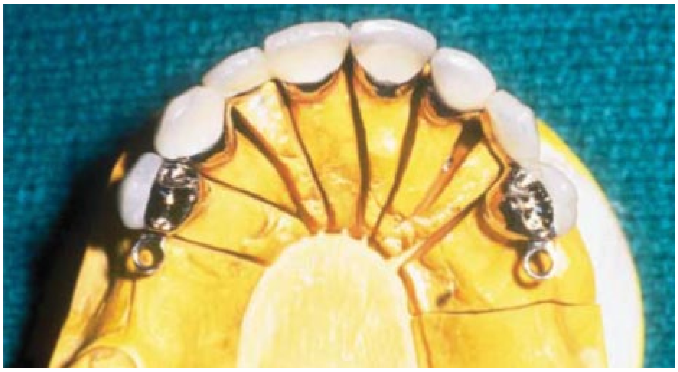

Figure 18.31 **(A)** Maxillary bilateral distal extension application of Stern ERA attachments.

Figure 18.31 **(B)** Patrix placement within an RPD framework. *Source:* Courtesy of Dr Steven K. Nelson.

Figure 18.31 **(C)** The need for parallelism with each other in the sagittal plane is not required. Note the splinting of fewer than six remaining anterior teeth.

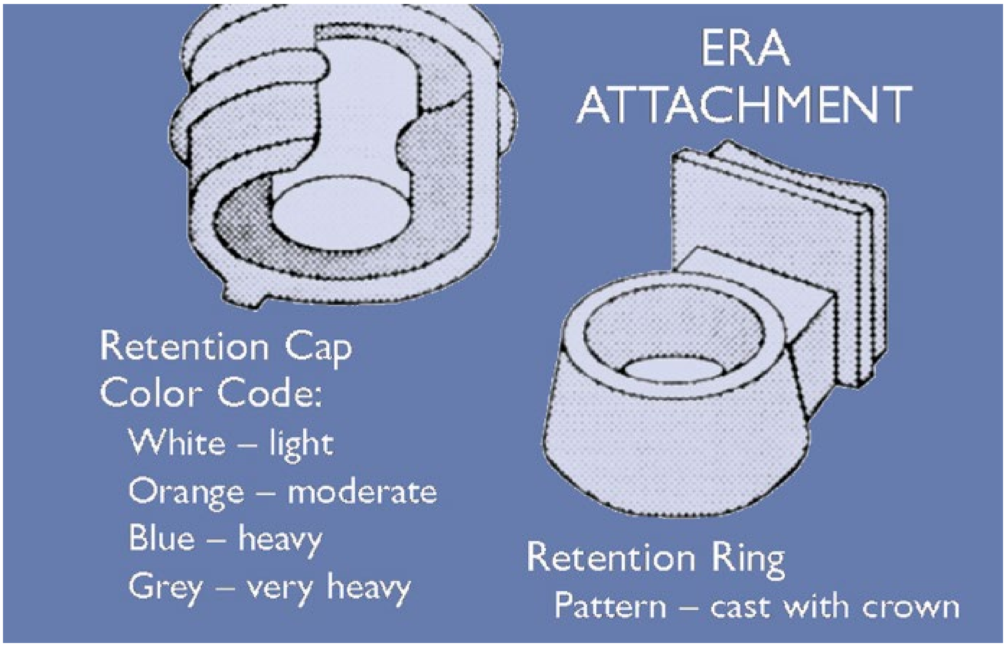

Figure 18.31 **(D)** Diagram of matrix and patrix components. The color-coded retentive cap has four different levels of retention. *Source:* Reproduced with permission from Sterngold, International.[43]

Figure 18.31 **(E)** An ERA attachment can be used with bar overdentures on implants or natural teeth.

Figure 18.31 **(F)** Color-coded retentive caps and plastic pattern cast to abutment. *Source:* Reproduced with permission from Sterngold, International.[43(p.21)] **(G)** Color-coded retentive caps. **(H)** Retentive caps incorporated into the framework design and retained with autopolymerizing acrylic resin.

Hader vertical

This extracoronal semiprecision attachment (Attachments International) is compatible with conventional clasping on the contralateral side.[43] The resilience of the attachment allows slight hinging movement, although it will load abutment teeth more strongly than other resilient attachments. This attachment requires a 4.5 mm vertical tooth height without internal preparation limitations.

Special-use attachments

Special-use attachments should be considered for limited use based on the esthetic, functional, or anatomic needs of the patient. These types of attachments augment the armamentarium of the practitioner, although they may often increase the complexity and expense. Plunger-type or pawl attachments are an excellent adjunct for esthetic anterior teeth with required function as retentive abutments.[49] Classified as an intracoronal attachment, the spring-loaded plunger allows for a full range of motion, mimicking a universal-type extracoronal design. This attachment may be used with conventional or attachment partial dentures. A reciprocal lingual arm should encompass 180° and terminate in a rest seat. Matrix components or concavities are incorporated into the natural tooth or crown dependent on the situation or attachment, whereas patrix components are luted with acrylic to the framework and not soldered. Examples of plunger attachments are the Hannes anchor, the IC attachment, and the SwissTac/Tach E-Z (Attachments International) (Figure 18.33A–C).[36,43]

Splint bar designs incorporate Hader/EDS, Dolder, CM bar and rider or Ackermann clips, ABS, CBS, or PPM bar systems.[36,43] Selection is based on the degree of resilience, anatomic limitations, or convenience. The primary indication would be the splinting of abutment teeth while providing retention for the RPD. Careful consideration for the degree of resilience and interocclusal space for tooth arrangement must be provided (Figure 18.34A–F).

Dental implant placement offers a highly predictable treatment approach for overpartial dentures. Long tooth-bounded modification spaces requiring a significant amount of tissue support for the partial denture bases can benefit from application of overdenture abutment attachments supported by endosseous dental implants. Class I and II RPD classifications may have significant improvement in retention and stability by dental implant placement in the distal region of the edentulous residual ridge. The support offered by the overdenture concept using a dental implant would dramatically reduce the tipping and leverage forces imparted to the distal abutment teeth. This treatment modality may offer support comparable to the Class III RPD.

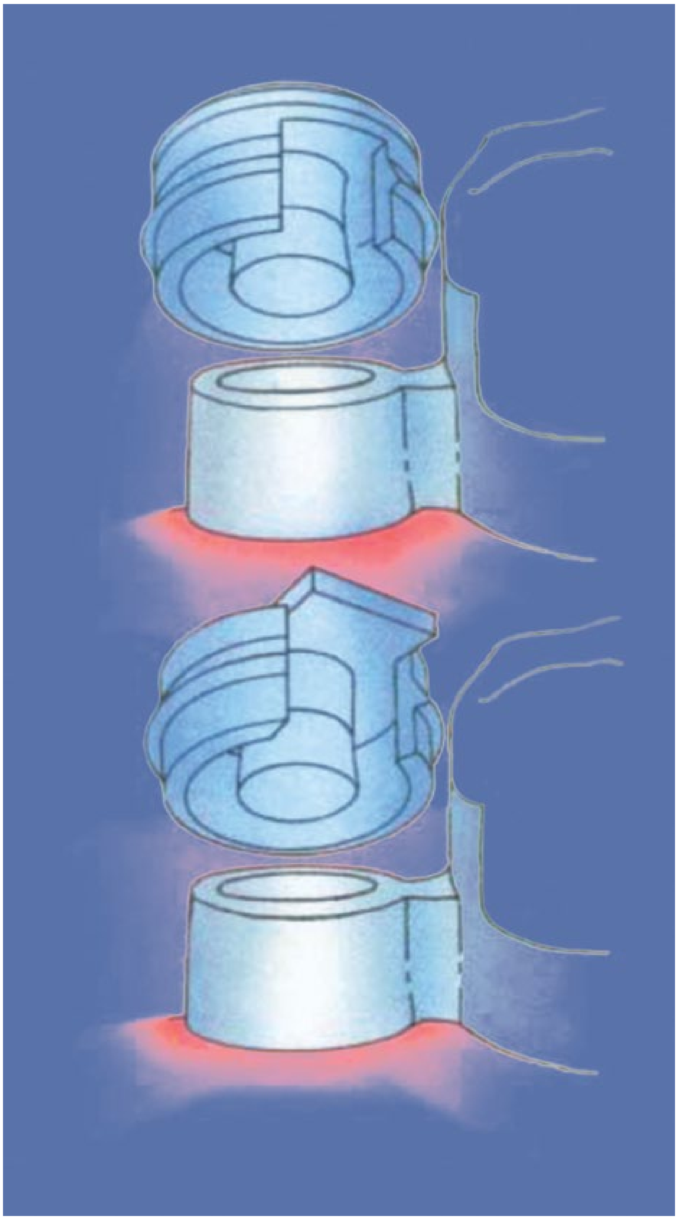

Figure 18.32 Comparison of the Stern ERA and the ERA-RV. The retentive cap varies in vertical height. *Source:* Reproduced with permission from Sterngold, International.[43]

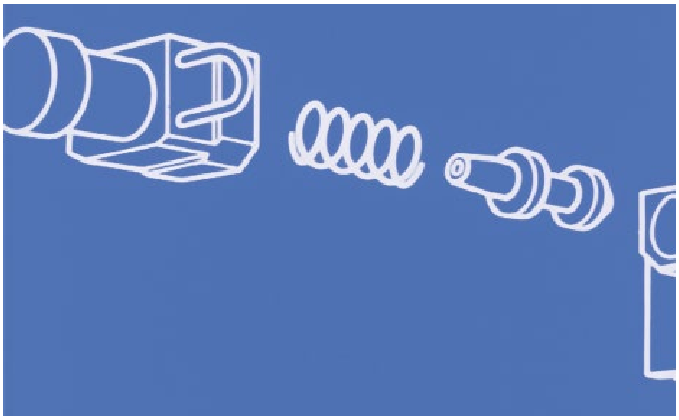

Figure 18.33 **(A)** Diagram of an IC plunger attachment.

Figure 18.33 **(B)** Matrix cast into abutment restoration.

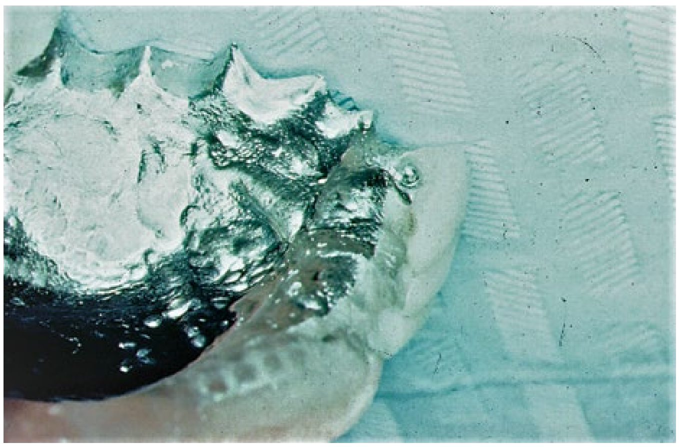

Figure 18.33 **(C)** Plunger and spring apparatus incorporated into acrylic resin or RPD.

Milled lingual ledges have been described as an adjunctive component that will accommodate placement of lingual bracing arms, generally providing compensation for short attachment length.[36,43] A technique of providing frictional retention of components through precision milling has been described. Spark erosion technology to create a precision milled fit has proved to be successful.[50] Adjunctive elastoclips may offer additional retention. The intimacy of fit developed with spark erosion or precision milling provides frictional retention, nearly eliminating any resilience. This type of attachment technology must be considered nonresilient and should be applied to the appropriate supportive elements. Additionally, the cost of this treatment approach may be prohibitive. A preprosthetic laboratory analysis of the anticipated cost may be useful in establishing the degree of remuneration required for the success of the rehabilitation.

Figure 18.34 **(A)** A 60-year-old man complained about his appearance. Examination revealed posterior occlusal collapse, extreme breakdown of his remaining teeth, and periodontal disease.

Figure 18.34 **(B, C)** Following periodontal surgery, maxillary and mandibular overdentures were constructed using Dolder bar attachments. Note the access that provides the patient with the ability for proper hygiene.

Figure 18.34 **(D)** This removable FPD provides excellent ridge adaptation plus Dolder bar secure retention for an ideal overdenture.

Figure 18.34 **(E)** The patient wanted some exposed gold and a somewhat crowded anterior tooth arrangement for what he considered a "natural look."

Figure 18.34 **(F)** A custom tooth staining and natural tooth arrangement gave the patient the appearance he thought appropriate.

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Additional resource

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Chapter 19 The Complete Denture

Walter F. Turbyfill Jr, DMD

Chapter Outline

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Dental esthetics and beauty of the smile are of prime importance in today's society. The edentulous patient is no exception, yet creating a natural-appearing smile for this patient is very difficult to obtain. The edentulous patient will no longer accept the prosaic straight line over the ridge denture esthetics of the past (Figure 19.1A). Dentists, not patients, must be educated that it does not have to be this way. The dentist has an awesome responsibility to the edentulous patient to produce a prosthetic appliance that appears so natural that it defies detection as a prosthetic replacement (Figure 19.1B).[1–3] This chapter is primarily concerned with denture esthetics; however, comfort and function must be addressed. The failure of a complete denture treatment can be traced to three areas: comfort, function, and esthetics. A denture can be functional and comfortable. However, if it is ugly in the eyes of the patient, it is a total failure. On the other hand, a denture can be esthetically superior, but if it is not functional and comfortable it is still a failure. Complete denture prosthetics has been taught in schools the very same way since the turn of the 20th century.[4] Materials are far superior (i.e., impression materials, teeth, acrylic, base tints, and precision processing equipment); however, the basic approach to satisfying the patient's needs has remained the same. Impressions are made, and bases and wax rims are constructed. The wax rims are adjusted in the mouth for tooth display, high lip line, and midline, and a jaw relation is determined. The teeth are set on the articulator by the technician or the dentist many times, with few guidelines. Then the wax-up is presented for patient approval. This is frustrating and may result in several resets to achieve patient acceptance. The denture is processed and delivered. In many cases, it is now when the patient begins to speak, eat, and observe the esthetics over a period of several days that the real problems arise. Unfortunately, many patients and dentists are far too familiar with the heart-breaking results using this unpredictable approach.

In the practice of fixed restorative dentistry, comfort, function, and patient acceptance of the esthetics are ensured prior to final prosthesis construction by first providing a provisional

Ronald E. Goldstein's Esthetics in Dentistry, Third Edition. Edited by Ronald E. Goldstein, Stephen J. Chu, Ernesto A. Lee, and Christian F.J. Stappert.

Figure 19.1 **(A)** Unesthetic denture.

Figure 19.1 **(B)** Esthetic denture. Maxillary anterior teeth are in the proper position; therefore, the entire denture is esthetic. The proper positioning of the anterior teeth guide all the teeth in the denture.

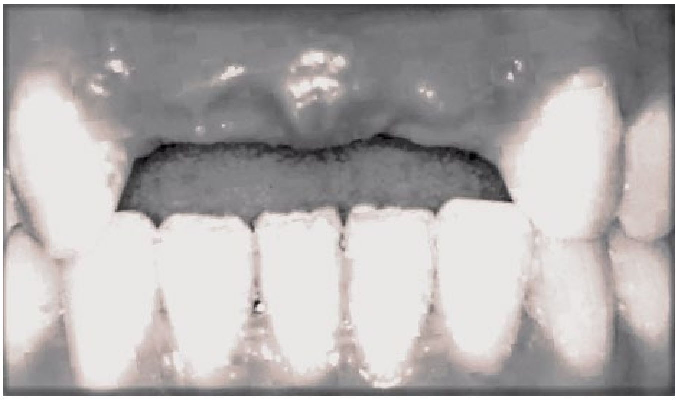

Figure 19.2 Maxillary anterior edentulous area to be treated with a fixed partial denture.

Figure 19.4 Maxillary and mandibular provisional training denture.

Figure 19.3 Provisional prosthesis placed to gain patient acceptance and to test esthetic and functional values.

Figure 19.5 Provisional training denture placed to prove all aspects of denture function, esthetics, and comfort and to gain patient acceptance.

prosthesis (Figures 19.2 and 19.3). In the modern practice of complete denture prosthetics, the edentulous patient is first provided with a provisional denture.[5–9] This provisional denture will allow the dentist to refine all of the functional esthetic aspects of the denture to their and their patient's satisfaction (Figures 19.4 and 19.5). After complete acceptance by the dentist and patient, the provisional denture is used much like a blueprint to construct the final continuance denture. This approach leads to patient happiness without the frustrating surprises of the past. This technique makes the practice of denture prosthetics very predictable. While the patient wears the treatment denture, an added benefit is the creation of functional

Figure 19.6 Mandibular functional impression is created as the patient wears the provisional denture.

Figure 19.7 Maxillary functional impression is created as the patient wears the provisional denture.

impressions (Figures 19.6 and 19.7). It is my experience that, after final delivery of the denture, few, if any, postinsertion adjustments are necessary.

Occlusion: the complete denture

No discussion of complete dentures can be complete without addressing the occlusion. Of all the causes of denture failure, the lack of a balanced occlusion in centric relation accounts for 90% of all denture failures. The most difficult challenge in denture prosthetics is occlusion. All of the denture teeth must occlude evenly as the mandible opens and closes on the arc of closure (Figure 19.8). Personal experience tells the dentist that patients with natural teeth many times function for a lifetime in a maximum intercuspal position that is not coincidental with centric relation. This is not true with the edentulous patient. These patients have lost most of the occlusal awareness, and the occlusion must be built to the repeatable position of centric relation.

This is often a difficult task because the precise jaw relation must be registered on two movable bases. In the treatment denture in Figure 19.5, the mandibular posterior teeth are replaced with a noninterfering bite block. This bite or chewing block acts as a superior repositioning splint to help the dentist obtain the optimum position of centric relation. Registering and confirming the occlusal relation position is done with various waxers and central bearing recording devices. The occlusal scheme is referred to as a lingualized occlusion that is characterized with a single maxillary lingual cusp that functions into a mandibular fossa. This occlusion seems to be very efficient and stable for the denture patient (Figures 19.9 and 19.10).

Figure 19.9 shows the posterior esthetics of lingualized occlusion with the natural maxillary facial cusp.

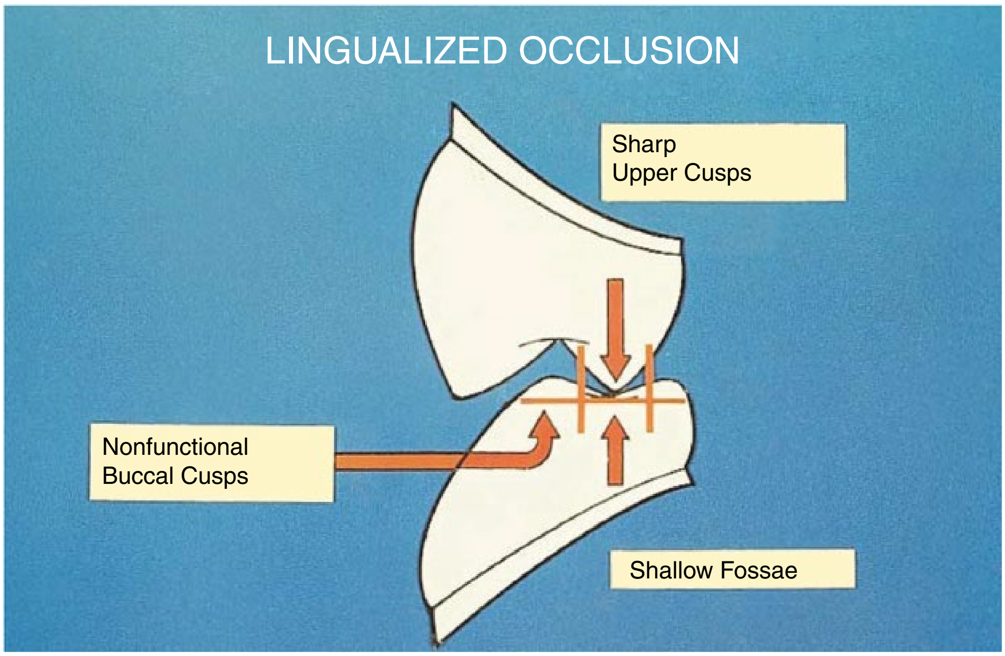

Figure 19.8 Schematic of lingual contact occlusion. Maxillary lingual cusp will function in a mandibular central fossa with no contact of the mandibular buccal cusp and the occlusal incline of the maxillary buccal cusp. *Source:* Reproduced with permission from Turbyfill.[10]

Figure 19.9 Lingualized occlusion in the completed denture.

Figure 19.10 The width of the face is measured from 1 inch behind the outer canthus of the eye. *Source:* Reproduced with permission from Turbyfill.[11]

The art of creating esthetic dentures: four esthetic harmonies

There are four esthetic harmonies that must be considered to produce a denture that will satisfy the patient's esthetic demands. These esthetic harmonies are (1) tooth size and form, (2) tooth color, (3) tooth position, and (4) background. The background is the denture base, which should be formed and colored to look like human gingiva and tinted to blend with the patient's overall complexion.

Of the four harmonies, the most important are tooth position and size. If the teeth are placed into the position that the natural teeth once occupied and in a size that is in harmony with the face, most of the esthetic requirements will have been achieved. In the consideration of tooth position and arrangement, it must be understood that everything that is done in this area has an influence on the esthetics. These considerations include the proper midline, incisal plane, posterior occlusal plane, horizontal and vertical positions of the maxillary anterior teeth, and horizontal and vertical positions of the mandibular anterior teeth.

Tooth selection

Size and form

Tooth size and form are considered simultaneously. The selection of the maxillary incisors is the starting point in creating esthetic dentures. There are many suggested ways to select teeth, including (1) preextraction records, (2) patient photographs, (3) patient desires, and (4) facial measurements.

The four methods of tooth selection are used routinely in complete denture prosthetics. There have been several theories set forth. It must be understood that none of these ways are accurate in all cases.[12–16] However, the selection is made; it is a guide or a starting place. In 1887, the temperamental theory was proposed.[17] It was one of the earliest to propose that a person's personality might influence the morphology of the teeth. In 1914, Williams[18] rejected the temperamental theory as a fallacy, proposing what is known as the geometric theory, and concluded that the shape of the face and the shape of the central incisor are related. This approach is still being used by many dentists. In 1939, House and Loop[19] expanded on Williams's works to include not only pure typal forms (square, tapered, and ovoid) but also combinations of typal forms and the discovery of the relationship of the width of the face and the width of the central incisor. In a study of 555 subjects, House and Loop found that the majority of central incisors were not only in harmony with facial outlines but they were also one-sixteenth of the size of the face. A study by LaVere et al. has confirmed their findings.[20] I still use this method as a basic starting place for tooth selection when other data are not available.

In 1955, Frush and Fisher[21] brought forth the sex, personality, and age (SPA) theory of tooth selection. By 1959, five additional articles followed describing the methods of applying the SPA factors. They concluded that tooth size is related to the width of the nose. With the use of the alameter (Productivity Training Corporation, Morgan Hill, CA), it is determined whether the patient needs a small, medium, or large central incisor. Although the esthetics achieved using the SPA method is very good, one study shows that it may not be anatomically accurate.[22]

At the annual session of the American Academy of Esthetic Dentistry in 1981 in San Francisco, an interesting study was conducted by Abrams.[22] One hundred slides of human teeth were chosen, and the audience, consisting of several hundred dentists, was asked to choose whether each slide was a male or a female (lips were blocked out so that only the teeth were visible). After the results were tabulated, it was determined that (1) gender cannot be determined by tooth morphology or arrangement and (2) the older the patient, the more the audience thought that the patient was a male purely because wear denotes vigorousness to most dentists. Nevertheless, using this approach can produce many quite esthetic and pleasing results.[23] Although none of these methods is absolutely accurate,[12–15] it must be reiterated that there must be a starting point.

Clinical tooth selection

From a clinical standpoint, measurement of the face is the first step. House and Loop have shown that the width of the central

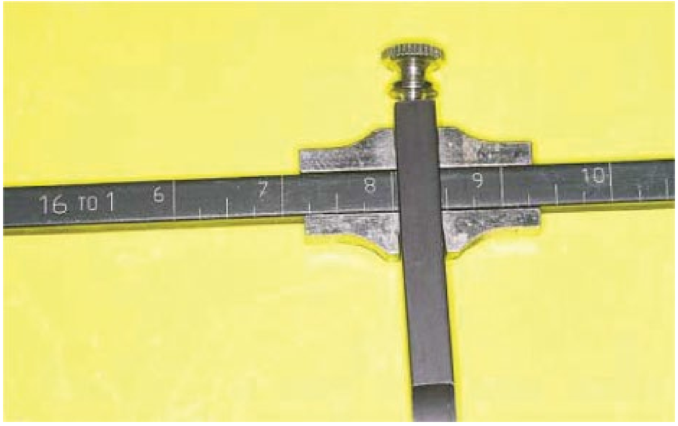

Figure 19.11 The measuring device reads the facial width in millimeters at a ratio of 1 to 16.

incisor is one-sixteenth of the width of the face as measured from 1 inch behind the outer canthus of the eye (see Figure 19.10). The length of the tooth is determined by measuring from the hairline to the lower border of the chin. If there is hair loss, then the top furor of the forehead is used. The measurement is made by using a device first described by House and Loop (Figure 19.11). The measurements have been interpolated to read in millimeters one-sixteenth of the width of the face.

Tooth form and mold

Most instruction on tooth selection suggests that tooth form be matched to the patient's facial form; that is, square, tapered, ovoid, or, in some manufacturers' teeth, combination form types. These combinations include square/tapered, square/ovoid, tapered/ovoid, and so forth. Some tooth manufacturers make only the basic square, tapered, and ovoid but do not make the combination forms. Other manufacturers make only different size teeth and no teeth designated for the different facial forms. However, these manufacturers do make molds that exhibit different amounts of incisal wear.

I rarely consider tooth mold in terms of square, tapered, or ovoid. Once the proper tooth size is selected, the mold is selected to fit the patient's maturity. Younger patients get more rounded molds with unworn tips on the cuspids. More mature patients will get teeth that show more incisal wear and cuspids where the incisal tip is worn flatter. I put tapered teeth in ovoid faces or square teeth in tapered faces and do not like ovoid teeth in most cases (see tip 2 in the "Tips on tooth selection" section).

After the upper anterior teeth are selected, the lower anterior teeth are selected as recommended by the manufacturer. For example, the 44E (DENTSPLY/Trubyte) maxillary anterior mold is opposed by mandibular mold F (DENTSPLY/Trubyte), and the Universal Lactona maxillary anterior mold M45 (Universal Lactona Dental) is opposed by mandibular mold M45 (Universal Lactona Dental). The combined width of the recommended six lower anterior teeth is generally 10 mm less than the combined width of the upper six anterior teeth (see tip 6 in the "Tips on tooth selection" section).

Tips on tooth selection

1. Facial width of one-sixteenth is determined to give the width of the central incisors. The laterals and cuspids in any mold are sized to be in harmony with this measurement. The facial length is never used because the length of the teeth is more determined by lip height and the size of the residual ridge. This maxillary central size is always in harmony with the size of the patient's face. Next, the shape or mold of the teeth must be selected. I use another method called "heart and imagination." This is hard to explain. Credit is to be given to Fillastre (Fillastre, personal communication, 1980). After the appropriate size is selected, the dentist pictures the patient in their mind's eye with the mold chart in front of them and imagines what mold would look good for the patient.
2. Facial types—square, tapered, or ovoid—have little to do with mold selection. The amount of incisal wear is a more appropriate guideline. The older the patient, the flatter the incisal edges. The younger patient will require more rounded edges that show less wear. Older patients tend to have flatter, more worn cuspids. There is basically no difference in molds for male or female.
3. Patients should be asked to bring pictures of them before they lost their natural teeth. This can show anterior tooth arrangement and situations such as diastemas. A trick to using a portrait-size picture is to measure tooth width on the photograph and also the interpupillary width on the photograph. Then the interpupillary width on the patient is measured. By using a simple mathematical proportion, the actual tooth size is determined.
4. Patients should bring pictures of people from magazines who have teeth that they think are attractive. This is done to point out that teeth are not set over the residual ridge[8] with small teeth hidden back in the mouth. Pretty teeth are prominent and support the lip. Most attractive people show all of their teeth when they smile, and many show some or all of their gingiva. This exercise allows the teeth to be placed more in the position that the natural teeth once occupied.
5. The molds are mixed. For example, the central and cuspids from one mold and the laterals from another are used. Also, the use of laterals from two different molds can create a nice effect. The patient must be educated to the fact that bilateral symmetry does not occur in nature and that this is not esthetic.
6. Manufacturers' suggestions for a mandibular anterior mold to use with a specific maxillary anterior mold are dictated by a combined upper and lower width that will allow the first bicuspids, maxillary and mandibular, to blend in harmony with the maxillary and mandibular cuspids and with the cuspids in a Class I relationship. To be esthetic, a denture must be in harmony with nature. It is good to remember that, in establishing natural denture esthetics, the teeth are to be set in harmony with original jaw relations, whether it is Class I, II, or III. In these cases, the mandibular anterior mold may have to be varied in size to produce a nice harmonic transition from the cuspids to the first bicuspids during setup.

7. In selecting posterior teeth, my preference is to use an anatomic maxillary posterior tooth (33° cuspid tooth) that occludes in a lingualized fashion into the central fossae of the lower.[8,24] The esthetics is far superior to flat plane and other lesser degree teeth. The beautiful maxillary buccal cusps look natural (see Figure 19.9). The purpose of the maxillary buccal cusp is esthetics, food manipulation, and overjet to prevent jaw biting.
8. Facial profiles can be important in denture tooth selection. For example, an individual with a flat profile might look better with a flat mold tooth, and the patient with a curved profile might look better with a more curved or rounded facial contour.
9. A choice is made between porcelain or acrylic teeth. Porcelain teeth keep their luster. They will not wear excessively, causing loss of vertical dimension, which leads to serious esthetic problems. There are times when, because of interarch space, acrylic teeth must be used. In these cases, metal occlusal surfaces should be used to prevent further loss of vertical dimension. The use of acrylic teeth does not reduce the pressure on the underlying bone. Rapid bone loss is caused by malocclusion. With plastic teeth, the malocclusion is soon worn in; with porcelain teeth, the malocclusion is there forever.
10. The newer composite resin teeth have certain advantages. Ro Youdalis (personal communication, 1985) pointed out that the hardness of these teeth will make many metal occlusal surfaces unnecessary because of their wear resistance.

Tooth color

The hues found in most natural teeth fall into the ranges of yellow, brown, and orange. The lightness and darkness of teeth are controlled by the value (degree of gray or white). Chroma (the saturation of hue) increases with advanced age, whereas the value decreases. Tooth color and gingival tissue seem to be related to tissue tones and the general overall complexion of the individual. The light-complexion, blue-eyed blond will usually display very light teeth, with little or no yellow. Contrasting this is the dark-complexion brunette and redhead whose teeth generally show more yellow, brown, and orange. As these individuals grow older, the yellow–brown of the brunette is intensified by a deeper color and lower value. As the blue-eyed blond advances in age, the greatest change is lower value. The teeth become more gray but still exhibit very little yellow–brown. There are always exceptions. It is not unusual at all to see a dark-complexion brunette with very white teeth with no yellow. There are exceptions to all of these rules.

Tips on tooth color

1. Consultation with the patient is the best way to establish rapport in the matter of tooth color.[25] No attempt should be made to convince a patient to accept any other shade than what they want.[26] All patients want nice white teeth, and the older denture patient is no exception. (A personal note on this subject is in order. In the early days, I tried to select teeth as my mentor did to be in harmony with the patient's age and complexion. It seemed that I was always at odds with patients who wanted white teeth.) Seminars are conducted during which dentures are provided for patients. Since all of the shades cannot be available during the seminars, only light shades are stocked. There is never a discussion about shades at the seminars. The fact that every patient gets young bright teeth is a key to success.
2. Every female patient is asked when looking at their old denture, "Wouldn't you like a brighter, more youthful tooth on your new denture?" The response is interesting: it is always yes.
3. Many patients love to see the artist in their dentist emerge. The dentist could try using central incisors of one shade and then change the shades of the laterals. The patient with the love of naturalness will respond.
4. Lower anteriors are one shade darker than the upper incisors.

Tooth arrangement

Once a proper tooth has been selected for the patient, the maxillary anterior teeth will be positioned on the base. The most important consideration in creating an esthetic denture is the position of the maxillary anterior teeth. This position will directly influence the position of every other tooth in the denture. Frank Lloyd Wright said, "Form and function are one." So it is with dentures: the closer the artificial teeth are placed to the position once occupied by the natural teeth, the better the function will be. Another advantage of natural tooth placement is that they will fall within the neutral zone, which is the neutral point of muscle balance between the lips and cheeks and the tongue. E. Pound (personal communication, 1975) said that, in the early days, when motion pictures became talking pictures, many actors lost their jobs because of poor dentistry and poor phonetics. He said that the sound people at the studios knew as little about speech as he did. Pound said that he strove to make dentures exquisitely esthetic and that the better they looked, the better they spoke. This is how his lifetime study of phonetics began. In the practice of complete denture prosthetics, if the dentist can position the artificial teeth in the position the natural teeth occupied, the better the esthetics and function will be.

Key to denture esthetics: proper placement of maxillary anterior teeth

The single most important thing that must be done to create an esthetic denture is proper placement of the maxillary anterior teeth. The key is the placement of the maxillary central incisors. If these two teeth are correct, they will directly influence the position of every other tooth in the denture. Correctly placed, the maxillary six incisors should be as close as possible to the exact position once occupied by the natural teeth. The notion that teeth should be set over the ridge to gain a mechanical advantage is simply outdated and untrue. If the teeth are set to anatomic harmony, then they will be in the neutral zone and vice versa.

Over the years, I have measured casts of natural maxillary anterior teeth to find a common position. A common average position of the maxillary anterior teeth to constant landmarks has been found by measuring hundreds of casts of natural healthy teeth. These measurements are (1) the distance of the incisal labial one-third of the maxillary central incisors from the center of the incisive papilla (Figure 19.12) and (2) the distance down the incisal edge from the general height of the maxillary anterior labial vestibule (Figure 19.13).

This position will not be appropriate for every patient. It will put the teeth in a reasonable position all of the time. Variations from this position require a judgment on the dentist's part. I have observed that when positioned in this manner, about 4 in 10 patients are close to ideal. The other 60% will need slight changes.

In Figure 19.14A, the patient has very unesthetic dentures. The ridges are healthy and well formed (Figure 19.14B). A stabilized base is constructed onto the cast of the maxillary edentulous ridge. A wax rim is placed onto the stabilized base. The wax rim is built 10 mm out from the center of the incisal papilla and 20 mm down from the general height of the labial vestibule. In addition, the wax rim is built level to the interpupillary line and parallel to Camper's line. Camper's line runs from the middle of the tragis of the ear to the base of the ala of the nose. The wax rim is tried into the edentulous mouth. The level of the incisal plane and Camper's line is verified. The facial midline is marked (Figure 19.14C–E).

The maxillary central incisors are set onto the wax rim (Figure 19.14 F) and confirmed in the mouth (Figure 19.14G and H). [27–29] Once the proper position of the central incisors is verified, then the remainder of the maxillary incisors is set (Figure 19.14I). At this point, the basic tooth position has been determined. Detailed esthetics, such as lapping of the lateral incisors and tipping of the cuspids, is done in the laboratory. Once the maxillary anterior basic tooth position has been verified, as a demonstration, a silicone matrix has been made onto the setup. In this case, the central incisors ended up 9 mm anterior to the center of the incisive papilla. The teeth follow the curvature of the edentulous ridge (Figure 19.14 J). If the ridge should be more square or more "V" shaped, this would be reflected in the

Figure 19.12 Average horizontal position of the maxillary central incisors is determined by measuring the distance from the center of the incisive papilla and the labial incisal one - third of the central incisors.

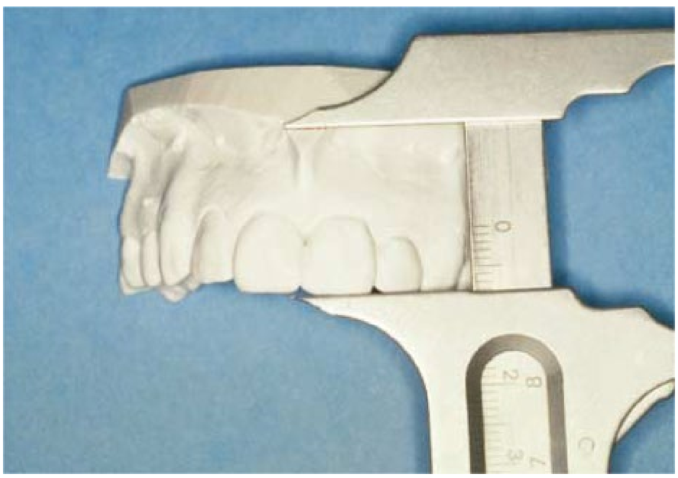

Figure 19.13 Average vertical position of the maxillary central incisors is measured from the general height of the anterior labial vestibule down to the incisal edge of the central incisors.

Figure 19.14 **(A)** A 32-year-old edentulous patient with teeth set over the ridge with a straight line setup resulting in the typical denture look.

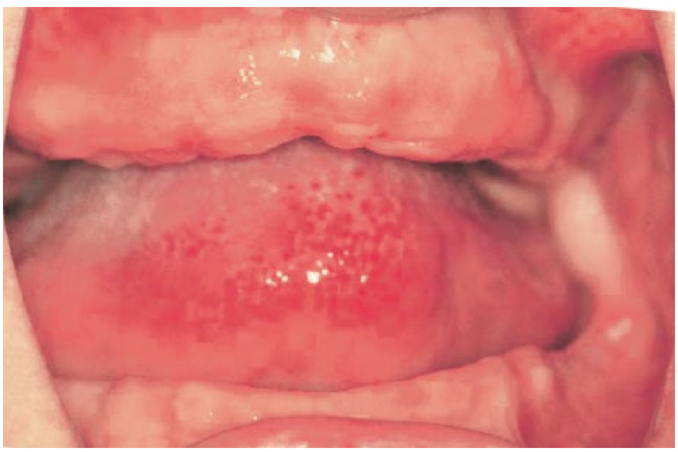

Figure 19.14 **(B)** The edentulous ridges appear adequate and healthy.

Figure 19.14 **(C)** The maxillary bite rim is built 10 mm anterior from the center of the incisive papilla horizontally and vertically 20 mm down from the general height of the labial vestibule. It is built level so that it is parallel to the interpupillary line. *Source:* Reproduced with permission from Turbyfill.[11]

Figure 19.14 **(D)** The midline is marked.

Figure 19.14 **(G)** The central incisor position is verified in the patient's mouth as to tooth display and midline.

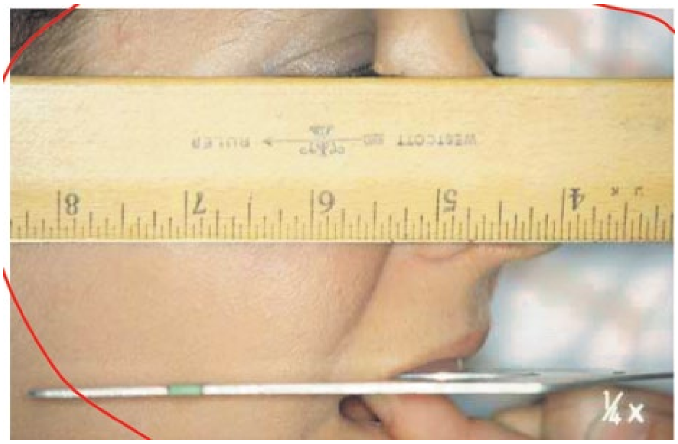

Figure 19.14 **(E)** The maxillary bite rim is built parallel to Camper's line.

Figure 19.14 **(F)** The maxillary central incisors are set to the previously determined midline and the horizontal and vertical determinants. *Source:* Reproduced with permission from Turbyfill.[11]

arrangement. The cuspid begins to be tucked closer to the ridge as the corner is turned from the anterior ridge to the posterior area of the ridge. The result is a much improved esthetics of the finished denture. Figure 19.14 K shows the superior esthetics that has been achieved using this approach.

Once the maxillary teeth are set to anatomic harmony and the dentist is satisfied with this position, the mandibular anterior teeth are set so that they exhibit 0.5–1 mm of clearance as the sibilant sounds are being enunciated (Figure 19.14 L). The vertical dimension of occlusion is recorded by arcing the mandible in the arc of closure in centric relation and closing the vertical down until the anterior stop comes into contact (Figure 19.14 M).

Figure 19.14 **(H)** The level of the central incisors is verified. *Source:* Reproduced with permission from Turbyfill.[11]

Figure 19.14 **(I)** The maxillary anterior tooth position is completed.

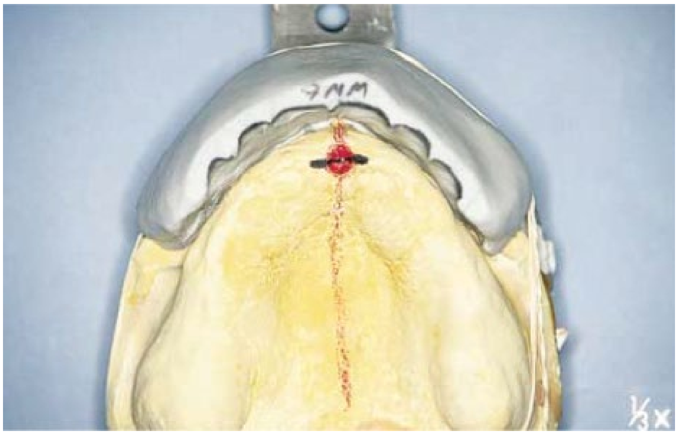

Figure 19.14 **(J)** The natural position of the maxillary teeth to the edentulous ridge.

A denture may appear to be reasonably esthetic at first glance, as is the maxillary denture shown in Figure 19.15A–C. The denture was remade because of poor function and comfort. The teeth are now set to a position more in keeping with anatomic harmony. This position is 20 mm down from the height of the maxillary vestibule and 10 mm out from the center of the incisive papilla. Figure 19.15D–F shows the subtle but exquisite improvement in esthetics and maxillary lip support.

Placement of the mandibular anterior teeth

The mandibular anterior teeth are set using phonetics. Dawson[30] noted that the vertical dimension of occlusion that has been lost can be regained by noting the closest speaking level and then establishing the vertical dimension of occlusion slightly more closed from that closest speaking position. Pound[31] referred to this as the vertical dimension of speech, and since the teeth are not to touch while a person is speaking, then the vertical dimension of occlusion should be slightly more closed than the "S" position. Further, the "S" position is the most forward, most closed position the mandible ever assumes during speech.

Two mandibular incisors are set to the "S" position. Pound defined the "S" position as the most intimate relationship of the teeth during speech.[31] There are intimate relationships that occur

Figure 19.14 **(K)** The superior esthetic results achieved by placing the maxillary anterior teeth to anatomic harmony.

Figure 19.14 **(L)** The mandibular anterior teeth are positioned to exhibit a 0.5–1 mm clearance with the maxillary anterior teeth as the patient enunciates "S" sounds.

Figure 19.14 **(M)** The mandibular position of centric relation is determined by a simple wax recording. This is considered a treatment position, and final centric relation determination is achieved by using a central bearing point and Gothic arch tracing.

between the incisal edges of the mandibular teeth and the incisal edges and lingual surfaces of the maxillary anterior teeth. This allows the dentist to verify the accuracy of the maxillary tooth arrangement and place the mandibular incisors in an anatomically natural position that produces an articulate speech pattern. After this position is verified, the anterior stop has been reestablished (see Figure 19.14 L).

Anterior denture occlusion

No anterior teeth should be in contact when the posterior teeth are in maximum occlusion. This anterior pressure will cause destruction of the bone of the premaxilla. It also causes instability of the dentures. Once the anterior teeth are set to exhibit a phonetic clearance when the "S" sounds are enunciated, the centric relation registration is then taken with the anterior stop in contact. In Class I and II jaw relationships, the mandible leaves the centric relation posture position and moves forward to the phonetic "S" position. Therefore, the articulator pins are opened slightly on Class I and II occlusions so that the anterior teeth will not contact in the centric relation. Since the mandible always moves forward in phonetics, the condylar guidance will keep the posterior teeth from contacting in speech. In Class III occlusion, there is no forward movement of the mandible during speech. Slight anterior contact in the Class III jaw relationship is inevitable. The occlusal contact should be heavier in the posterior than in the anterior.

Figure 19.15 **(A)** A denture with a poor maxillary anterior tooth position.

Vertical dimension

I use phonetics and the closest speaking position to develop the incisal edge position of the mandibular anterior teeth, and the vertical dimension of occlusion is determined from this. It must be understood that this method is not always accurate. Some patients exhibit an adapted position that is obviously overclosed. In cases like this, the vertical is opened on the trial bases until the facial profile looks more normal. In other words, the patient should not look older below the nose than above the nose. Since all patients are treated with a provisional treatment denture, this "arbitrary" vertical dimension is tested before denture finalization. Even though phonetics is not accurate in every case, it is still the preferred way because the different movements of the mandible for the different classes of occlusion help to position the incisal edges in a more natural position.

There are many ways to establish the vertical dimension of occlusion on dentures, such as phonetics, relaxation of the mandible to establish the resting level of the mandibular freeway space, having the patient wet the lips and breathe out, and measuring dots on the nose and chin and other facial dimensions. Volumes have been written about vertical dimension. The subject of vertical dimension is a very emotional one, and some heated arguments can erupt over it.

The most important thing that the dentist must remember about vertical dimension is that if the vertical is opened too far so as to cause the posterior teeth to hit as the patient speaks, a failure will always result. Another important observation is that the dentist should give each denture patient the greatest vertical dimension possible. The patient will look, chew, and feel better. Improper vertical dimension can have a profound effect on esthetics. In Figure 19.16A, the patient looks prognathic and old below the nose with a vertical dimension that is overclosed. Figure 19.16B shows excellent esthetics when the vertical dimension is properly restored. Figure 19.16C demonstrates the poor esthetics created by improper vertical and horizontal positioning of the maxillary anterior teeth and the denture look. Figure 19.16D shows the improved esthetics with proper maxillary anterior tooth positioning.

Figure 19.15 **(B)** Note the depressed position of the incisors.

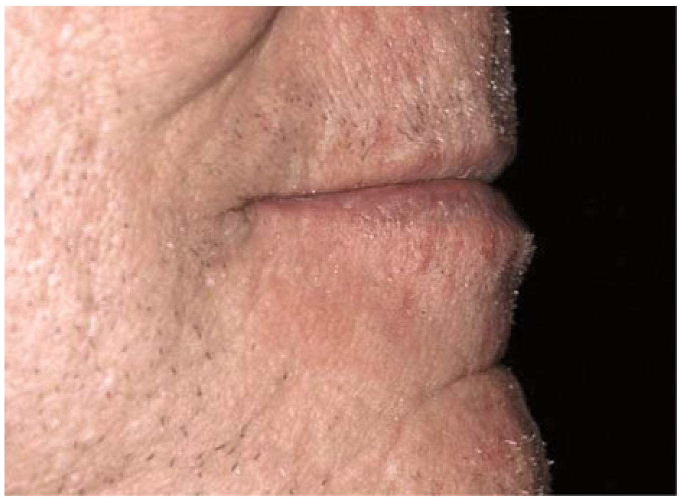

Figure 19.15 **(C)** Note the look of the maxillary lip support.

Consideration of the vertical dimension of the occlusion for the edentulous patient as it differs from the patient with natural teeth needs to be addressed. Patients with natural teeth are very adaptive to changes in the vertical dimension of the occlusion because of the exquisite proprioception of natural teeth. Many times, a slight opening of the vertical dimension is needed to facilitate restorative procedures. Edentulous patients do not adapt nearly as well. Generally, when the closest speaking position is determined, any opening from that position should be done while the patient is wearing the provisional training denture. An excessive vertical dimension of the occlusion in complete dentures results in a restriction of normal muscle activity, and the posterior and anterior teeth will hit during speech. When opened experimentally using the training denture, if the teeth continue to hit during speech for 1 week, then adaptation is not possible, and the teeth will hit during speech forever.

Figure 19.15 **(D)** An esthetic denture with the maxillary central incisors set to the 10 × 20 rule.

Posterior occlusion as it relates to denture esthetics

One area often overlooked or misunderstood is the effect of the posterior tooth position on esthetics. An extremely poor esthetic denture can result by establishing the posterior plane of

Figure 19.15 **(E)** Note the more natural tooth position.

Figure 19.15 **(F)** Note the improved lip support.

Figure 19.16 **(A)** Overclosure of the vertical dimension of the occlusion. Note the prognathic appearance and decreased lower facial length.

Figure 19.16 **(B)** Proper vertical dimension of occlusion. Note how much younger the patient appears.

Figure 19.16 **(C)** Everything looks bad: the denture look.

Figure 19.16 **(D)** The natural look: correct maxillary anterior tooth placement and correct vertical dimension of occlusion.

occlusion too high or too low. This is demonstrated by the patient who smiles, and the maxillary posterior teeth can be seen hanging down below the plane of the maxillary incisors. Camper's line will position the posterior occlusal plane on a line beamed from the maxillary anterior incisal edge posterior to the middle of the retromolar pad (Figure 19.17).

The buccolingual placement of the posterior teeth can also affect esthetics. If the maxillary teeth are placed too far to the buccal aspect, then the buccal corridor between the maxillary posterior teeth and the corner of the mouth is lost. If the maxillary teeth are placed too far lingually or palatally, then they appear not to exist. Either extreme produces unacceptable esthetics. The guideline for the maxillary posterior tooth position is found in the mandibular arch. The lingual central line is from the mesial contact of the cuspid to the lingual aspect of the retromolar pad. The lingual surface of the mandibular posterior teeth should fall on this line. The mandibular

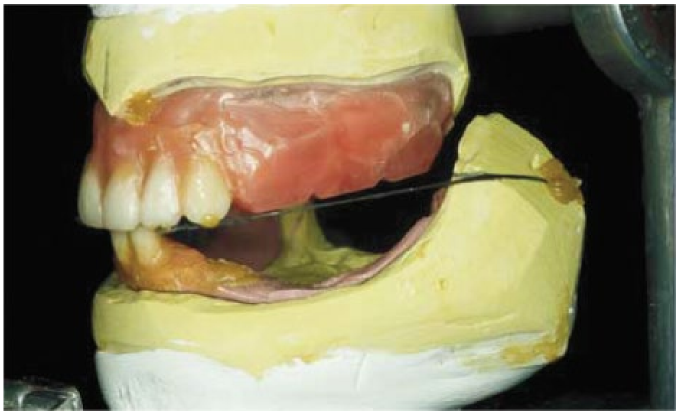

Figure 19.17 Posterior occlusal plane lines up from the maxillary incisal edges to a point halfway up the retromolar pad (Camper's line).

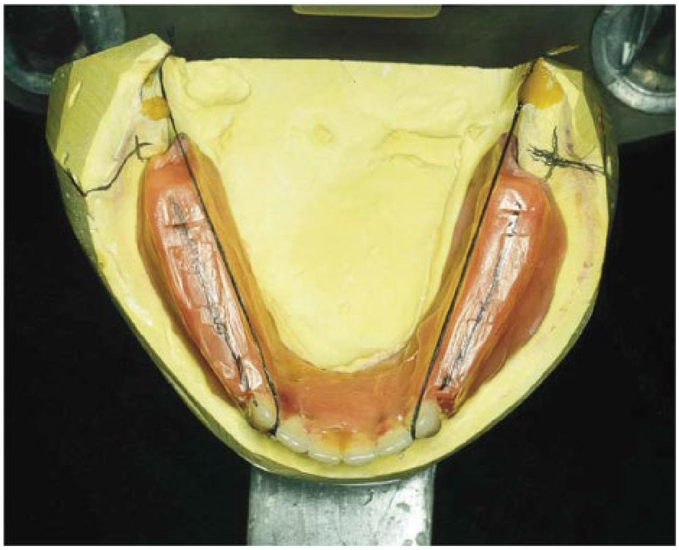

Figure 19.18 Buccolingual placement of the posterior occlusal plane. The lingual control line runs from the mesial contact of the cuspid to the lingual aspect of the retromolar pad.

posterior teeth are positioned closer to the tongue than this line (Figure 19.18).

Tips for tooth arrangement

1. The position of the maxillary central incisors is the key to denture esthetics. Once they are placed and accepted, all other tooth positions are a product of these two teeth.
2. Placement of the anterior teeth must be done at chairside in the presence of the patient. The author never lets the patient see the results of this initial placement because the setting is a very straight-line prosaic setup and represents basic tooth position. Detailed esthetics is done at the laboratory bench.
3. The appointment for this initial setting is from 1 to 1.5 h. The rapport that is built with the patient at this time is unbelievable. The patient will always say, "I've never had a dentist spend so much time with me."

4. The "S" position is the most intimate relationship of any teeth during speech.[32,33] As the "S" sounds are formed, the anterior teeth will exhibit a space of 1–1.5 mm. The "S" sounds are produced by forcing air between the incisal edges of the maxillary incisors and the mandibular incisors. The "S" sounds can also be produced by forcing air between the incisal edges of the mandibular incisors and the lingual surfaces of the maxillary incisors, as will be found in many Class II occlusal relationships. It should be remembered that the teeth do not touch when the "S" sounds are being enunciated.
5. The vertical dimension of occlusion is very easy to determine since it is always less than the vertical dimension of speech.[34–36] Therefore, when the anterior teeth are set to the "S" position, the mandible is retruded and closed down 2 mm to tooth contact or, if no teeth touch, merely closes in a centric relation 2 mm less than the vertical dimension of speech.
6. The "F" and "V" sounds are produced when the incisal edges of all six maxillary anterior teeth make a fleeting seal at the vermilion border or the wet–dry line of the lower lip. If the maxillary teeth are placed in anatomic harmony, the "F" and "V" position will always be correct. This is an extremely valuable check on the accuracy of the maxillary anterior tooth placement.
7. The anterior teeth, both maxillary and mandibular, should appear as if they are coming from the bone at a slightly different angle. Sharry[37] wrote, "There is one prominent guide for providing an excellent arrangement of anterior teeth; they must be separate." Bilateral symmetry is not found in nature. The laterals can be mesially lapped or winged out distally. Laterals can be set to be shorter than the centrals or cuspids; however, the older the patient is, the more even the incisal edges should be. If photographs are available and show diastemas, they can be placed subject to patient approval. It should be remembered that the younger the patient is, the more open the incisal embrasures.
8. Always keep the incisal plane level and slightly curved to follow the smile line of the lower lip. There is nothing more unesthetic than a slanted occlusal or incisal plane.
9. In a few patients, flaring of the cuspid can be esthetic, but in most cases it is best to set the cuspid so that only the mesial surface can be seen.
10. It should be remembered that the first introduction of dental esthetics to dental students and dental technology students was a Columbia Dentiform.
11. Pictures of "pretty" people should be used to show how beautiful smiles are made in nature. Dentists should point out the asymmetry and how prominent the teeth appear in a full smile.
12. Some interesting studies have been done concerning the arrangement of teeth for the edentulous patient by the use of cephalometric radiographs.[38] Orthodontists use the method of fixed bony landmarks to determine the ideal placement of natural teeth. It seems that this would be a valuable aid for tooth placement in complete denture prosthetics, particularly in the advanced resorbed dental arch.
13. I use "heart and imagination" in selecting and arranging teeth. In the laboratory, there should be a large selection of teeth, and as the dentist looks at the basic tooth position set at chairside, they must picture the patient in their mind's eye and set and select teeth to what they feel will be pleasing.

Denture base

The denture base is important in esthetics.[39,40] Its normal contour aids in support of the soft tissues of the lips and face. If the patient has a short upper lip and would normally show gingival tissues in a broad smile, an unesthetic denture base can destroy an otherwise esthetically successful denture. An anatomically accurate denture base is important to function, since "form and function are one." The food tables that we find facially at the tooth neck in normal healthy tissue help the buccinator muscles keep food out of the vestibule and up onto the occlusal surfaces. The form of the lingual surfaces is important, in that it imparts a feeling of naturalness to the tongue. It is also paramount that the neutral zone of the tongue not be violated by an overcontoured mandibular lingual flange. The denture base that copies nature is also self-cleaning. The interdental papilla is full and rounded, and there are no "festoons." They only create food traps and prevent a sweeping of the tongue from its cleaning action. Tinting of the denture base is important in several respects (Figure 19.19). A natural-looking base is desirable on the facial aspect and on the palatal as well. Nothing gives away a denture faster than an individual laughing with head held back as the slick mono color of the palate is viewed by others (Figure 19.20).

Tips on creating a natural-looking denture base

1. Casts of human tissue should be studied, noting stippling, gingival collars, and the interdental papilla. There should be no slick, flat, and shiny surfaces in human gingival tissues.

Figure 19.19 Denture base carved and tinted to appear natural. *Source:* Reproduced with permission from Turbyfill.[10]

2. Whatever is wanted in the finished base should be carved in wax. No carving with rotary acrylic finishers can be done after it is processed (Figures 19.21, 19.22, and 19.23).
3. The denture should be invested with the same degree of care as was used in investing an inlay (Figure 19.24).
4. A denture base tinting acrylic (Kay-See Dental Manufacturing, Kansas City, MO) should be used (Figure 19.25).
5. Tints should be placed in eye dropper bottles with the glass droppers turned upside down to control the placement of the tints.

Figure 19.20 Correct anatomy of the palate with singulum carved on anterior teeth and lingual surfaces carved on the posterior teeth. The palate is also tinted.

Figure 19.21 Anatomic wax-up.

Figure 19.22 Anatomic wax-up.

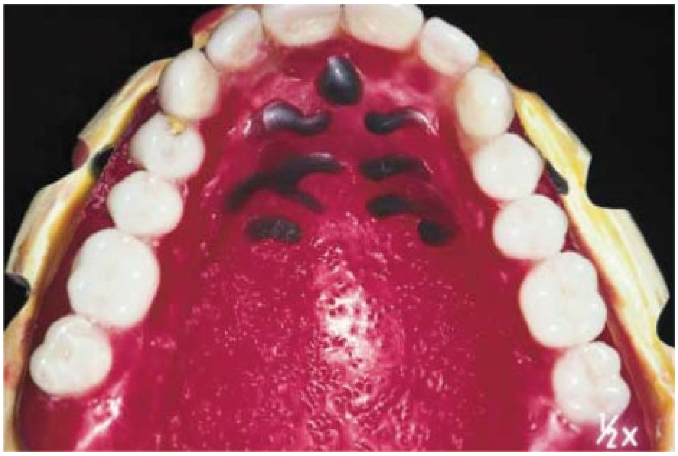

Figure 19.23 Anatomic wax-up. Note that the palate is lightly stippled so as not to appear shiny.

Figure 19.24 Investment is poured using a sable brush to capture the full anatomic wax-up.

Figure 19.25 Shades of tints available for the wax-up. There is no carving of the base with rotary instruments.

6. The tints are sifted into the boiled out flasks and then are wet with monomer as the technician goes around the arch three or four teeth at a time (Figures 19.26, 19.27, and 19.28).
7. Cases are tinted in four basic shades: (1) light-complexion blue-eyed blonds, (2) medium-complexion brunettes, (3) dark-complexion brunettes, and (4) nonwhites.

Figure 19.26 Tints are sifted around teeth.

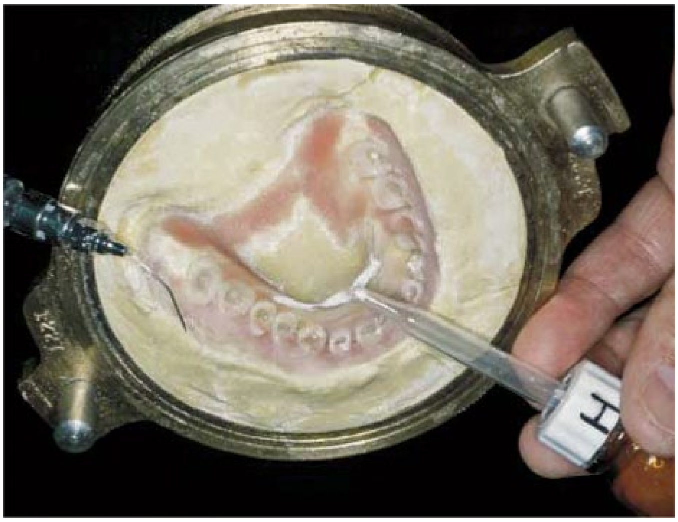

Figure 19.27 The palate is tinted.

Figure 19.28 The maxillary case tinted. Dentures are then processed with acrylic of a color to complement the overall complexion of the patient.

Clinical examples of esthetic dentures

Figure 19.29A–F presents examples of esthetic dentures.

Bone quantity and quality dictate every procedure

Dentistry is the art and science of keeping people dentally healthy. This involves keeping patients comfortable, esthetic, and functional. This is a daunting task. In earlier times, when life expectancy was maybe 65–70 years of age, most patients could be somewhat comfortable and functional without too much trouble. We are now seeing patients who live often 90 years and older. Keeping patients comfortable, functional, and esthetic may not be possible. Patients who have good dental genes and who are resistant to dental disease are very fortunate. The increasing age of patients makes the art and science of removable prosthodontics more important than ever before. As I have observed over the years, there is less and less time and effort spent with dental students on this subject. Teaching partial and full denture prosthodontics for over 40 years has led me to the conclusion that the skills in removable prosthodontics are totally lost.

Figure 19.29 **(A)** Full-smile view of esthetic dentures.

Figure 19.29 **(B)** Close-up of esthetic dentures. *Source:* Reproduced with permission from Turbyfill.[41]

Figure 19.29 **(C)** Full-smile view of esthetic dentures.

Figure 19.29 **(D)** Close-up of esthetic dentures.

Figure 19.29 **(E)** Full-smile view of esthetic dentures.

Figure 19.29 **(F)** Close-up of esthetic dentures.

Everything in dentistry depends on bone. Bone quantity and quality dictates everything that a dentist does. When there is no bone, then the only option is removable prosthodontics. With no bone, the endodontist, periodontist, orthodontist, fixed restorative dentist, and implant surgeon are out of work. No bone makes the treatment provided by the removable prosthodontist far less than satisfactory. There are now predictable methods to grow bone through grafting procedures, but so many patients have systemic health problems and financial limitations that the long process makes this option available to very few.

Porcelain versus plastic

The way removable prosthetics are constructed has an effect on preservation of bone. If you believe or have been taught that porcelain denture teeth destroy the bone, that is incorrect and there are no peer-reviewed studies to support that. American tooth manufactories have all but stopped making porcelain denture teeth. Technicians dislike using porcelain teeth because it is difficult, and broken sets of porcelain teeth are not returnable for credit. The widespread use of plastic teeth in my opinion is one of the shames of modern prosthodontics.

For example, this is a typical clinical scenario that proves my point. A patient loses all of the maxillary teeth and requires a maxillary complete denture. Now that patient may be a candidate for implants, but any thinking dentist will provide a conventional denture for that patient to establish acceptable esthetics, vertical dimension, and make sure that the patient has no serious problems accepting a prosthesis. Anytime there is a maxillary complete denture, the occlusion is a denture occlusion. It makes no difference what is in the mandible; if the maxillary is a complete denture, it must be a denture occlusion, which is as follows. To review, the definition of denture occlusion is *no anterior contact of the maxillary anterior teeth in centric closure, chewing, or speaking*.

The dentist makes a maxillary denture with all plastic teeth against a full complement of mandibular natural teeth. If the denture is properly made with good occlusal contact, the patient can chew very well. So with function, the posterior teeth will wear four times faster than the anterior teeth, and with the possibility of continuous eruption of the mandibular anterior teeth, it will not take long before the anterior teeth are bumping like crazy. Now the Kelly triad does its nasty work and the maxillary and premaxillary bones are destroyed, leaving only the nasal spine. The maxillary anterior teeth disappear under the upper lip, and because of a fibrous down growth of the posterior tuberosity, the posterior teeth seem to drop down.

Properly used porcelain denture teeth will preserve the bone. I have been using porcelain denture teeth for 40 years, and my experience is that the bone is preserved. The widespread use of plastic denture teeth in my opinion is one of the downfalls of removable prosthodontics as it is taught and handed down in dentistry over the years. The companies that make denture teeth are halting their manufacturing and sales of porcelain denture teeth. They claim that porcelain denture teeth can be "special ordered," but I am still awaiting delivery of my last "special order." The denture in the patient in Figure 19.30A–D has been in function for 28 years with no relines. Notice that the ridges look healthy, with no apparent bone destruction.

For a denture to function for this many years with no bone destruction, the envelope of anterior function should be in total freedom. This means that the anterior teeth do not hit during chewing, closing into maximum intercuspation, and there is no contact during speech. The only time that the anterior teeth will function is in straight protrusion, and then if a patient learns to control the back of the dentures with the tongue as they incise on the front teeth.

Another interesting observation is that the only border movement of concern is straight protrusion. Lateral check bites and so-called group working and group balance are not only impossible but also a waste of time (Figure 19.31A).

What destroys the bone is the unstable occlusal stops. The plastic teeth are not stable stops. If these two patients had worn their dentures for the years that they have, the plastic posterior teeth would have worn faster than the anterior teeth, and the anterior teeth on both of these patients would have been pounding on the anterior bone for many years, making them dental cripples.

Closing on cotton rolls takes out of the equation the possibility of a deflective interference being felt as a pressure area (Figure 19.31B). The second photo was taken 32 years later. The patient is still wearing the same denture with no relines or adjustment (Figure 19.31C). The centric stops of the sharp maxillary lingual cusps into the mandibular central fossa are a bit larger. There has been some wear of the porcelain teeth (Figure 19.31D). The porcelain teeth have done their job and kept the anterior envelope of function totally free (Figure 19.31E). The patient admits that her love for red wine and cigarettes is responsible for the staining (Figure 19.31D and E). The ridges are as healthy as can be—if there has been bone destruction, it is minimal (Figure 19.31 F and G).

Figure 19.30 **(A)** Denture has served patient for 28 years.

Figure 19.30 **(B)** Stable occlusal contacts.

Figure 19.30 **(C)** Anterior occlusal relation maintained by porcelain teeth.

Figure 19.30 **(D)** Healthy ridges—no noticeable differences in 28 years.

Figure 19.31 **(A)** New denture delivered—biting on cotton rolls to determine comfort.

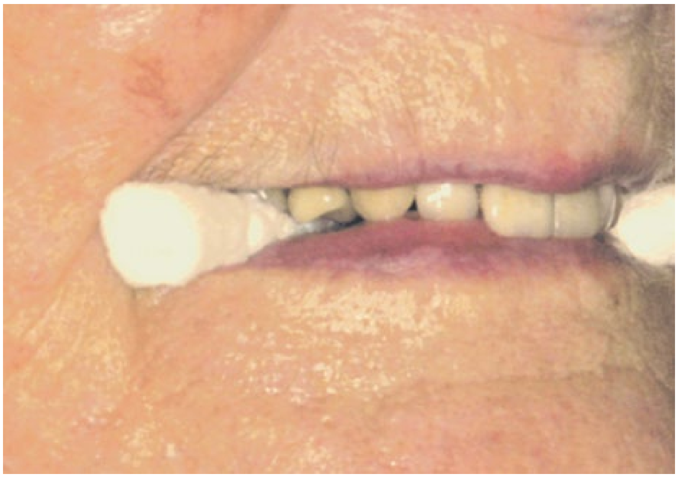

Figure 19.31 **(B)** Same denture 32 years later.

Figure 19.31 **(C)** Stable occlusion.

Dentures that oppose natural teeth

One of my patients told me, "I was told by my dentist that if I continue to wear an upper denture that if later on I decide to upgrade my dentistry with dental implants that there would be no bone." I looked at his denture and told him if he keeps wearing that denture then what he was told would be absolutely true (Figure 19.32A–F). This patient was treated 40 years ago and has been wearing an upper complete denture and a lower distal extension partial. The denture has all porcelain teeth. The lower partial could have had porcelain teeth but there was not enough room, so custom metal occlusals were placed on the lower partial. The defect on the left maxilla was due to a traumatic accident that evulsed the left cuspid and bone. This is the second denture and partial done in those 40 years. The case shows a distal extension

Figure 19.31 **(D, E)** Red wine and cigarette staining.

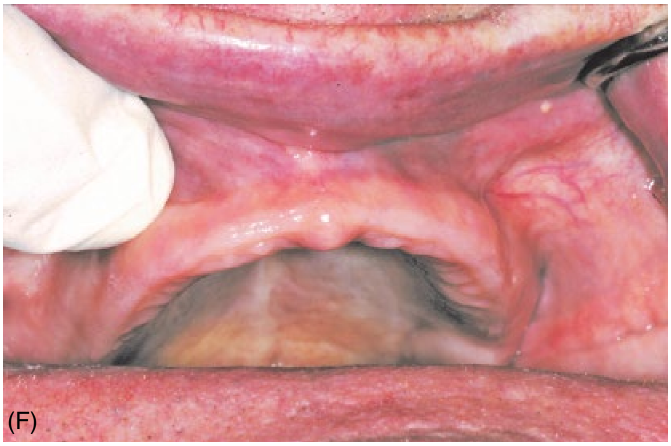

Figure 19.31 **(F, G)** The ridges are healthy.

Figure 19.32 **(A)** Maxillary denture—mandibular anterior natural teeth and a free-end partial denture.

Figure 19.32 **(C)** Lingualized occlusion in posterior segment. Note: mandibular plastic teeth had to be used because of little space.

Figure 19.32 **(B)** Maxillary denture with all porcelain teeth.

mandibular partial that occludes with a maxillary complete denture.

The photos in Figure 19.33A–E are from patients who have a full complement of mandibular teeth that occlude with a maxillary full denture. To preserve the bone of the maxilla, it is necessary to provide an occlusal design to maintain the denture occlusion. This will prevent the combination syndrome from destroying the maxillary bone.

Implants and complete dentures

All patients who present for full denture prosthesis should be given the opportunity to know the possibility of dental implants. After the patient has been successfully treated with the diagnostic or provisional denture, they must be given the choice of conventional dentures or implants. At this point, we know the patient. Placing implants prolongs the treatment process. If the patient has been difficult and unreasonable in accepting any treatment, the dentist can advise away from implants or inform of the limitations. The patient in Figure 19.34A–D had no problems and was entirely satisfied with the treatment denture that

Figure 19.32 **(D)** Stable posterior contacts in centric.

Figure 19.32 **(E)** With no space for porcelain teeth on partial, custom metal stops are used.

Figure 19.32 **(F)** Note healthy maxillary ridge—no bone loss in 40 years of maxillary denture.

Figure 19.33 **(B)** Anterior denture occlusion.

Figure 19.33 **(A)** Maxillary denture—mandibular natural teeth.

Figure 19.33 **(C)** Porcelain denture teeth cannot be used against natural teeth—custom metal occlusion.

she almost decided against the implants. Clear duplicates are made of the treatment dentures and can be used as surgical guides. We have found that the functional impression material that lines the dentures shows up on a computed tomography scan the same as hard acrylic. There is no need to make clear duplicates (Figure 19.34E–H). The implants have been placed using the clear duplicates of the patient-approved treatment dentures (Figure 19.34I–N).

Figure 19.33 **(D)** Nightguard splint to prevent mandibular natural teeth from super eruption.

Figure 19.33 **(E)** Nightguard in patient's mouth—also in denture occlusion.

Figure 19.34 **(A)** Implant-assisted complete denture.

Figure 19.34 **(B)** Patient has worn the trial dentures for several months to gain approval. Clear duplicates will be constructed to use as surgical guides.

Figure 19.34 **(C)** Maxillary denture surgical guide.

Figure 19.34 **(D)** Mandibular denture surgical guide. Gutta percha markers placed to show ideal implant position.

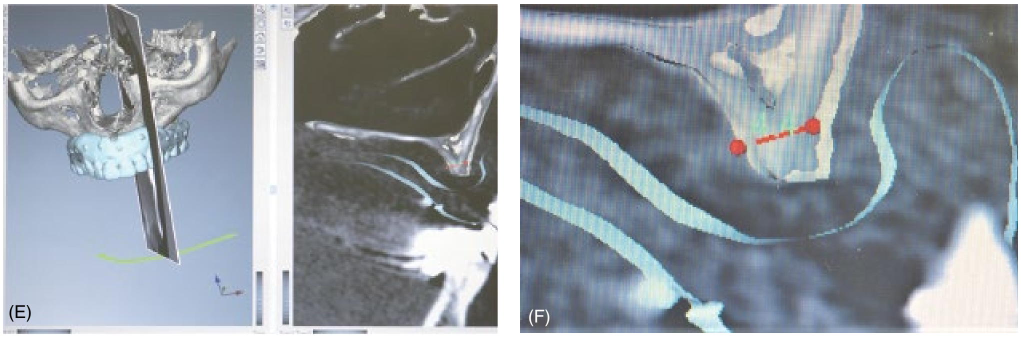

Figure 19.34 **(E, F)** The trial denture that has been approved by the patient can be used to scan. The functional impression material shows on the scan like hard acrylic.

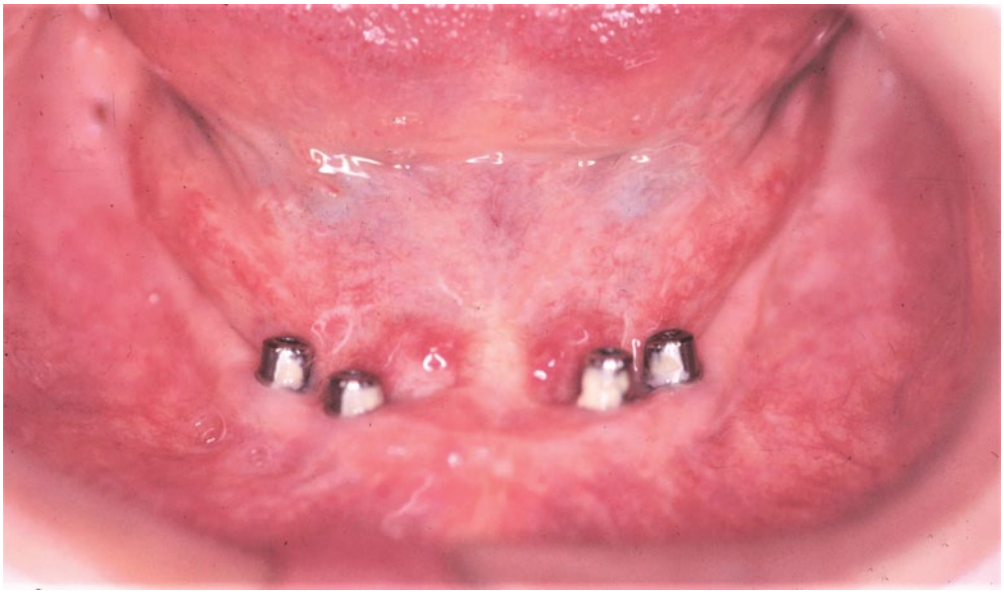

Figure 19.34 **(G)** Mandibular healing cap.

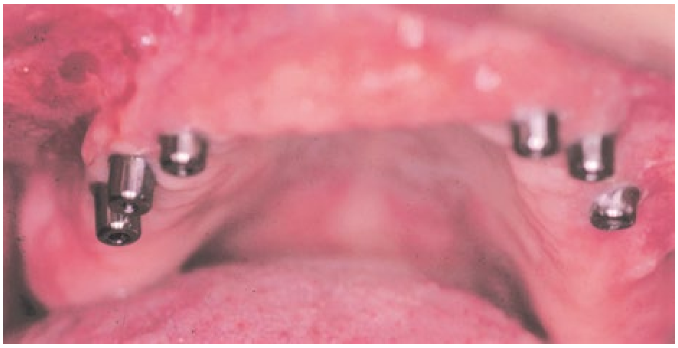

Figure 19.34 **(H)** Maxillary healing cap.

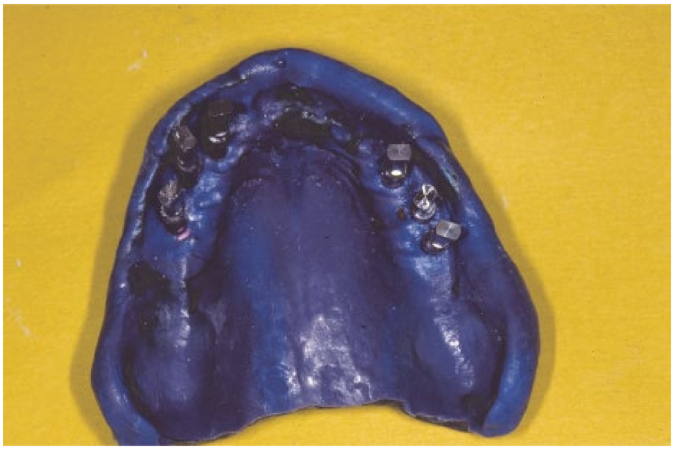

Figure 19.34 **(I)** The clear duplicates that were used as surgical guides are now used like custom impression trays.

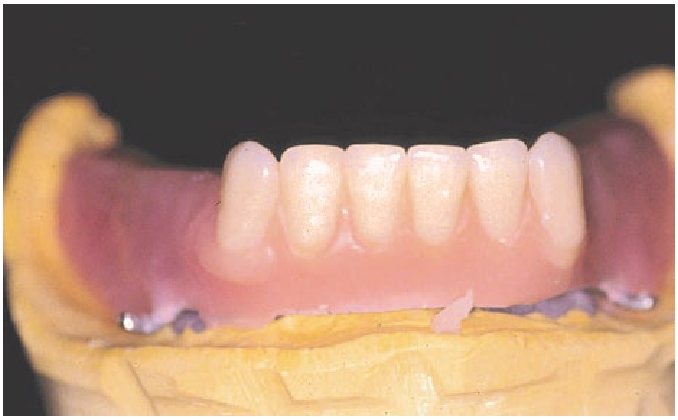

Figure 19.34 **(J)** Mandibular anterior teeth set to partial frame that fits implant bar.

Figure 19.34 **(K)** Maxillary anterior teeth set to partial frame that fits implant bar.

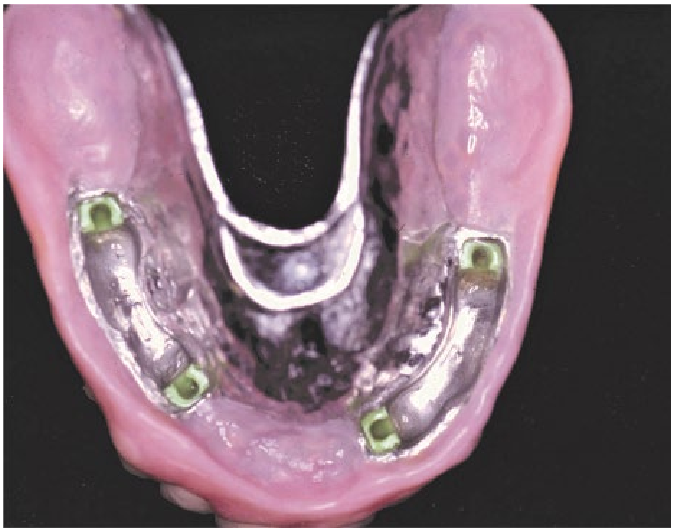

Figure 19.34 **(L)** Maxillary overdenture showing fit to implant bar.

Figure 19.34 **(M)** Mandibular implant-assisted overdenture. Note the separate fit of the free-end saddle.

Figure 19.34 **(N)** Completed case.

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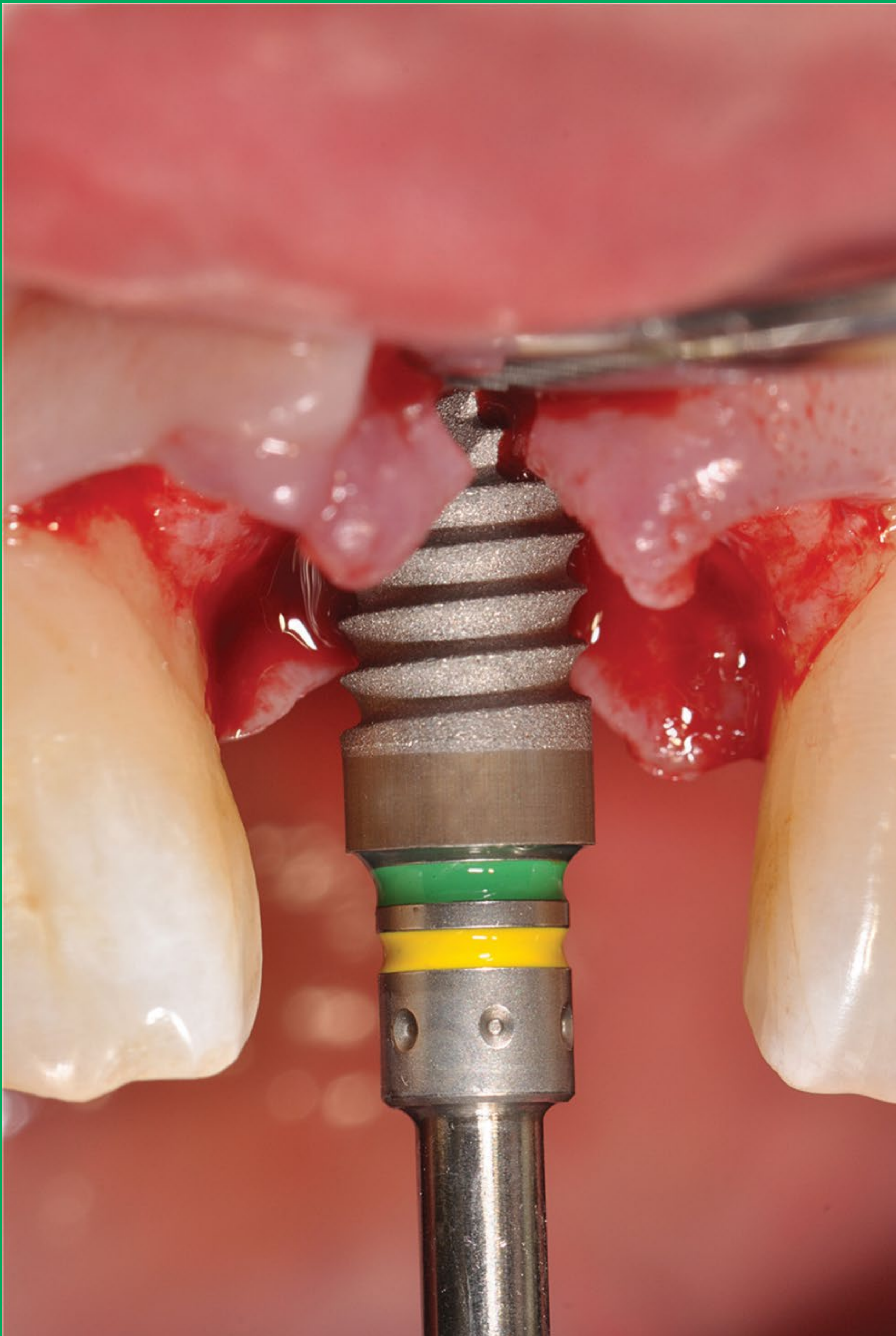

Chapter 20 Implant Esthetics: Concepts, Surgical Procedures, and Materials

Sonia Leziy, DDS and Brahm Miller, DDS, MSc

Chapter Outline

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Implant-based therapy has dramatically impacted the way we can treat our patients, with a broad range of applications including the use of implants to restore single and small edentulous spans, as well as the fully edentulous patient. Implant treatment outcomes are commonly viewed in terms of implant survival and success rates.[1–6] This chapter will focus on the many criteria that must be considered for successful treatment outcomes in the esthetic zone.

Many tissue-related outcomes must be considered, including gingival tissue color/contour/texture, tissue level, and symmetry with adjacent and contralateral teeth, completeness of papilla fill, along with restoration form, color, and material characteristics as they relate to the natural dentition. Creating a harmonious transition between teeth and implant-supported restorations can be difficult and at times impossible to achieve. The measureable elements of the implant treatment process are emphasized and

Ronald E. Goldstein's Esthetics in Dentistry, Third Edition. Edited by Ronald E. Goldstein, Stephen J. Chu, Ernesto A. Lee, and Christian F.J. Stappert.

reported in the literature today, and yet, despite this, esthetically pleasing outcomes can still elude the clinician, sometimes due to treatment planning errors, at times the result of clinical errors, but often linked to biologic constraints that are not predictably correctable.

The experienced clinician or implant team will often develop a treatment plan based on experience and education, drawing on various materials and technology to achieve the desired outcome. For the less experienced clinician, the many factors that should be considered in an implant treatment plan in an esthetically sensitive area can be daunting due to a lack of awareness of the biologic variables related to ridge and soft-tissue form and quality, and implant and restorative material selection.

This chapter will highlight concepts and procedures important to achieving a desirable outcome, complications that can occur, prevention and management of these complications, and references for further study.

Smile line and lip dynamics

The lip can be considered friend or foe in any oral rehabilitation program, and it is generally accepted that the clinician must assess and document the lips at rest, and the lips in the posed or "forced" smile.[6] This is especially important in implant dentistry, where treatment planning and treatment errors can significantly impact soft-tissue level and form.[7]

It is obvious that a low lip line with little tooth and no gingival display can be very forgiving, as subtle or gross tissue-level problems are masked or not apparent during normal activities or expressions (Figure 20.1A–D). However, even the low lip line produces a challenge when a patient evaluates the treatment outcome with a mirror placed close to the face while lifting the lip with a finger to appraise the result of the treatment.

Ridge form and how ridge architecture impacts implant placement

Peri-implant bone volume and anatomy act as the foundation for the overlying soft-tissue form. With this in mind, it is important to understand that it is common for ridge resorption to develop following tooth extraction, which manifests as soft-tissue changes.[8] There is a high probability for horizontal bone loss after extraction, with the majority of this change occurring in the first 3 months, followed by gradual reduction in ridge volume thereafter. Figure 20.2A–C shows typical horizontal bone change as a result of tooth loss.[9–11]

Recent systematic reviews provide clear statements as to the ridge changes that occur in the 6 months after tooth extraction, as well as indications and contraindications for ridge preservation, and these are summarized in Table 20.1.[8,12,13]

Contributing factors to changes in ridge form and volume include bone loss or damage due to extraction complications or

Figure 20.1 **(A)** Low lip line: no gingival display.

Figure 20.1 **(B)** Medium lip line: minor display of papilla and free gingival margins.

Figure 20.1 **(C)** High lip line: significant gingival display.

Figure 20.1 **(D)** Asymmetric lip with varying levels of gingival display.

Figure 20.2 **(A)** Moderate facial ridge resorption (>3 mm) due to tooth extraction without ridge preservation. **(B)** Mild papilla blunting due to tooth loss and no ridge preservation. **(C)** Significant papilla blunting due to adjacent tooth loss and associated ridge remodeling.

Table 20.1 Ridge Changes and Indications and Contraindications for Ridge Preservation after Tooth Extraction[8,12,13]

Mean ridge resorption
Mean horizontal reduction in ridge width: 3.8 mm
Mean vertical reduction in ridge height: 1.24 mm
Rationale for ridge preservation procedures
Maintain existing soft-/hard-tissue envelope
Maintain stable ridge volume for optimized function and esthetic outcomes
Simplify treatment procedures subsequent to ridge preservation
Contraindications for ridge preservation procedures
General contraindications for oral surgery interventions
Patients taking bisphosphonates (controversial)
Local infections that cannot be eliminated or adequately treated
Radiation treatment history in the area of treatment

poor technique, poor vascularization of facial cortical bone due to thin buccal bone (commonly <1 mm in the anterior maxilla) (Figure 20.3A and B), as well as due to the impact of loss of the periodontal ligament and its blood supply, and loss of the periosteal blood supply in the case of flap elevation.[14,15]

In efforts to reduce ridge remodeling associated with extraction procedures, a number of conservative extraction approaches can be considered. Among these are new extraction tools, including vertical root extraction devices that eliminate luxation motion, periotomes, or piezotomes to effectively separate the root from the socket wall. Although there are controversial reports in the dental literature, minimizing flap elevation is often considered important to minimize disruption of the blood supply between periosteum and underlying bone. Coupled with this, it has become routine to consider ridge preservation procedures where bone or bone substitutes are placed in the extraction socket, coupled with membranes to confine a graft material in the case of dehisced, fenestrated, or damaged socket walls.[16,17] At this time, there is no clear consensus as to the most desirable product or product combination for the purpose of ridge preservation. For most clinicians, the decision on the type of product that is used is often based on experience, exposure to techniques and materials from lectures or media, and colleagues or opinion leaders. Figure 20.4A–H shows a typical procedure using a mineralized bone allograft and a resorbable membrane to correct a facial fenestration of the bone. It is important to remember that although ridge preservation procedures can reduce postextraction dimensional changes, they rarely completely prevent resorption.

Edentulous sites that have undergone remodeling often require buccal ridge augmentation to support long-term crestal bone stability and to satisfy esthetic treatment demands. The importance of adequate bone thickness to support facial and, to some degree, interproximal soft tissue was discussed by Grunder et al.;[18] a minimum of 2 mm bone thickness in all dimensions is recommended, but greater facial volumes are perhaps beneficial. To achieve this volume of bone mandates optimal implant position from a facial–lingual perspective; careful planning as to an appropriate implant diameter (bigger is not always better); and bone grafting, ridge splitting, or expansion procedures to enhance ridge volume. In Figure 20.5A, facial bone volume is ideal as viewed at the time of implant placement. This contrasts to commonly observed thin facial bone that may present with a dehiscence or fenestration, as shown in Figure 20.5B. Many materials and techniques have been described to increase the

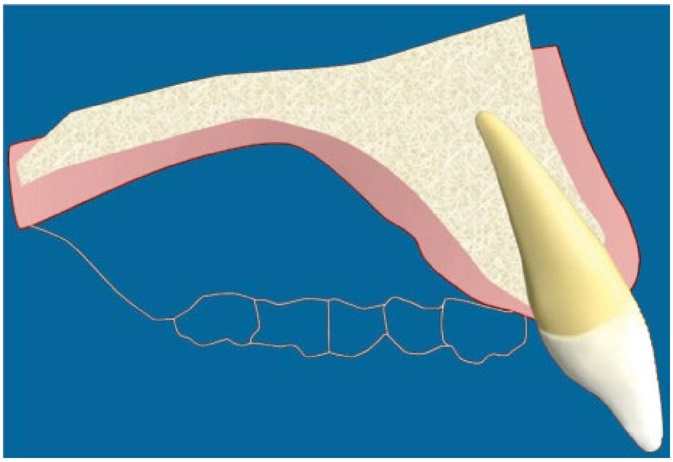

Figure 20.3 **(A)** In the premaxilla, the facial bone plate is generally thin (0.9 ± 0.4 mm). Thin bone is generally poorly vascularized due to its cortical nature. This translates into risk for postextraction resorptive changes.

buccolingual ridge volume. In contrast to vertical ridge augmentation, horizontal bone grafting is a relatively predictable event.[19–21] Perhaps more controversial is the subject of what type of material to use for this purpose. When ridge augmentation is carried out at the time of implant placement, it is the authors' opinion that structurally stable products with low substitution rates such as the xenograft Bio-Oss®, may offer a long-term

Figure 20.3 **(B)** Facial root inclination and position relative to the ridge midline is a common observation, resulting in thin facial bone.

Figure 20.4 **(A)** Preoperative clinical photo.

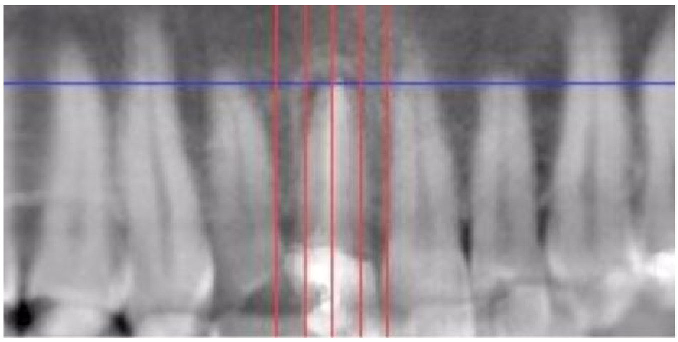

Figure 20.4 **(B)** Preoperative cone beam computed tomography (CBCT) scout view (panoramic) of tooth 8.

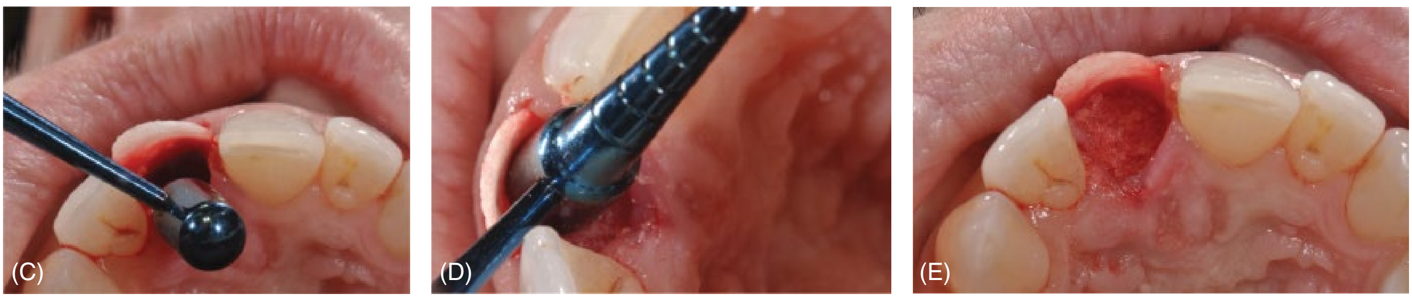

Figure 20.4 **(C)** A resorbable collagen membrane (Zimmer socket repair membrane) has been adapted palatal to the facial bone plate to seal a facial fenestration. A mineralized bone allograft (BioHorizons–Mineross cancellous allograft) is being condensed into the socket. **(D)** Same as Figure 20.4C, but lateral view. **(E)** Condensed bone graft, as viewed before crestal closure with the membrane.

Figure 20.4 **(F)** Collagen membrane adaptation over the condensed mineralized allograft.

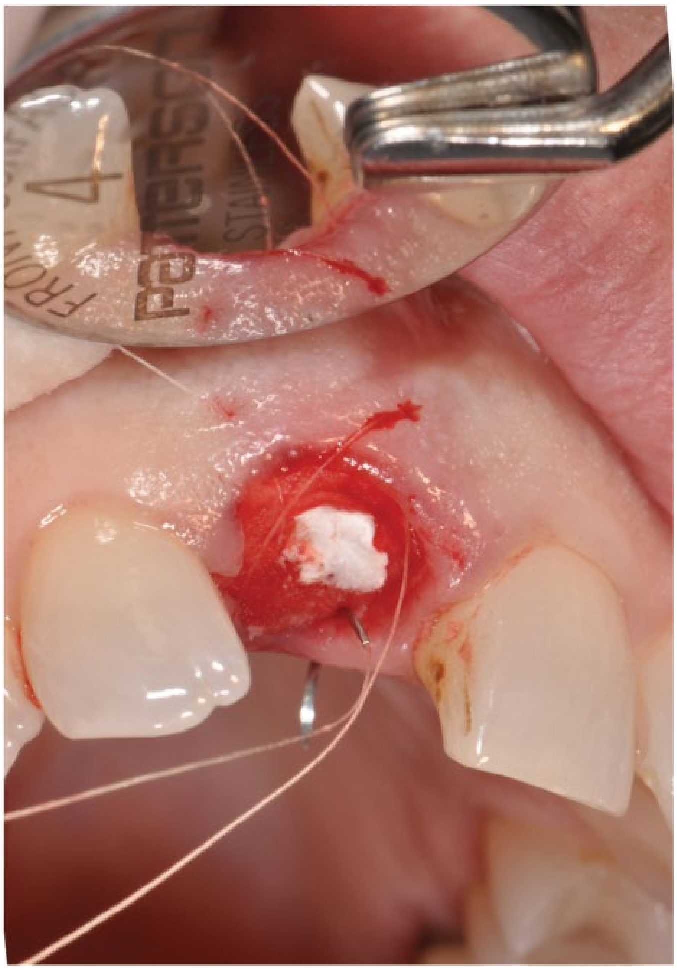

Figure 20.4 **(G)** Suturing with a resorbable figure-of-eight style suture (6-0 polyglycolic acid).

Figure 20.4 **(H)** Transitional provisionalization with a fiber-reinforced splinted crown (mirrored view).

Figure 20.5 **(A)** Thick facial bone volume (>2 mm) at the time of tooth extraction. This ridge volume is unusual in the premaxilla.

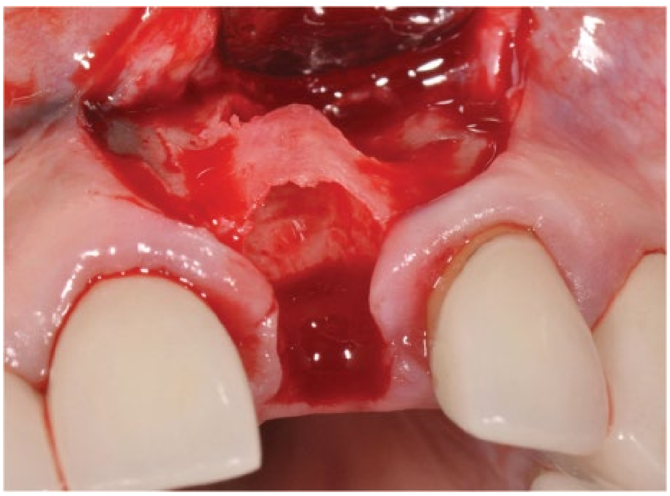

Figure 20.5 **(B)** Thin facial bone (<1 mm) coupled with a facial fenestration increases the treatment planning and treatment challenges. This type of clinical presentation increases the risk for adverse hard- and soft-tissue changes regardless of implant placement protocol selected (to be reviewed under implant placement protocols).

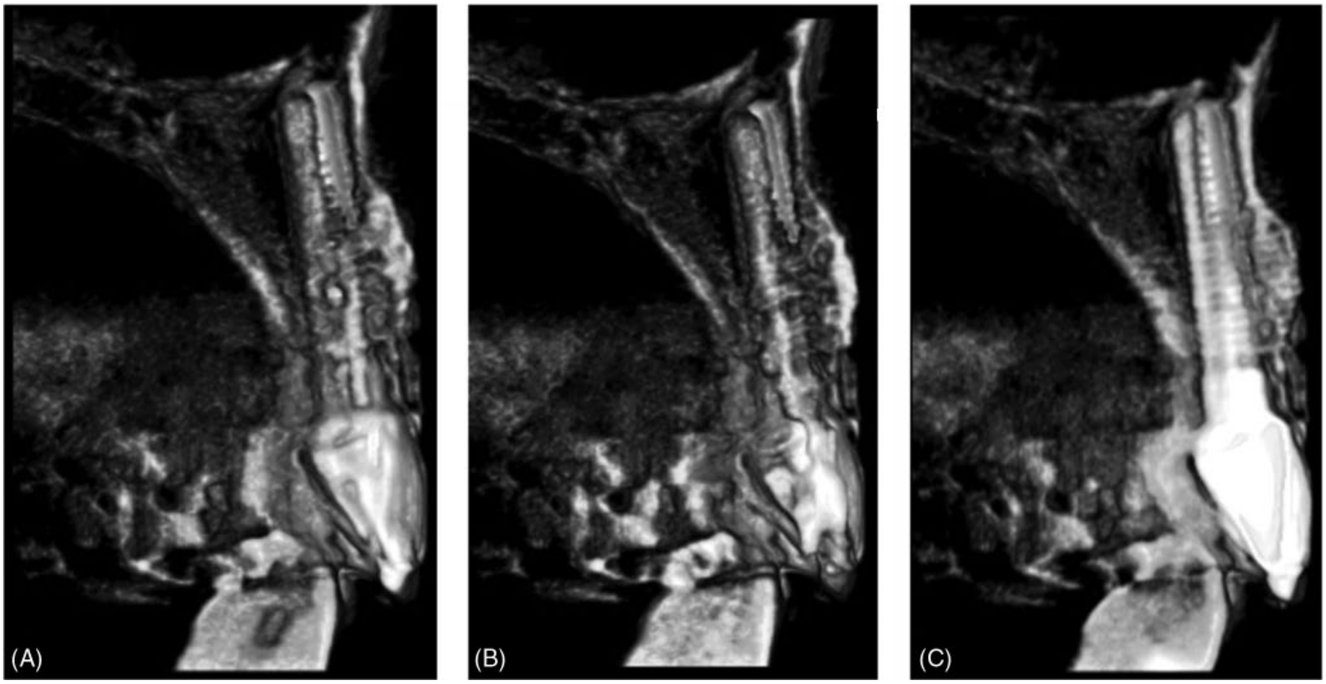

Figure 20.6 CBCT capturing an implant placed 8 years earlier: **(A–C)** three consecutive cross-sectional images separated by 1 mm. The residual horizontal defect had been grafted at the time of implant placement with a structurally stable xenograft product (Bio-Oss, Geistlich). This has predictably maintained the facial ridge contour.

advantage over other products that undergo faster replacement. CBCT cross-sectional images show the presence of a facial bone graft material and good bone volume 8 years after implant placement (Figure 20.6).

The challenge in bone grafting today continues to be the correction of vertical bone defects.[22] Despite many new materials and procedures to address ridge height deficiencies, vertical augmentation is not predictable for many clinicians. It is important to understand the limitation of vertical augmentation and to inform the patient of the likelihood that residual soft-tissue deficits will require prosthetic correction, including the use of longer contact areas or "pink" porcelain to replace the missing gingival tissue.

Bone substitutes in combination with a variety of membranes or meshes are increasingly used in efforts to reduce the treatment morbidity associated with autogenous graft procurement, and to thereby improve treatment acceptance. Figure 20.7A–C shows the use of bone allograft in block form to augment a horizontally and vertically deficient ridge.[23–26] An area of interest to the clinician struggling with vertical bone augmentation is the potential use of autogenous growth factors to enhance ridge augmentation results, with early reports on the use of recombinant growth

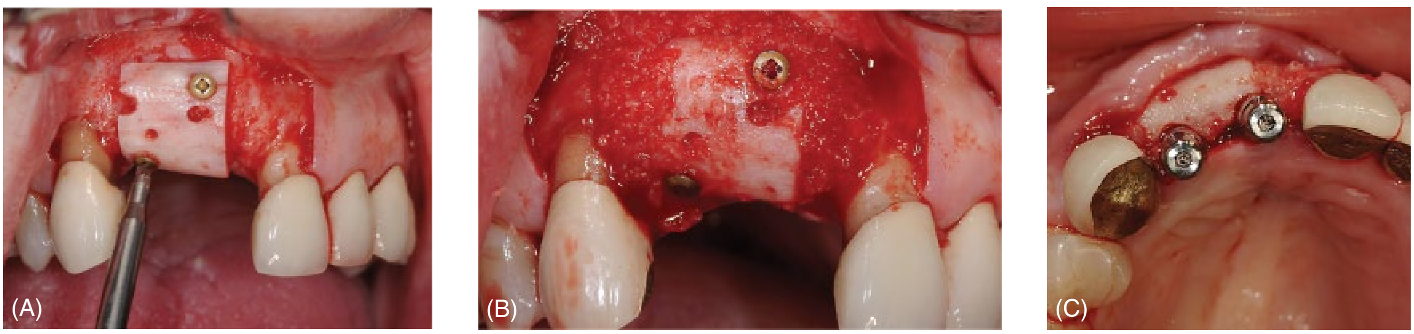

Figure 20.7 **(A)** A block allograft (Puros corticocancellous block, Zimmer) is shaped to intimately adapt to the underlying deficient ridge to regenerate both the buccal deficiency and height deficiency. Underlying cortical perforations improve blood supply to the graft. **(B)** Particulate mineralized graft material (Puros mineralized cancellous allograft, Zimmer) is adapted to fill proximal voids around the block graft. This is then confined and protected with a rapidly resorbed membrane, in this case, Bio-Gide (Geistlich). Other materials, including platelet-rich fibrin/autologous membranes or other resorbable membranes can be used. **(C)** Four-month reentry for implant placement illustrates ideal facial ridge volume. Implants have excellent primary stability (>45 N cm). Fixture level impressions were taken to fabricate lab-processed screw-retained provisional restorations.

Figure 20.8 Autologous growth factors or factors produced by recombinant technology are increasingly incorporated into bone grafting procedures. In this illustration, a mineralized allograft is being reconstituted with platelet-derived growth factor-BB (off-label use of GEM-21S).

factors like platelet-derived growth factor-BB (shown in Figure 20.8), and BMP2 showing promise in select applications.[27,28] Most of the literature describing the use of these products has been in "space-making" defects that are generally considered predictable to treat with conventional treatment approaches.

Because of the potential difficulties and lack of predictability of grafting procedures, great care needs to be given to planning extraction procedures, in terms of timing, techniques, and instrumentation that will favor ridge preservation. In this respect, immediate implant placement and provisionalization may be beneficial to minimize bone and soft-tissue changes.

Implant placement and restoration protocols: deciding the best strategy

Many surgical and restorative treatment protocols are used in the management of single sites, small edentulous spans, and the fully edentulous arch. With respect to timing relative to tooth extraction, these range from late and delayed implant placement (4 months or more after extraction), early placement (8 weeks after extraction), to immediate placement at the time of extraction. In addition, restoration options include immediate or delayed provisionalization (postintegration). These restoration options can be combined in a variety of permutations with the surgical methodologies mentioned earlier.

Multiple factors influence these treatment-planning and procedural decisions. These approaches may not significantly affect the esthetic outcome of treatment if properly executed, although "stacked" or multiple procedures combined into one event increase the treatment complexity and the potential risk for adverse outcomes. From an esthetic perspective, adverse events often translate into unfavorable tissue changes. At this time, there is insufficient evidence to support one approach over another, as many of the reports are underpowered or of low quality. It is our opinion, however, that immediate and early implant placement do not result in a higher risk for failures or complications, as reported in some publications.[29]

Delayed or late implant placement (12 weeks or more following extraction)

In delayed implant placement (12–16 weeks after extraction) there is clinical and radiographic evidence of socket bone fill, and in late placement (more than 16 weeks) socket fill is complete. Varying degrees of resorption of the buccal plate and ridge height may be present, requiring augmentation procedures before or at the time of implant placement. These treatment approaches have commonly been used with long-term follow-up.[30] These protocols are generally implemented in cases where teeth have already been lost, or when in situations where immediate and early placement are contraindicated. In addition, it is frequently used by the inexperienced clinician. Figure 20.9A–C shows a typical case of implant placement into a healed ridge, including bone and soft-tissue management.

Early implant placement (4–8 weeks following extraction)

This treatment approach has been suggested as potentially advantageous, because it may benefit from the healing potential of the extraction socket, before the completion of ridge remodeling and resorption while providing soft-tissue closure. This treatment approach also creates a more favorable environment by allowing for resolution of infection prior to implant placement. Typically, additional bone augmentation and soft-tissue grafting procedures may be required to correct dimensional limitations and to enhance the quality and the volume of the soft tissue.[31–35]

Immediate implant placement (at the time of extraction)

Immediate implant placement is increasingly considered in esthetic sites. This decision may be driven in part by patient demands to minimize the number of interventions and decrease treatment time. It also provides an opportunity for immediate provisionalization, thus facilitating patient management during the osseointegration phase. Additional benefits include the potential for reduced treatment costs, more conservative surgical procedures, and, importantly, maximum bone volume compared with late or delayed treatment, where resorptive changes may develop. In our opinion, predictable outcomes are expected as long as adequate primary implant stability can be

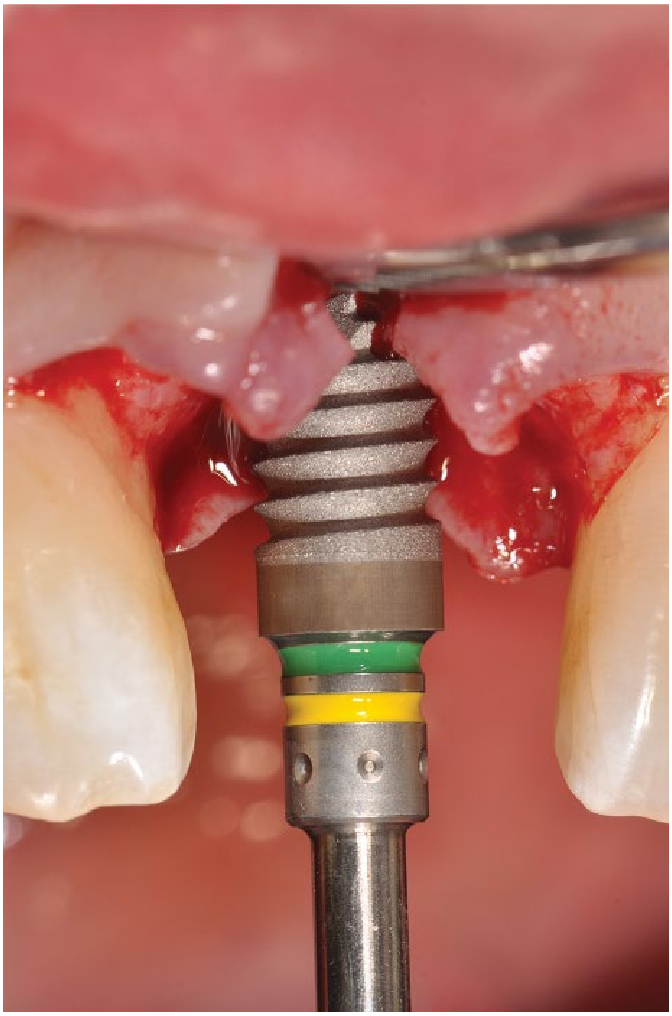

Figure 20.9 **(A)** Implant placement into a healed ridge, 4 months following ridge preservation. An implant design and thread form that offers high primary stability and the potential for enhanced long-term crestal bone stability with a unique laser-etched pattern (BioHorizons tapered internal implant) has been selected.

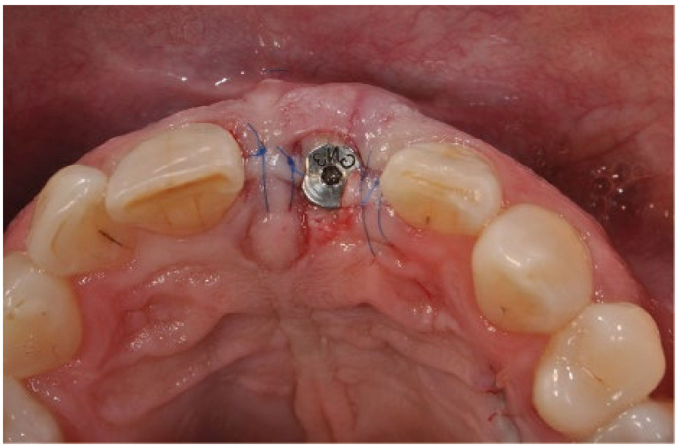

Figure 20.9 **(B)** A connective tissue graft adapted on the facial and extending around the healing abutment is used to augment the ridge volume and to enhance the gingival biotype. A lab-processed screw-retained provisional restoration will be inserted within 1 week of the surgical procedure.

achieved, and bone and soft-tissue grafting procedures are incorporated to manage ridge defects and to enhance the soft-tissue biotype when necessary. Figure 20.10A–J shows immediate implant placement at the time of extraction, coupled with immediate provisionalization. Table 20.2 summarizes the findings and conclusions of two recent systematic reviews on the outcomes of implant placement at the time of extraction.[3,36]

Immediate implant restoration: functional (loaded) or nonfunctional (unloaded)

The use of provisional restorations is potentially beneficial in achieving esthetic implant treatment outcomes. One of the benefits is the ability to prosthetically guide the remodeling of the peri-implant soft-tissue contours. Figure 20.11A–C shows tissue form changes that can be developed though provisionalization.

Immediate provisional restorations (placed at the time of implant surgery) are being more frequently used in both healed ridges and extraction sites in single, small edentulous, or large edentulous spans. Immediate provisionalization of splinted and unsplinted restorations in the esthetic zone has not been shown to adversely impact osseointegration and implant survival rates as long as primary implant stability is adequate and the occlusion can be controlled.[36,37] In addition, patient education is important to prevent overload following surgery and before osseointegration.[38,39]

Significant differences in crestal bone levels have not been identified in most clinical studies that compare immediate provisionalization and conventional restoration methods. In addition to the advantage of avoiding a removable partial temporary denture, the positive impact on gingival integration

Figure 20.9 **(C)** Ideal soft-tissue outcome 6 months after delivery of the definitive restoration. Numerous factors contribute to the outcome, including tissue grafting and the tissue sculpting as defined by the provisional restoration.

Figure 20.10 **(A)** Preoperative occlusal view: number 8 fractured to tissue level.

must also be considered.[40] Soft-tissue responses have been assessed and quantified both in terms of papilla development and facial gingival architecture in numerous studies. Papilla form tends to be maintained and/or developed more rapidly in immediate restoration cases compared with delayed restoration. In studies that have reported conflicting results in terms of the risk for mid-facial recession, excessive buccal position of the implant has been identified as the most deleterious risk factor.[41] In several studies, immediate implant placement and simultaneous restoration of single implants in the esthetic zone produced predictable treatment results in terms of papillary fill and mid-facial tissue levels.[42–44] Implant placement into a healed ridge and coordinated provisionalization are shown in Figure 20.12A–K.

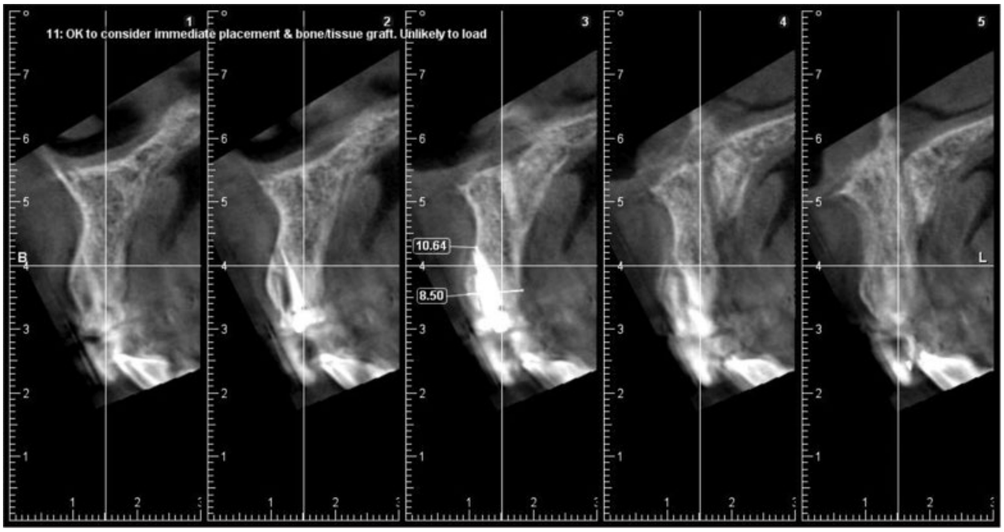

Figure 20.10 **(B)** Preoperative cross-sectional views from CBCT indicate that number 8 is facially canted. There is adequate palatal and apical bone for preparation of the osteotomy at the time of extraction.

Figure 20.10 **(C)** Extraction of number 8 with a vertical extraction system (BENEX, Meisenger, Germany). This extraction device permits extraction without luxation, thereby preserving the thin facial bone.

Figure 20.10 **(D)** Surgical guide: defines the preparation of the osteotomy in three dimensions.

Implant position: a pivotal point in the treatment blueprint

Implant placement is often discussed as a restoratively driven protocol; this underscores the importance of evaluation of the existing ridge anatomy, coupled with planning implant position based on the desired restoration and tissue outcome, and not just on the availability of bone.

The height of the papilla adjacent to a single implant is dictated for the most part by bone levels on adjacent teeth, whereas between implants it is dictated by interimplant bone height.[45] The potential impact of different implant–abutment connections, the spacing between implants, and the impact of prosthetic manipulation of the peri-implant tissues on bone height and long-term crestal bone stability will be discussed in this chapter.

It cannot be overemphasized how important it is to place the implant in the ideal location to achieve restorative success.[46] Given the broad literature relating to this aspect of treatment, it is not acceptable to make three-dimensional placement errors today. In Figure 20.13A–E, a distally and lingually canted implant cannot be restored and must be removed. Replacement and correction of implant position allows the use of a more appropriate implant diameter for the available restorative space. Poorly positioned implants not only jeopardize implant restorability and success but can also cause esthetic problems due to gingival recession and, significantly, can cause negative changes in the periodontium of adjacent teeth or implants.

Many surgical tools are available to help the clinician accurately plan and execute treatment, including CBCT to assess ridge anatomy, software planning systems using computer-aided design (CAD) that permit virtual implant placement and restoration, and surgical guides of varying degrees of precision.

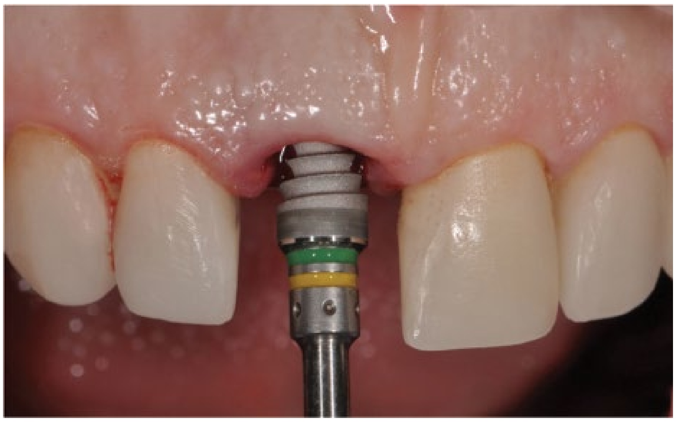

Figure 20.10 **(E)** Implant placement: a 4.6 mm diameter, 15 mm long BioHorizons tapered internal implant (BioHorizons, Birmingham, AL) engages the palatal and apical bone. This implant design—buttress threads and Laser-Lok surface technology—contributes to short-term high stability and long-term favorable crestal bone stability.

Figure 20.10 **(F)** Ideal implant placement. Note that there is a large buccal residual horizontal defect between the facial bone plate and the implant. This area must be grafted to ensure regeneration and to reduce the risk for facial bone remodeling.

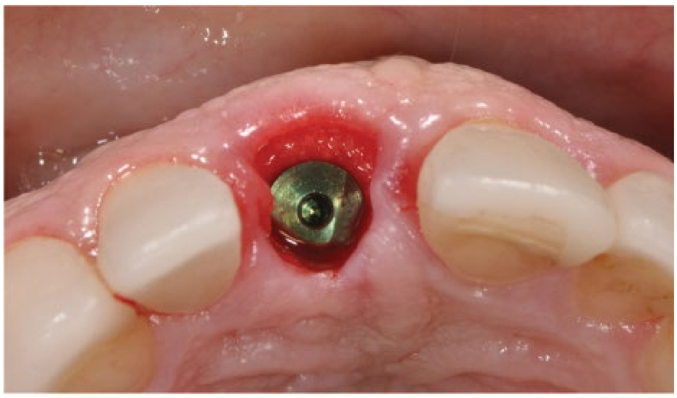

Figure 20.10 **(G)** Grafting of the residual horizontal defect with a structurally stable bone graft material. In this case, Bio-Oss (Osteohealth, Shirley, NY) was placed into the defect.

Figure 20.10 **(H)** Views of an ideally contoured screw-retained provisional restoration fabricated based on a fixture level impression taken at the time of surgery. Note the undercontouring of the crown in the subgingival area to avoid excess pressure that could induce recession.

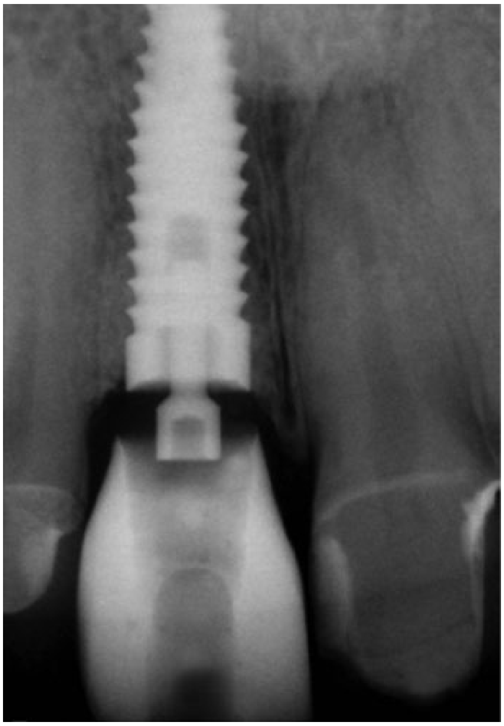

Figure 20.10 **(I)** Radiograph of the implant and provisional restoration after 4 months of healing. Note the radiopaque area correlates with the polyether ether ketone polymer abutment (BioHorizons, Birmingham, AL).

Table 20.2 Literature Findings and Risk Factors for Immediate Implant Placement Procedure[3,36]

Results of immediate implant placement procedure
High implant survival rates
High risk for mucosal recession (wide range reported in the literature)
Soft- and hard-tissue augmentation procedures are frequently necessary
This procedure should be used restrictively and by experienced clinicians
Recession risk factors
Smoking
Thin buccal bone (<1 mm thick), dehiscence/fenestration/damaged
Thin gingival biotype
Facial malposition of the implant

A conventional guide fabricated in the laboratory can drive the preparation of the osteotomy both buccolingually and mesiodistally, but as importantly can define the reference point for depth of implant placement if properly designed, as shown in Figure 20.14A and B. Stereolithographic surgical guides are more accurate and allow the greatest intraoperative precision Figure 20.15A–D) CAD/computer-aided manufacturing (CAM)-based surgical implant and restorative treatment is gradually penetrating clinical practice. This technology can improve surgical precision, reduce surgical time, minimize surgical

Figure 20.10 **(J)** Provisional restoration as viewed 4 months after surgery. Note that the gingival tissue has been developed and supported by the provisional restoration.

invasiveness, and can be coupled with preplanned provisional or definitive restorations; however, subtle deviations in linear and angular implant position between planned and actual implant position are reported, albeit less than with conventional procedures.[47–50]

Currently, recommended surgical guidelines on three-dimensional implant placement include the following.

Buccolingual position

Implants should be positioned in a restoratively driven manner with the secondary goal of creating at least 2 mm of facial/buccal bone at the ridge crest and/or implant collar level.[18] Adequate facial bone volume enhances the long-term ridge crest stability, translating into stable gingival tissue levels.[51] Coupled with this, it is important to select implants of adequate diameter without reducing the buccal bone volume. Where large diameter implants may be used because of available bone, the impact on facial/buccal bone thickness must be considered because recession may be an unintended consequence. Figure 20.16A and B shows the impact of facially dominant implant position due to the use of a large implant diameter compared to an adjacent more appropriately sized implant.

Mesiodistal position

See Figure 20.17 for a graphic rendering.

- *Implants adjacent to teeth:* spacing of 1.5 mm from adjacent roots is recommended, based on efforts to minimize bone changes on adjacent roots due to the remodeling that occurs around the implant collar.[52] The redefinition of minimum spacing requirements may be forced by the introduction of new implant designs (platform-switching, one-piece, soft-tissue level implants), unique microtextured surface treatments that enhance crestal bone and soft-tissue stability (Laser-Lok®), or concept changes such as the placement of final abutments at the time of surgery to reduce the effect of repetitive disruptive prosthetic procedures that can contribute to the apical migration of bone and gingival tissues. If crestal remodeling and establishment of an apicalized biologic width is no longer a common outcome of the

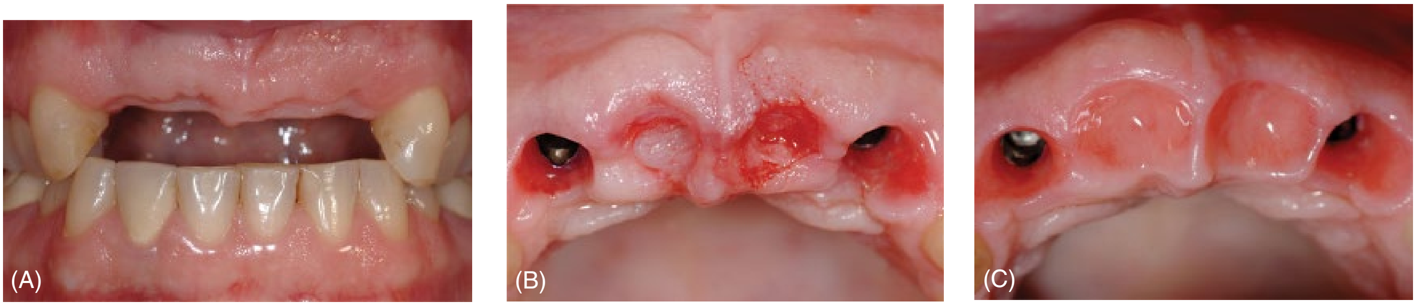

Figure 20.11 **(A)** Preoperative flat ridge anatomy due to longstanding partial edentulism. **(B)** Modification of the soft (and hard)-tissue anatomy at the time of implant placement, or after implant integration, can be accomplished using provisional restorations to guide the tissue form around implants and in pontic sites. Where necessary, tissue can be resected with burs, electrosurgery, or a laser and then guided with the provisional restoration. **(C)** Tissue form as viewed 3 months later on removal of the provisional restoration.

integration process, perhaps the minimum spacing requirements that were established with traditional implant designs need to be revisited. It will be interesting to assess whether reduced interproximal spacing (<1.5 mm separation from adjacent teeth) can be accepted in the future.

- *Adjacent implant placement and interimplant spacing:* separation between implants has historically been set at a 3 mm minimum, again to prevent coalescing of remodeling zones that occurred at the implant–abutment interface.[45]

With the introduction of platform switching, there is some evidence that reduced interimplant spacing may be acceptable since there is less crestal bone remodeling. It has been suggested that spacing of as little as 2 mm between implants does not result in an apical movement of the crestal bone. From this, one can extrapolate that the papilla should remain stable despite the closer proximity of implant placement. However, in our opinion, the effect of reduced space recommendations on soft-tissue volume or papillary form and size between implants and between implants and teeth needs to be considered.

Papilla height between an implant and tooth is defined by the bone height on the adjacent root and the location of the contact area, and not the proximal bone level next to the implant. It appears that the distance between the interproximal crest and the contact area is still the predominant factor determining the presence of the papilla. Between natural teeth, a distance of 5 mm or less will result in papilla fill. Between implants, however, this dimension decreases to 3.5 mm.[53,54]

Numerous techniques have been proposed to enhance the papillary architecture between implants, including bone and

Figure 20.12 **(A)** Preoperative view: failing number 8 due to internal resorption.

Figure 20.12 **(B)** Preoperative radiographic view. The large root size and length, along with the limited apical and palatal bone, do not permit immediate implant placement.

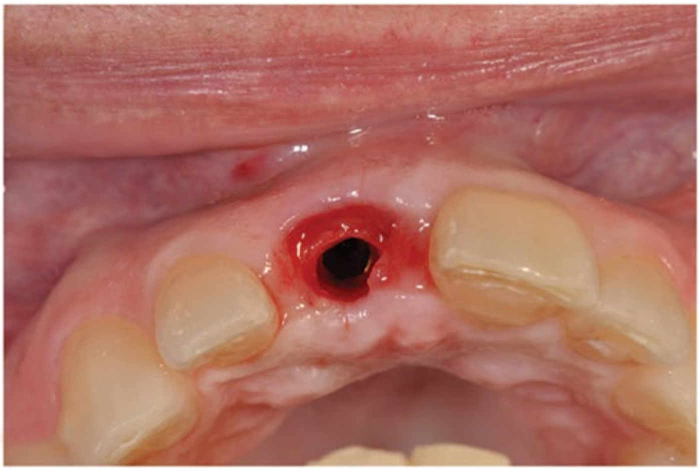

Figure 20.12 **(C)** Implant placement 4 months after extraction and ridge preservation.

Figure 20.12 **(D)** A screw-retained provisional restoration is fabricated based on a fixture level impression taken at the time of surgery.

Figure 20.12 **(E)** The provisional restoration is delivered within 7 days of surgery. Its role is to coengineer the soft-tissue anatomy during the osseointegration period.

Figure 20.12 **(F)** Incisal view of the developed gingival anatomy after 12 weeks of healing.

Figure 20.12 **(G)** Facial view of the developed gingival anatomy after 12 weeks of healing.

tissue grafting, correct three-dimensional implant position, implant and abutment design, and placement strategies. It has also been suggested that sequencing or staged implant placement may result in improved papilla form in contrast to simultaneous placement of side-by-side implants.[55] A comparative assessment of this and other commonly used surgical approaches, such as side-by-side implants placed in healed ridges, early implant placement (8 weeks of healing after extraction), and sequenced implant placement, did not identify significant esthetic benefits of one approach over another.[56]

The predictable achievement of adequate interimplant papillae still remains a significant clinical challenge.

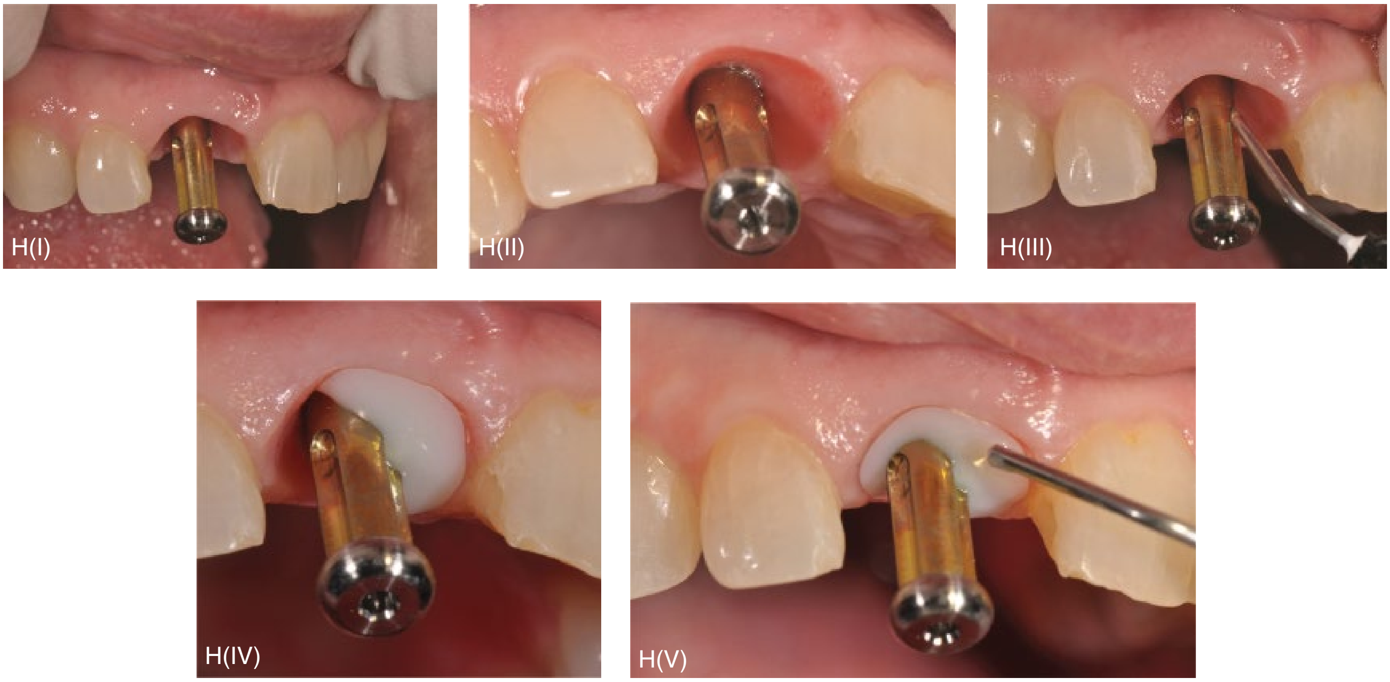

Figure 20.12 **(H)** Intraoral customizing of an impression coping used to record the implant position and the developed gingival anatomy. This technique works well when the gingival tissues are fibrous and stable. Thinner or more volatile tissues will collapse once a provisional restoration is removed, rendering the information less accurate for the technician. Extraoral indexing of the provisional restoration should be considered in this situation.

Figure 20.12 **(I)** Delivery of an ideally designed zirconia abutment in terms of support for the definitive restoration and position of the cement line.

Figure 20.12 **(J)** Insertion of the definitive restoration (feldspathic porcelain-veneered zirconia crown).

Figure 20.12 **(K)** Radiographic view of the definitive restoration following cementation.

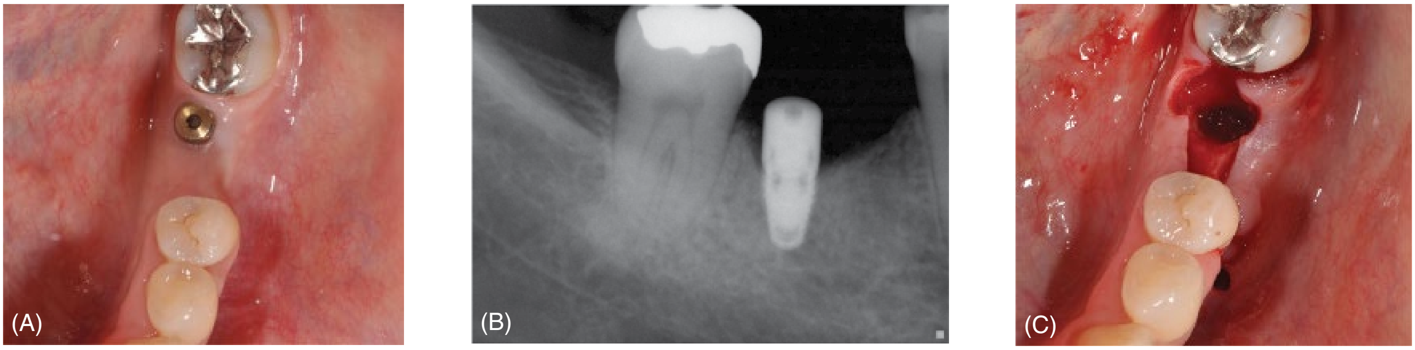

Figure 20.13 **(A)** Preoperative view: distally and lingually canted implant, and small diameter due to poor positioning render this implant unrestorable. **(B)** Preoperative radiographic view. **(C)** Removal of the implant can be accomplished with a variety of techniques, including reverse torque if not completely integrated, piezosurgery, or, in this case, removal with a hollow-core trephine.

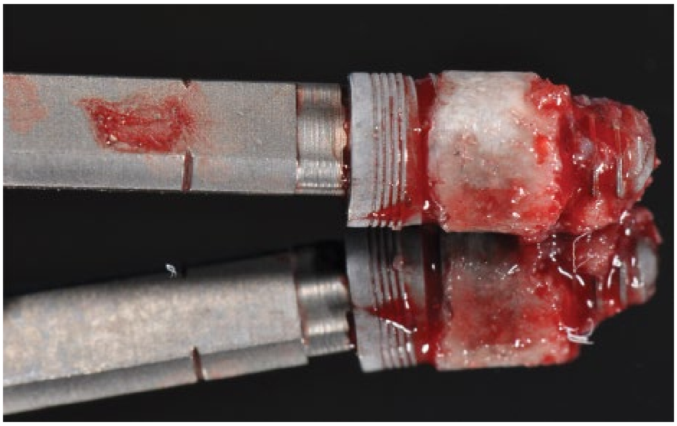

Figure 20.13 **(D)** This implant was removed with reverse torque following trephination of two-thirds of the implant length.

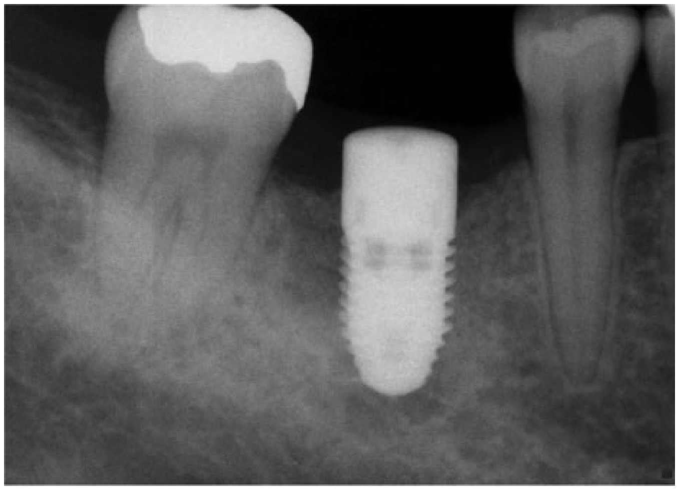

Figure 20.13 **(E)** Replacement of the implant 4 months following the implant removal and ridge augmentation. Radiographic view of the implant after a 3-month integration period. Note the improved position and larger diameter that could be placed due to the corrected position relative to the adjacent roots.

Figure 20.14 **(A)** A lab-processed surgical guide defines the mesiodistal and facial-palatal position for the future implant and restoration. Used at the time of surgery, this guides the preparation of the early drilling steps of the osteotomy preparation. With subsequent widening of the hole/access, larger drills can also be used to finalize the implant osteotomy.

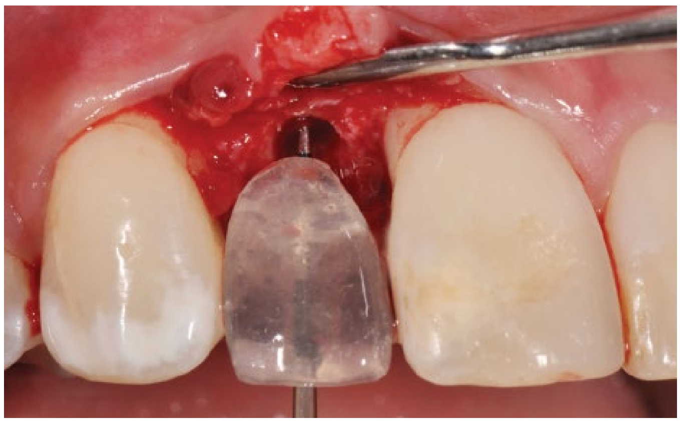

Figure 20.14 **(B)** An ideally designed surgical guide also defines the desired depth of implant placement. In this case, a probe placed through the guide to the head of the implant shows that the implant has been positioned 3 mm apical to the desired facial free gingival margin.

Figure 20.15 **(A)** Ideal tooth position as established in a provisional restoration is used to fabricate a radiographic template, before a CBCT.

Figure 20.15 **(B)** A stereolithographic surgical guide is fabricated and will guide the implant site preparation and implant insertion.

Figure 20.15 **(C)** Implant osteotomy preparation through a printed surgical guide improves the placement precision as planned virtually.

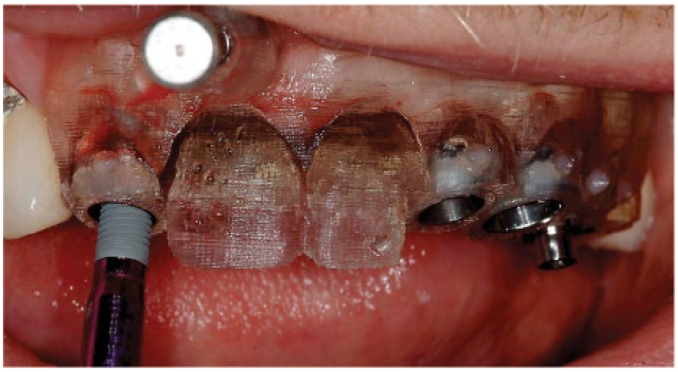

Figure 20.15 **(D)** Implant placement through the guide.

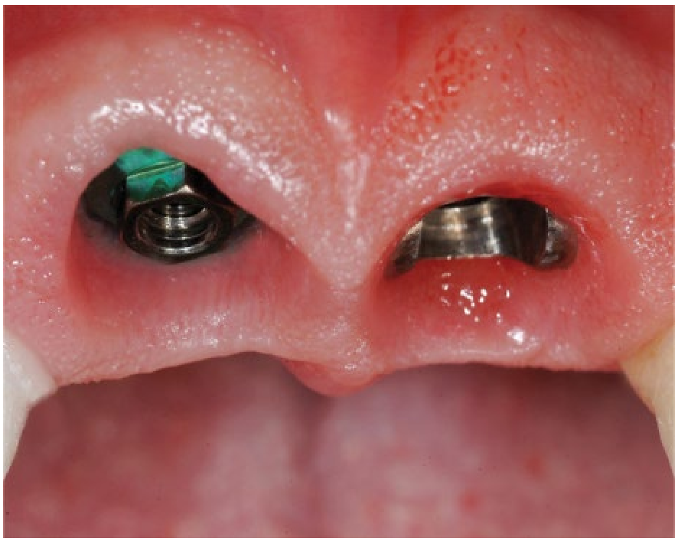

Figure 20.16 **(A)** Two different implant diameters (6 mm versus 4.3 mm) result in facial dominance of the larger implant, thinning of the buccal bone, and reduced restorative room for the abutment. This clearly translates into early negative soft-tissue level changes.

Figure 20.16 **(B)** The clear contrast in facial tissue level due to a treatment planning error on implant size, resulting in a long clinical crown, relative to the more normal and desirable tissue level in site number 9.

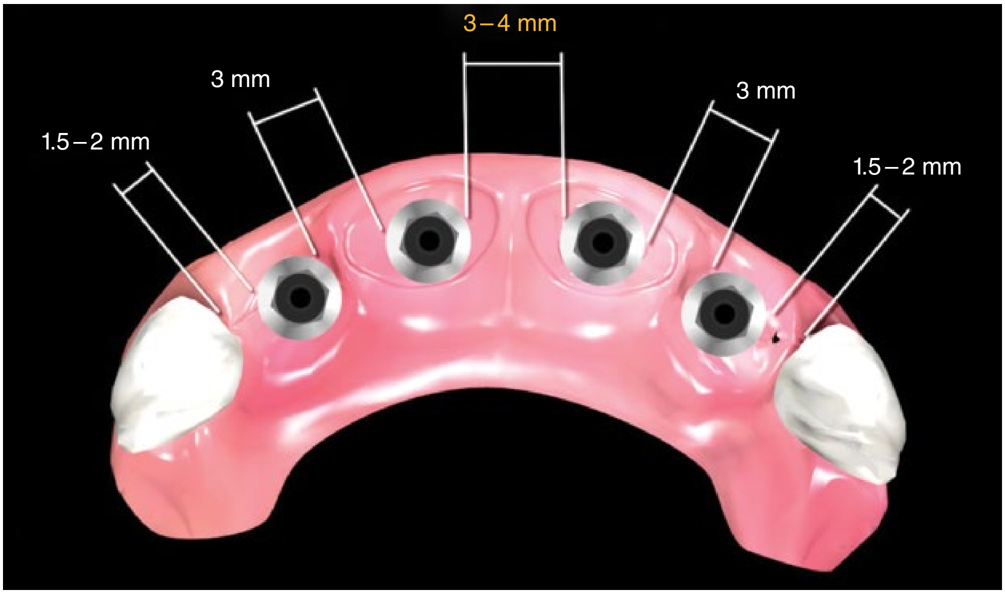

Figure 20.17 Graphic illustration showing ideal spacing between an implant and an adjacent root (1.5–2.0 mm) and between implants (3 mm).

Apicocoronal position (depth of implant placement)

In the esthetic zone, depth of implant placement is generally driven by the position of the desired future free gingival margin. Typically, the implant is positioned 3 mm apical to this position, allowing room for the transmucosal restorative components to develop both subgingival tissue contours and to support the desired marginal soft-tissue profile. As shown in Figure 20.14B, this is most predictably accomplished using surgical templates that define the gingival margin of the planned restoration. Some studies now also suggest that the use of implants with textured or grooved collars may benefit from slightly subcrestal placement, as it is suggested that this can lead to reduced crestal bone remodeling by placing the implant into a more protected or sheltered environment relative to bacterial challenge.[57–59]

Implant designs

The implant market offers a variety of designs, which are all basically evolutions of the original Brånemark root-form implant—a metal cylinder with screw threads. They are usually manufactured from commercially pure titanium or titanium alloy, although there have been recent attempts to use zirconia. Additional features have been incorporated into different implant designs, usually for the purposes of improved osseointegration, crestal bone preservation, and facilitating restoration.

A significant departure from the original Brånemark design is the incorporation of modified surfaces. Although early implants showed machined surfaces, most contemporary implants are treated to provide a roughened surface, for the purpose of improving bone-to-implant contact and enhancing the biologic response.[60] At this time, one surface technology has not been shown to be superior to another in terms of implant survival or success.

Another area where current implant designs differ from the Brånemark original is the abutment–implant interface. Root-form implants were initially manufactured with external connections. Over time, however, there has been a migration toward implant designs that feature internal connections. The reasons for this evolution range from attempts to decrease the bacterial load at the implant–abutment interface, to improving stress distribution at the bone–implant interface. Whether an implant has an external or an internal connection, however, does not seem to have an effect on implant success or survival rates.[61] Nevertheless, implants with internal connections show significant advantages from a restorative perspective. The most important may be the reduction in the incidence of screw loosening, mainly as a result of superior connection stability and axial support. In addition, they are more operator friendly, because it may be easier to properly seat abutments and other restorative components, particularly in areas of limited access.

Internal implant connections may be conical or parallel walled. There has been substantial disagreement as to whether or not conical connections provide a superior sealing ability from oral fluids, thereby decreasing bacterial contamination of the internal implant chamber, which may be beneficial in preventing crestal bone remodeling around implants. However, it appears that abutment micromotion may play a more important role with respect to the latter.[62]

Platform switching has been proposed as an alternative to improve crestal bone maintenance around implants. This concept incorporates the use of restorative components of a lesser diameter than that of the implant. In other words, the implant platform is "switched" to a narrower restorative platform. This results in a situation where the implant–abutment junction is located in a more medial location. Therefore, whether or not peri-implant bone remodeling is caused by bacterial leakage or abutment micromotion, platform switching places the potential etiologic factors further away from the implant–bone interface. The potential for platform switching to preserve crestal bone maintenance has been supported by extensive publications, including systematic reviews.[63–66]

In terms of macrogeometry (implant shape), "tapered implant designs" have recently gained in popularity. This may be due in part to their potential to achieve increased primary stability that offers significant advantages in terms of immediate placement and immediate restoration. For example, an implant design that routinely achieves outstanding primary stability may be used in more compromised situations, hence consolidating procedures and decreasing morbidity and treatment time. In addition, high primary stability facilitates immediate loading. Implant placement into fresh extraction sockets followed by immediate provisionalization has been increasingly used by clinicians because of the potential for predictable esthetic results by guiding tissues early in the treatment process.[42–44] Tapered implant designs are often advantageous when using this protocol.

Gingival biotype: assessment methods and enhancement procedures

The gingival biotype has long been recognized as an important parameter in treatment planning for the natural dentition, but it is just as essential a consideration for the health and esthetics of the peri-implant soft tissues.[50,67] Although success in terms of osseointegration is not impacted by gingival biotype, it has become clear that gingival margin stability, risk of recession, and maintenance of peri-implant soft-tissue health may be influenced by it.[68–71] Although there is a trend to focus on these issues in the esthetic zone or anterior maxillary dentition, it is important to assess tissue characteristics in nonesthetic areas as well.

The biotype can be described as thin (≤1.0 mm) or thick (>1 mm).[72–74] In the natural dentition, it is believed that a thin biotype is a contributing factor to recession and root exposure. A thick gingival tissue biotype has been suggested to protect underlying bone,[75,76] reduce the risk for postrestoration recession, improve esthetics, and mask the color of the underlying restorative. It is also important in facilitating oral hygiene procedures.[77]

A variety of techniques can be used to assess the thickness of the gingival tissue, including visual assessment, transmucosal probing under local anesthesia, sulcular probing and probe transparency, CBCT imaging, and experimental but not routinely used procedures such as ultrasound devices. In clinical practice, it is probably most common to use visual assessment to characterize the gingival biotype, but this is the least accurate method to assess tissue thickness.[78] Sulcular probing before tooth extraction, or around an implant, would be preferential as this allows the practitioner to estimate the tissue thickness based on the degree to which the probe can be visualized through the tissue, thus allowing an extrapolation to the potential impact of different restorative materials on gingival tissue color.[79] Similarly, transmucosal probing provides a numeric measurement, but can certainly be affected by probe or instrument size and tissue desiccation. Each of these procedures has pros and cons, as described in Table 20.3. Along with studies that emphasize the importance of the tissue thickness, other studies suggest that the width or height of the keratinized tissue band is also important to long-term facial tissue stability.[80]

Tissue thickness may also be influenced prosthetically. For example, undercontoured or concave emergence profiles, whether at the abutment or the restoration level, can be used to enhance the tissue thickness, offering potentially beneficial effects in terms of marginal tissue stability.[81,82] This concept will be reviewed in more detail in the "Provisionalization: refinement of the gingival tissue architecture" section.

Today, gingival and dermal grafting procedures are often incorporated into implant treatment plans to prevent mid-facial gingival recession, rather than using these procedures to remediate esthetic complications around implants (see Figure 20.18A–D). Connective tissue grafts,[83,84] and, to some degree, pediculated or rotated flaps[85,86] can be successfully used to enhance both tissue volume and quality before or at the time of implant placement. Although there is no supporting literature,

Table 20.3 Gingival Biotype: Strengths and Limitations of Assessment Techniques

Gingival Tissue Thickness Assessment Techniques	Pros	Cons
Visual assessment	Simple, inexpensive, noninvasive	Subjective (no numeric outcome)
Sulcular probing and probe transparency	Simple, inexpensive, noninvasive	Relatively subjective (no numeric outcome)
Transmucosal (gingival) probing	Simple, inexpensive, provides a numeric outcome or measurement	Requires local anesthesia, accuracy affected by probe size/form, tissue hydration
CBCT imaging (possibly coupled with radiopaque sulcular markers)	Simple, noninvasive	Expensive, accuracy influenced by type of CBCT device, marker size, restoration material scatter artifacts
Ultrasonic devices	Not available at present for routine clinical use	

Figure 20.18 **(A)** Implants placed 8 years before this clinical photo were well positioned three-dimensionally. Embrasure between number 8 and number 9 shows deficient interimplant papilla typically associated with adjacent implants. The thin biotype was not addressed with a graft during the treatment, contributing to the recession, margin, and abutment exposure. Note the gray tissue color due to the underlying titanium abutment.

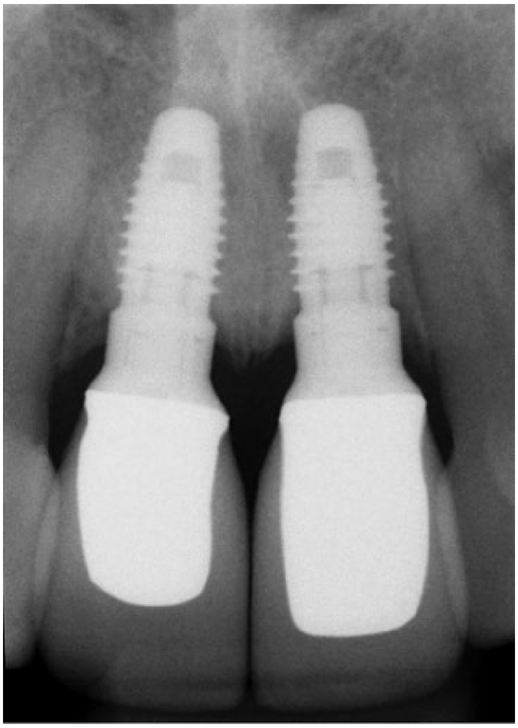

Figure 20.18 **(B)** Radiograph of the implants number 8 and number 9 after 8 years in function. Bone levels are normal with evidence of remodeling around this implant design to the first major thread (Nobel Replace Select, Nobel Biocare, Yorba Linda, CA).

Figure 20.18 **(C)** Remedial connective tissue graft procedure using a microsurgical technique as viewed 10 days after surgery. The treatment goal is to enhance the tissue volume and quality before replacement of the restorations.

Figure 20.18 **(D)** Replacement of the restorations 4 months after the graft procedure. Note the long contact areas and long clinical crowns. Esthetic outcomes of treatment are rarely ideal when a corrective, rather than interceptive, approach is considered.

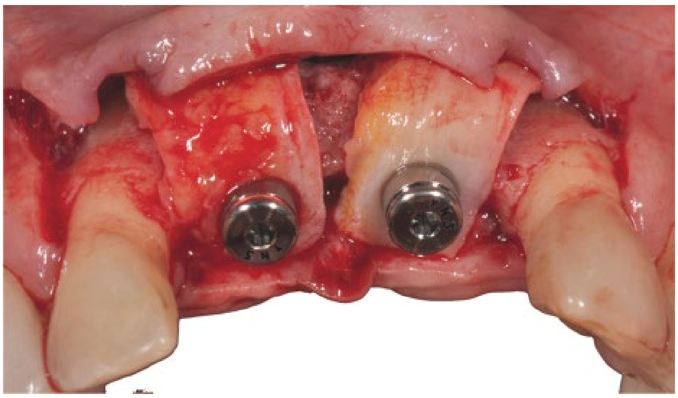

Figure 20.19 **(A)** Three-dimensional tissue augmentation to enhance the tissue biotype and the tissue volume. Palatal and proximal extension of the grafts improves the buccal tissue volume, the papillary form, and potentially protects the underlying ridge crest.

our clinical observations suggest that graft quality may play a role on the degree of tissue volume achieved, as well as its long-term stability. In this regard, gingival grafts with high fat content do not appear to perform as well as grafts composed of dense connective tissue. Figure 20.19A–C shows current graft techniques to three-dimensionally enhance tissue volume as well as the impact of variable graft quality on the maturation and potential impact on long-term tissue stability. It must be pointed out, however, that corrective soft-tissue procedures around implants may not offer predictable results or long-term peri-implant tissue stability.

In summary, although three-dimensional bone volume around implants is important to integration and crestal bone stability, the soft-tissue volume and quality are equally important in achieving optimal esthetics and peri-implant tissue health.

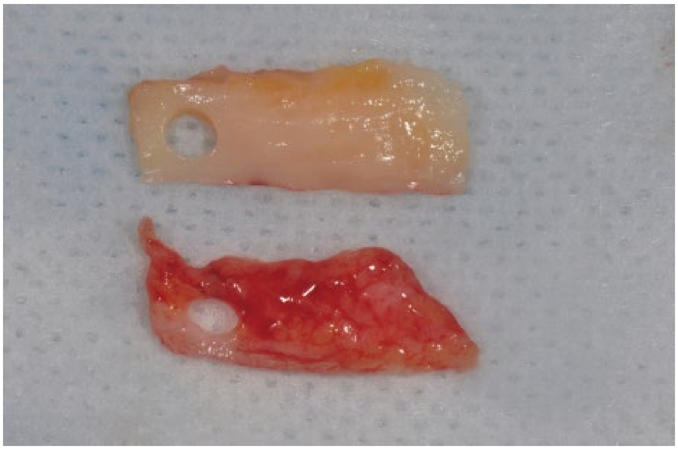

Figure 20.19 **(B)** Contrasting tissue quality, due to different graft harvesting techniques. One graft has a greater fatty component. We propose that grafts with lower fibrous composition heal in a different pattern and are not stable long term.

Figure 20.19 **(C)** Healing of the implants and grafts as viewed at 10 days postsurgery. Clear differences in healing patterns are noted between the fattier graft at site number 8 and the more fibrous graft at site number 9 early in the healing phase.

Provisionalization: refinement of the gingival tissue architecture

Today's final "surgical step"

Creating peri-implant tissues that are stable and look the same as those seen around healthy adjacent teeth requires (1) an understanding of how to preserve the existing hard and soft tissues and, if need be, regenerate them, (2) that the implant position be correct three-dimensionally, and (3) that the tissues be properly managed as they mature. Often overlooked is the importance of provisionalizing the implant and the distinct benefits of this step.

Provisionalization is generally thought of as the first step in the restorative phase of treatment, but it should perhaps be redefined as the final phase in surgery. Even if provisionalization is started after implant integration, its role is to define or finalize the tissue form in the transmucosal area and particularly at the gingival margin level.

As previously discussed, the temporary crown or fixed partial denture has the role of guiding and developing the transmucosal tissue form; this may be accomplished by using cemented provisional restorations on temporary or final abutments, or screw-retained provisional restorations.[87,88] Immediate provisionalization is advantageous for patients that object to the use of a removable temporary prosthesis. In addition, it may provide the benefit of preserving peri-implant tissue levels, particularly in the mid-facial aspect. Figure 20.20A–I shows the development of the tissue form with a provisional restoration that will subsequently serve as a template for the final restoration. Many studies report that immediate provisionalization outcomes are similar to those of conventional restoration protocols.[89] However, adverse soft-tissue changes presenting as advanced recession (>1 mm) have been reported as a risk in many studies. These undesirable sequelae are usually the result of labial implant position and/or inadequate restorative contours.[80,90,91]

Provisional restorations must be designed with appropriate supragingival contours for esthetics, but also in the subgingival area to develop the peri-implant tissue contours. As previously discussed, the contour of the provisional restoration must be optimized to support the desired gingival architecture. Overcontouring the implant restoration in the transmucosal area increases the risk for tissue recession, negatively impacting the esthetic outcome; in our opinion, this may be an important issue in studies that report gingival recession problems in immediate restoration scenarios. Conversely, undercontouring the implant restoration in the transmucosal area will result in coronal proliferation of the gingival margin.

In summary, implant provisionalization offers the following advantages for the patient and clinician:

1. Immediate gratification as the patient leaves with the tooth/teeth in place.
2. Time to assess the results of treatment; that is, evaluating the treatment plan.
3. If any additional treatment is required, such as soft-tissue revision, the provisional can be used to guide the healing process and to reevaluate the esthetic outcome.
4. The provisional can be modified to support the tissue or to change its form. Provisional materials that are typically used are acrylic resins such as polymethyl-methacrylates, bis-acryl composite resins, and visible-light-cured urethane dimethacrylates. They are easily modified by using a shaping disc or bur or by adding adhesives and light-cured composites. In some cases, roughening and sand blasting before adhesive addition will help with the durability of the bond of the composite used to modify the provisional restoration.
5. The information as to the three-dimensional shape of the accepted emergence profile can be registered by either customizing a stock impression post directly in the mouth [shown in Figure 20.12H(i–v)] or indexing the provisional restoration itself (the latter requires a screw-retained provisional). If it is possible to pour the impression right away, an extended lab-screw can be substituted for the conventional temporary abutment screw and an open tray impression carried out. In this way the provisional acts as the impression post or coping, producing an exact replica of the subgingival tissue contours. The use of any of these techniques insures that the technician will have the required

information to design the ideal final abutment and crown contours. All too often, the technician is asked to guess at the final dimensions of the subgingival area, resulting in either under- or overcontoured definitive restoration.

Material choices: final abutments and restorations

Abutments

Final abutments for cemented restorations are generally available in either titanium or zirconium. The most widely used material is titanium, although each material offers distinct advantages. Titanium is a metal that can be alloyed to produce a strong, lightweight material for the production of both dental implants and abutments. It is corrosion resistant and has the highest strength-to-weight ratio of any metal available. It is less brittle than zirconia and has higher fracture toughness, and can be readily used in posterior regions of the mouth or where additional strength is required. The use of zirconia-based ceramics has emerged onto the scene in recent years for a wide range of clinical applications, including crowns, bridges, frameworks, and implant abutments. This has come under the banner of metal-free restorative materials, and the application of zirconia abutments has gained considerable interest because of its pleasing color, thus avoiding the "gunning" or "graying" appearance through the facial gingival tissues.

The physical and mechanical properties of zirconia oxide ceramics show a unique ability to resist crack propagation when properly handled and designed. Zirconia abutments in particular have been documented to resist fracture under normal occlusal loads.[92–94] The design of the abutments should allow for a minimal axial thickness of the crown of 1.2–1.5 mm and an occlusal or incisal thickness of 1.5–2.0 mm. The abutments should be created with rounded internal line angles. In other words, implant abutments should be designed with similar preparation guidelines to those of natural teeth. As a cautionary note, in situations where implant position demands that axial walls of the abutment be modified to the point where they become too

Figure 20.20 **(A)** Preoperative facial view: congenitally missing lateral incisor.

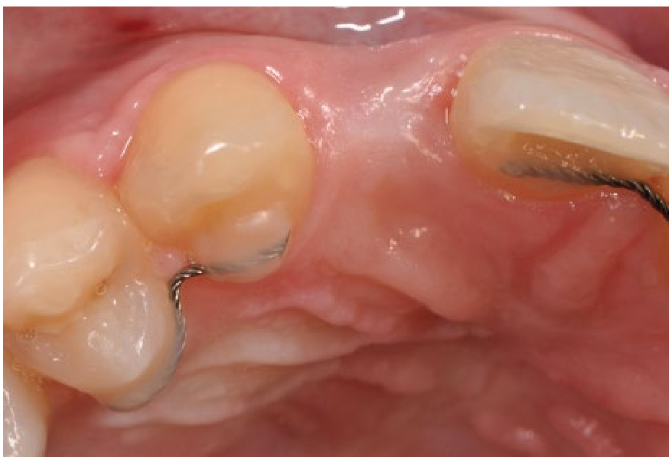

Figure 20.20 **(B)** Preoperative occlusal view.

Figure 20.20 **(C)** Preoperative radiographic view showing ideal root alignment around the edentulous site. On the basis of clinical measurements and a CBCT, spacing of 6 mm permits 3 mm diameter implant placement, maintaining spacing of 1.5 mm on either side.

Figure 20.20 **(D)** Three months postsurgery: narrow healing abutment in place. **(E)** Three months postsurgery. Undeveloped tissue anatomy as defined by the healing abutment. A fixture level impression is taken to fabricate a screw-retained provisional restoration that will be used to define the marginal tissue anatomy. **(F)** Facial view after 3 months with the provisional restoration in place.

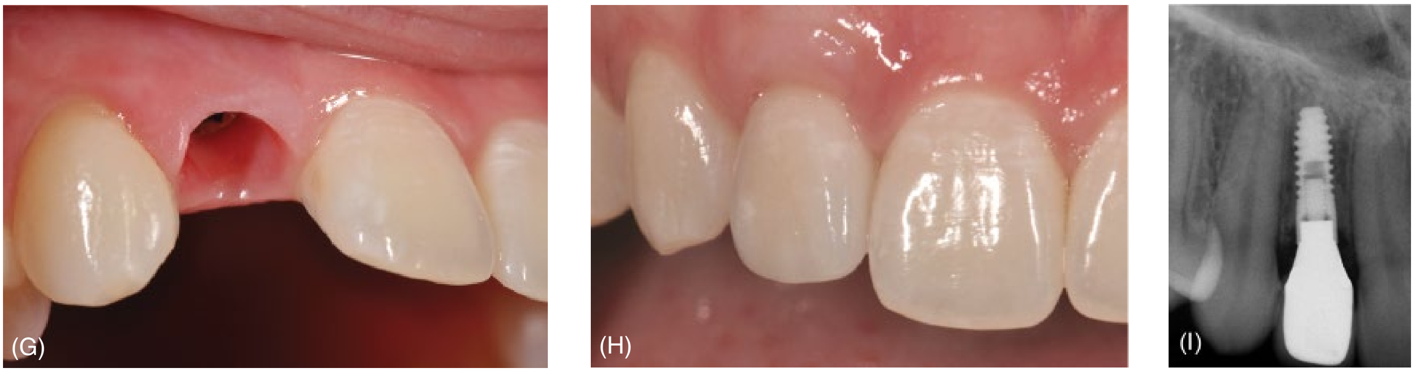

Figure 20.20 **(G)** Occlusal view of the subgingival prosthetic envelope and marginal tissue contours as developed by the provisional restoration. **(H)** Definitive restoration: postcementation clinical view. **(I)** Definitive restoration: postcementation radiographic view.

thin, particularly in the region of the head of the retaining screw, making it more prone to fracture, titanium is a better choice of material. Figure 20.21A indicates that adequate material volume around the head of the implant is necessary to avoid fracture of the abutment (as shown in Figure 20.21B) in the case of zirconia (one implant manufacturer suggests that a minimum thickness of 0.8 mm is necessary for the first 3 mm coronally from the head of the implant mating surface).

Both materials have been cited in the literature as showing adequate soft-tissue biocompatibility, with some evidence suggesting that zirconia is superior to titanium in this respect as suggested by lower bacterial colonization and reduced inflammation.[95–97] It is interesting to note, however, that zirconia biocompatibility may be affected by handling procedures, including polishing, veneering, or milling/preparation procedures.[98]

Zirconia abutments are increasingly used in the esthetic zone due to obvious color advantages compared with titanium or gold-hued abutments. The graying effect caused by titanium through the soft tissues can affect the esthetic outcome.[81,99] The use of zirconia also allows the clinician to locate the finish line just below the gingival margin to allow for easier isolation and control of cementation (Figure 20.22C). Zirconia abutments can also be colored to avoid the relatively opaque or white color if necessary. This may be an advantage in terms of creating color symmetry next to an adjacent tooth-supported restoration. Figure 20.22A and B compares the cement-line position on a titanium abutment to avoid the "graying" of the soft tissues, which invariably forces the final margin to be more deeply placed, compared with a more coronal position on a zirconia abutment.

This in turn places the veneering porcelain further into the tissue. This material has not been shown to be as biocompatible as zirconia. Furthermore, the deeper placement of the margin can result in the inability to thoroughly remove any residual cement, leading to possible peri-implantitis.[100,101] Figure 20.23A shows residual cement that can lead to inflammation in many cases, and to bone loss in some cases (as noted in Figure 20.23B).

Implant restorations: ceramics

Metal-based crowns and fixed partial dentures still constitute the majority of implant restorations today, especially where titanium abutments have been used. Again, in highly esthetically sensitive areas where zirconia abutments are used, it makes sense to couple this technology with metal-free restorations. Zirconia crowns are currently produced through CAD/CAM systems, which for the most part use partially sintered Y-TZP ceramics, where the crowns are dry milled and then undergo a final sintering process. The strength of zirconia is essentially higher than the functional forces that are generated in the mouth; however, the applied veneering porcelains, which have a high glass phase content to enhance translucency and esthetic properties, are significantly weaker than the zirconia coping and subject to crack growth and cumulative damage in a wet environment. The chipping of the

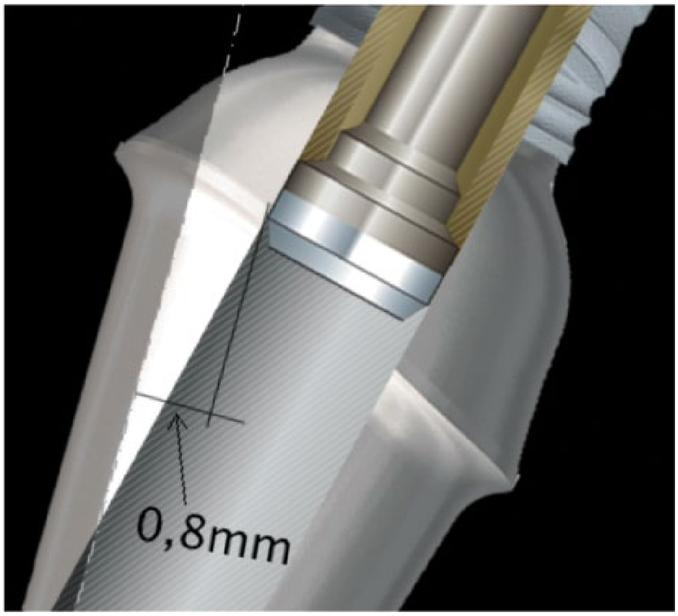

Figure 20.21 **(A)** Graphic illustration of the minimum thickness of zirconia required around the abutment screw head to avoid fracture under function.

Figure 20.21 **(B)** Abutment fracture has occurred around the abutment screw due to thinning of the zirconia; this was deemed to be the result of the facial position of one of the implants supporting a fixed partial denture.

Figure 20.22 **(A)** Titanium abutment with an apically repositioned margin or cement line, in an effort to reduce the graying effect of titanium.

Figure 20.22 **(B)** In a similar case, zirconia allows a more coronal margin placement, because the white color of the zirconia will minimally impact the gingival tissue color.

Figure 20.22 **(C)** An ideally designed abutment with a minimally submerged margin (0.5–1.0 mm) allows relatively easy access for cement removal.

feldspathic porcelain is commonly encountered in clinical practice and is attributable to several factors, including the bond between the veneering ceramic and zirconia substructure,[102–106] inadequate framework support design,[107,108] as well as residual stress buildup caused by the thermal mismatch between the veneering porcelain and the zirconia substructure. Tensile and compressive residual stresses can increase the occurrence of chipping.

Figure 20.23 **(A)** Retrieved crown removed as a result of chronic marginal tissue discomfort. Note the retained cement circumferentially around the restoration margin.

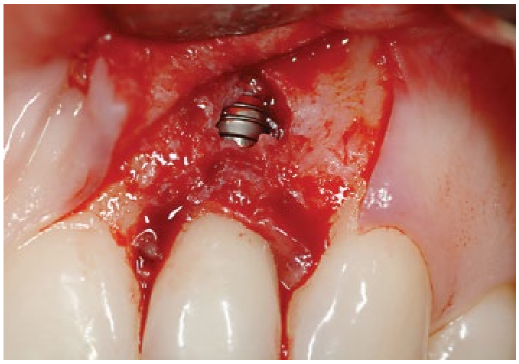

Figure 20.23 **(B)** Retained cement has resulted in extensive bone loss at the implant–abutment interface. Note crestal granulation tissue and thread exposure apical to this.

Design and cementation

The guidelines for zirconia crown dimensions are essentially the same for natural abutments and implants, effectively allowing room for adequate veneering porcelain application. The substructure copings of the crowns for zirconia crowns, if they are to be fully veneered, require anatomic designs and not just thimble-like shapes, which will result in unsupported veneering porcelain. Figure 20.24A–J shows ideal abutment design and cement-line position, which, coupled with careful placement of a retraction cord, minimizes the risk for subgingival cement trapping. Figure 20.25A–E shows a simple bench-top method to ensure adequate, but not excessive, cement before intraoral introduction to the abutment.[109]

Modified axial wall designs may allow better venting during cementation, thus allowing the crown to seat more fully. It can also minimize the cement thickness, which has been shown, at least in the case of zinc phosphate, to improve the retention of

Figure 20.24 **(A)** Facial view: provisional restoration inserted at the time of implant placement.

Figure 20.24 **(B)** Occlusal view: provisional restoration before elimination of eccentric contacts/guidance.

Figure 20.24 **(C)** Three months postsurgery: developed tissue as defined by the provisional restoration.

Figure 20.24 **(D)** Occlusal view 1: zirconia abutment delivered and torqued to 35 N cm. A retraction cord has been placed below the margin to deflect excess cement away from the sulcus.

Figure 20.24 **(E)** Occlusal view 2: complete visualization of the retraction cord.

Figure 20.24 **(F)** Insertion of the definitive crown. Note that cement is not spilling out of the crown as adequate, but not excessive, cement has been placed in the crown.

Figure 20.24 **(G)** Minor cement expulsion as the crown is fully seated.

Figure 20.24 **(H)** Cement is trapped and introduction to the sulcus limited by the cord.

Figure 20.24 **(I)** Removal of the retraction cord with adherent cement.

Figure 20.24 **(J)** Definitive restoration as viewed postoperatively.

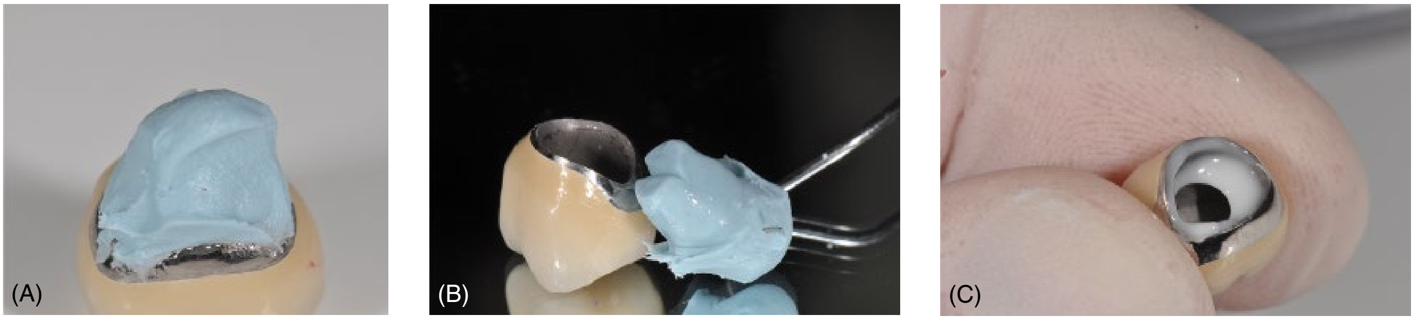

Figure 20.25 **(A)** Bite registration paste introduced into the restoration. **(B)** Retrieved impression of the intaglio surface of the definitive restoration. A notch is cut into the occlusal to create space for a cement to ensure sufficient, but not excess, volume. **(C)** Cement is introduced into the crown.

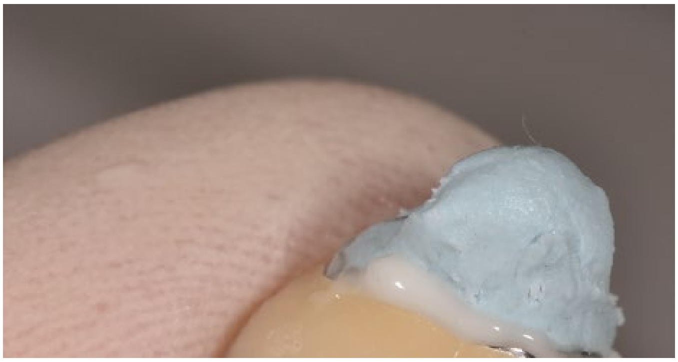

Figure 20.25 **(D)** Reintroduction of the bite registration index. Note that excess cement is expressed extraorally.

the crown. The cement layer must spread along the entire axial wall and margin of the abutment to achieve maximum retention.[110] In addition, resin cements show higher peak loads (better fracture resistance) than temporary cements or resin-modified glass ionomers, resulting in increased retention, better marginal adaptation, and less microleakage.[111] For effective bonding of zirconia to titanium or to zirconia itself, a cement containing methacryloyloxydecyl dihydrogen phosphate, adhesive, or silane or the use of tribochemical silica coating such as CoJet™ (3 M ESPE) or air particle abrasion with 30–50 μm aluminum oxide particles are recommended as these materials and techniques can improve the bond strength.

Figure 20.25 **(E)** Removal of the impression material reveals adequate and well-distributed cement. The crown is now ready for intraoral introduction to the abutment.

Lithium disilicate glass-based ceramics (e.max®, Ivoclar Vivadent, Liechtenstein), which allow surface modification through hydrofluoric acid etching, exhibit excellent clinical performance as a metal-free ceramic in restoration of the natural dentition and implants.[112,113] The etching of the glass results in additional adhesive strength, improving the fracture resistance of the crown, provided the zirconia abutment surface can be

Figure 20.26 **(A)** Etchable lithium disilicate (EMAX, Ivoclar Vivadent, Lichtenstein) and a nonetchable full-contour (Wieland Zeno-Tec, Mannheim, Germany) zirconia crown.

Figure 20.26 **(B)** Both restoration materials produce excellent esthetic results.

similarly modified. This material can be either stained in monolithic form or partially veneered in nonfunctional areas to improve esthetics.

More recently, manufacturers have improved the esthetic appearance of zirconia with increased translucency without having to add veneering feldspathic porcelain. Monolithic zirconia can be conventionally cemented and essentially can provide a fracture-free solution, particularly in the posterior regions of the mouth where isolation for resin bonding is more difficult. This has been described as the "full contour" or monolithic zirconia crown.[114,115] Figure 20.26A and B compares etchable lithium disilicate (e.max, Ivoclar) and a nonetchable zirconia crown (Wieland Zeno-Tec, Mannheim, Germany). Note that the esthetic results of the crowns are similar. Of importance, the full contour zirconia crown is virtually three times as strong as the lithium disilicate crown, making it a superior material for use in high-load areas such as molar regions or in individuals displaying parafunctional activities.

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Appendix A Esthetic Evaluation Form Summary

The esthetic evaluation form is a tool for the clinician to identify the esthetic problem, visualize a solution, and then choose the appropriate technique. To *Identify the problems* and visualize the solution through a three-step analysis of the macro- and micro-esthetics and function, we use the Esthetic Evaluation Form as an esthetic checklist, digital pictures, and mounted study casts. We *Visualize the solution* through a diagnostic wax-up of the mounted study casts, and via intraoral mock-up. Once the solution is visualized, we *Choose the appropriate technique*, which means the most conservative option that will achieve your esthetic goals. The key objective of the Esthetic Evaluation Form is to establish the incisal edge position and the gingival margin of the maxillary central incisor, two critical landmarks while focusing on three views, facial, dentofacial and dental.

Ronald E. Goldstein's Esthetics in Dentistry, Third Edition. Edited by Ronald E. Goldstein, Stephen J. Chu, Ernesto A. Lee, and Christian F.J. Stappert.

Aesthetic Evaluation Form©

Patient ________________________ Examiner ________________________ Date __________

1. Effective Questions

:A: If there was anything you could change about your smile, what would it be?

____

____

:B: Do you like the visual image of "Straight, White, Perfect", "Clean, Healthy, Natural", or "White and Natural" looking teeth?

____

____

:C: History of Aesthetic Change

____

____

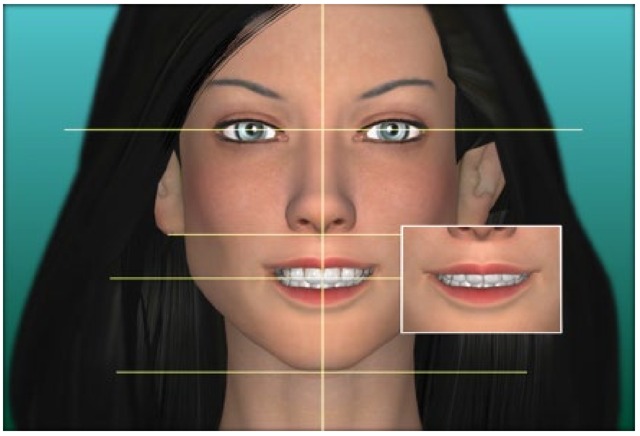
:D: Previous Records – Do you have any photos of your smile, or any smile you like, to aid in aesthetic treatment planning?

○ Yes ○ No

2 Facial Analysis

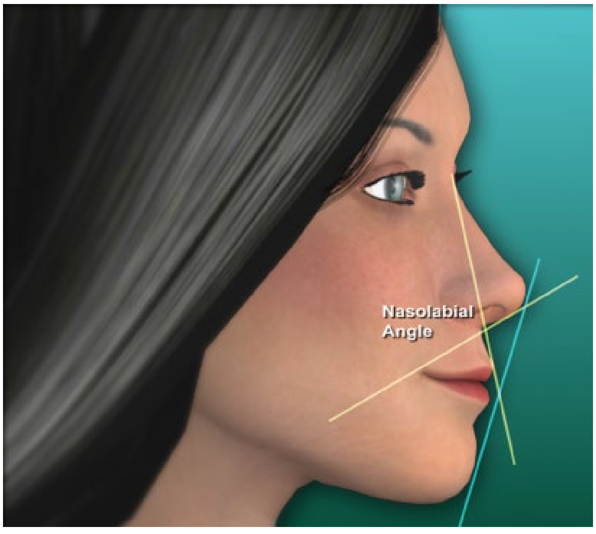
:A: Full Smile

1. **Interpupillary Line to Occlusal Plane**
   - ○ Parallel
   - ○ Canted right
   - ○ Canted left
2. **Midline Relationship of Teeth** (Maxillary) **to Face** (Philtrum)
   - ○ Coincident
   - ○ Right of center
   - ○ Left of center
3. **Relationship of Lips to Face** (Lip Symmetry)
   - ○ Symmetrical
   - ○ Left side higher
   - ○ Right side higher



:B: Lips at Rest

1. **Upper Lip**
   - ○ Full
   - ○ Average
   - ○ Thin
2. **Lower Lip**
   - ○ Full
   - ○ Average
   - ○ Thin
3. **Lips**
   - ○ Prominent
   - ○ Retruded
4. **Tooth Exposure at Rest:**
   Maxillary _____ mm
   Mandibular _____ mm



:C: Profile View: Facially – Directed Treatment Planning

1. **Nasolabial Angle**
   - ○ Normal (approx. 90°)
   - ○ Prominent Maxilla (<90°)
   - ○ Retruded Maxilla (>90°)
2. **Ricketts E-Plane** (Drawn from tip of nose to chin)
   Upper Lip to E-Plane _____ mm (ideally 4 mm)
   Lower Lip to E-Plane _____ mm (ideally 2 mm)
3. **Profile Shape**
   ○ WNL ○ Convex ○ Concave

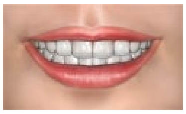
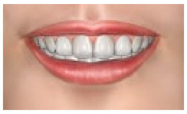
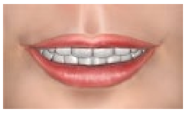
If maxilla is prominent, nasolabial angle is < 90°, or profile is convex, consider smaller, less dominant maxillary anterior restorations.

If maxilla is retruded, nasolabial angle is > 90°, or profile is concave, consider more dominant maxillary anterior restorations.

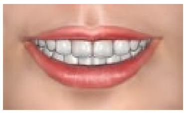
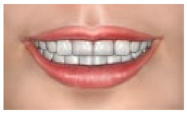
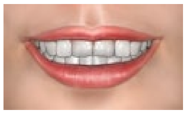
Aesthetic Evaluation Form created by Jonathan B. Levine, DMD

3. Dentofacial Analysis – Vertical and Horizontal Components

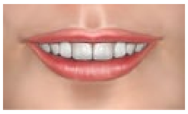
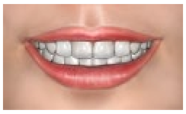
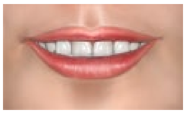
:A: Upper Smile Line

○ Average

○ High

○ Low


:B: Incisal Edges to Lower Lip

○ Convex Curve

○ Straight

○ Reverse


:C: Tooth – Lower Lip Position

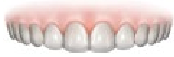
○ Touching

○ Not Touching

○ Slightly Covered


:D: Full Smile – Number of Teeth Displayed

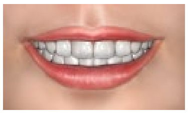
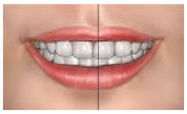
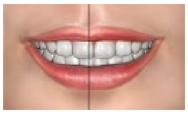
○ 6

○ 8

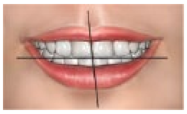
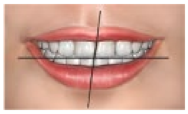
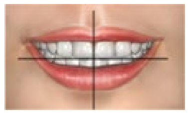
○ 10

○ 12


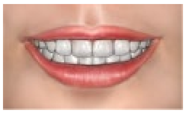
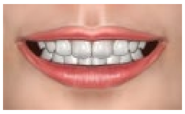
:E: Midline Location – Central Incisors to Philtrum

○ Center

○ Right of Center

○ Left of Center


:F: Midline – Skewing to Left or Right

○ Right

○ Left

○ Straight


:G: Bilateral Negative Space

○ Normal

○ Increased


:H: Phonetics

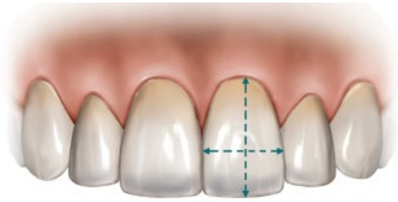
1. **F** Sounds - Incisal edge of maxillary centrals on wet/dry line of lower lip?
   ○ Yes ○ No
2. **S** Sounds - Closest speaking space – clear sound?
   ○ Yes ○ No

4. Dental Analysis

:A: Starting shade

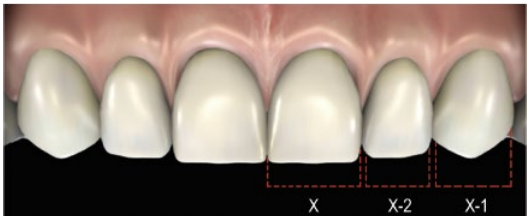
Maxillary _____
Mandibular _____

:B: Central Incisor Width/Height Ratio



○ > 80% ○ < 80%

:C: Proportion of Central/Lateral/Canine



Central Width: _____ mm
Lateral Width: _____ mm
Cuspid Width: _____ mm

:D: Occlusal Analysis

1. Complete Occlusion

Interferences: ___________
____
____
____

2. Incisive Position

Interferences: ___________
____
____
____

3. Left Working

Interferences: ___________
____
Guiding teeth: ___________
____

4. Right Working

Interferences: ___________
____
Guiding teeth: ___________
____

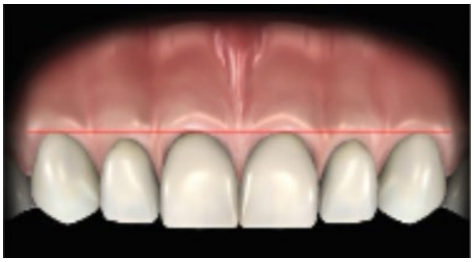
Aesthetic Evaluation Form created by Jonathan B. Levine, DMD

:E: Micro-Aesthetic Elements: Acceptable or Not?

1. Incisal Edge Position ○ Yes ○ No

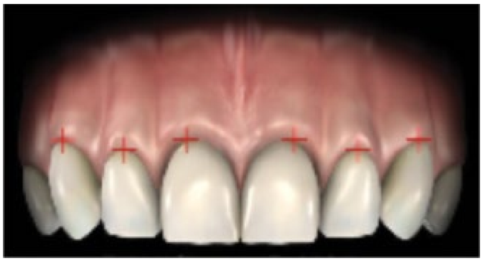
Proposed changes: ______________________
____
____

2. Soft Tissue Symmetry ○ Yes ○ No



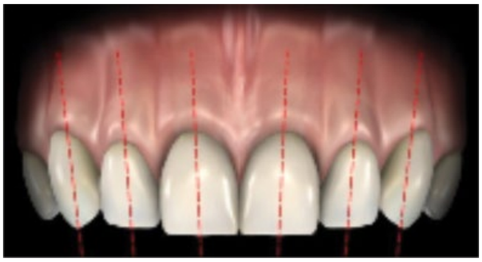
Proposed changes: ______________________
____
____

3. Zenith Positions ○ Yes ○ No



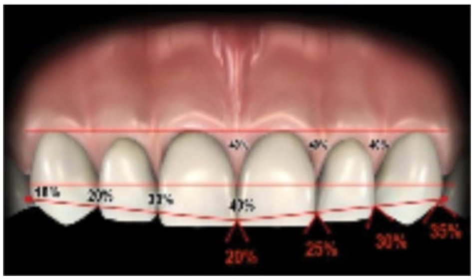
Proposed changes: ______________________
____
____

4. Axial Inclination ○ Yes ○ No



Proposed changes: ______________________
____
____

5. Embrasures and Contacts ○ Yes ○ No

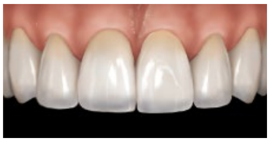


Proposed changes: ______________________
____
____

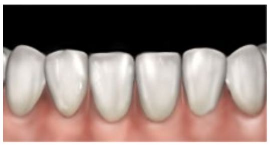
6. Texture and Edge Contour ○ Yes ○ No

Proposed changes: ______________________
____
____

:F: Diagnostic Wax-Up Information



Proposed Max. Central Incisor Length:
_____ mm
Proposed Max. Central Gingival Position:
____



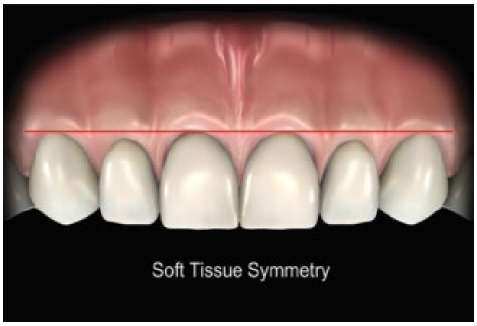
Proposed Mand. Central Incisor Length:
_____ mm
Proposed Mand. Central Gingival Position:
____

Additional Notes to Guide Diagnostic Wax-Up:
____
____
____
____
____
____
____

Aesthetic Evaluation Form created by Jonathan B. Levine, DMD

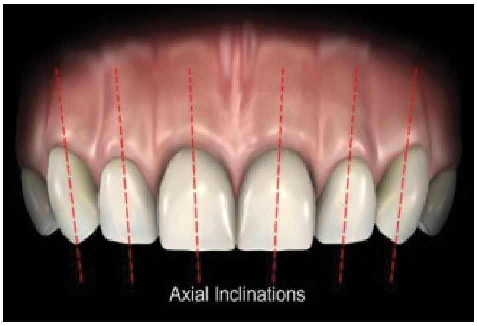
Esthetic Evaluation Form. Micro Esthetics

☐ a ☐ n/a

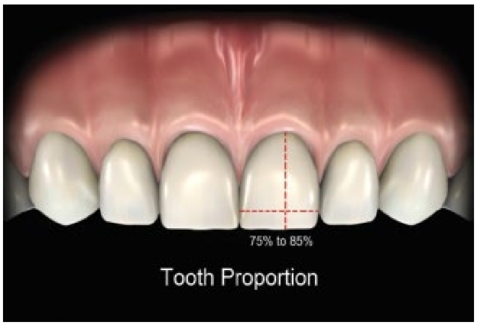


☐ a ☐ n/a

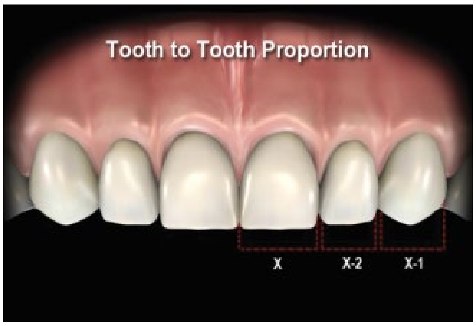
☐ a ☐ n/a



☐ a ☐ n/a

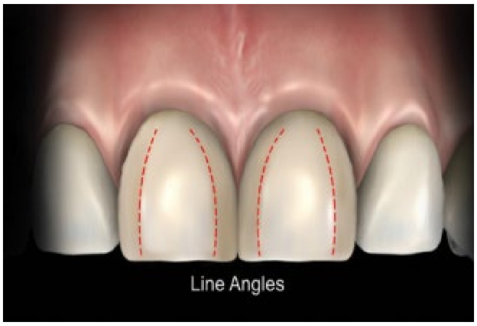


☐ a ☐ n/a

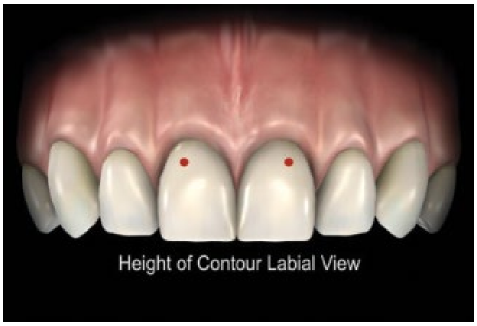


☐ a ☐ n/a

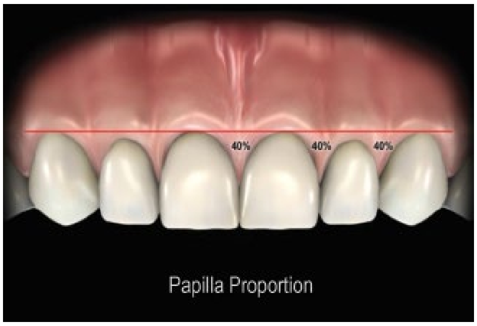
Aesthetic Evaluation Form created by Jonathan B. Levine, DMD and Anabella Oquendo, DDS



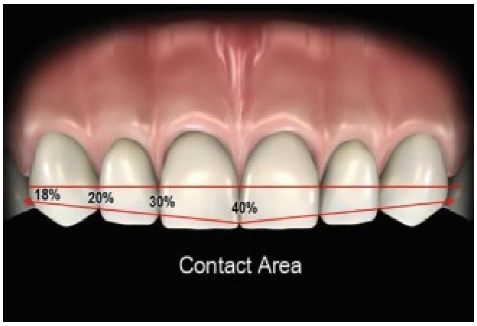
☐ a ☐ n/a



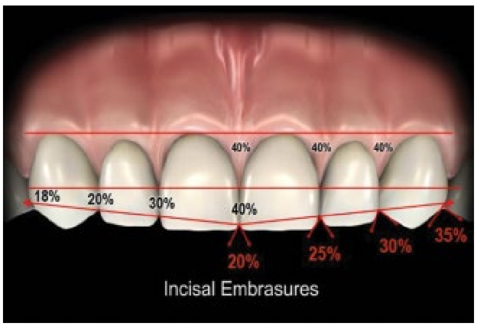
☐ a ☐ n/a



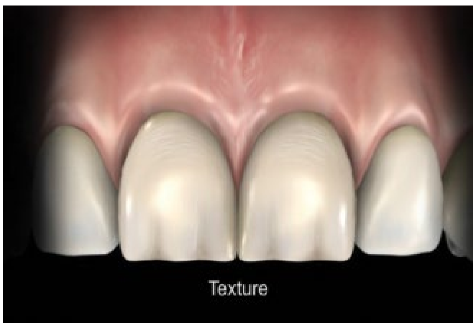
☐ a ☐ n/a



☐ a ☐ n/a



☐ a ☐ n/a



☐ a ☐ n/a

Appendix B The Functional-Esthetic Analysis

Ronald E. Goldstein's Esthetics in Dentistry, Third Edition. Edited by Ronald E. Goldstein, Stephen J. Chu, Ernesto A. Lee, and Christian F.J. Stappert.

FOR ______________________

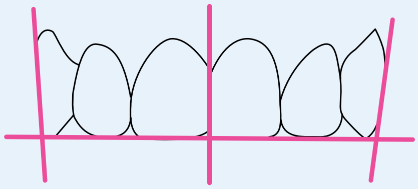
DUE ______________________

DR. ______________________

UPPER ANTERIORS

INCISAL PLANE

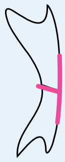
☐ ALIGNED WITH BENCH-TOP
☐ SAME AS MOUNTED CAST OF TEMPS
☐ CENTRAL EMBRASURE VERTICAL



INCISAL EDGE POSITION

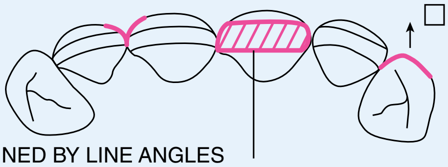
☐ FOLLOW E/O CAST
☐ COPY CAST of TEMPS
☐ COPY CAST of ORIGINAL

☐ NO CONTACT
☐ LABIALS ALIGNED IN PROTRUSIVE EDGE-TO-EDGE with AG TABLE



LABIAL EMBRASURES

☐ FORMED BY CONVEX PROXIMALS



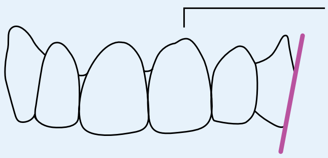
☐ CUSPID MES-LAB LINE ANGLE FACES FORWARD

☐ INCISAL EDGES OUTLINED BY LINE ANGLES

☐ ______________________

EMERGENCE CONTOUR

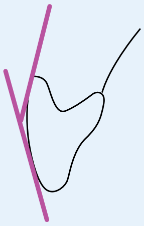
☐ STRAIGHT or CONCAVE
☐ FOLLOW TISSUE MODEL
☐ NO BULGE AT MARGIN
☐ ALL SPACES CLOSED

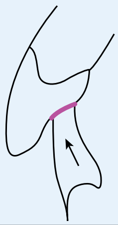


☐ TRIGONAL SHAPE ON PONTICS
☐ GINGIVAL MARGIN SAME AS TEMPS
☐ CUSPID PROFILE

LABIAL CONTOUR

☐ ALIGNED WITH ALVEOLAR CONTOUR
☐ 2 PLANES FOR LABIAL CONTOUR
☐ COPY TEMPS



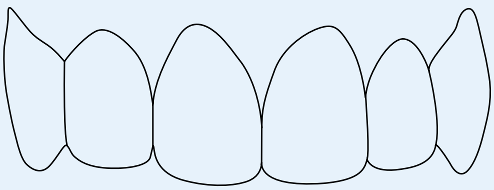


☐ DEFINITE STOP FOR LOWER ANTERIORS

☐ NO CONTACT

☐ SPECIAL INSTRUCTIONS

☐ SHADE INSTRUCTIONS



☐ CHECK CONTACTS ON SOLID MODEL

LOWER ANTERIORS

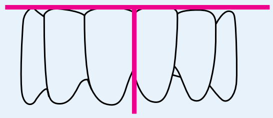
FOR ____________________

DUE ____________________

DR. ____________________

INCISAL PLANE

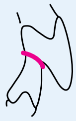
☐ COPY CAST of TEMPS
☐ INCISAL PLANE aligned with bench top
☐ LABIAL EMBRASURES aligned with VERTICAL
☐ ____________________



INCISAL EDGE POSITION

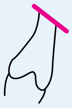
☐ FOLLOW E/O CAST
☐ COPY CAST of TEMPS
☐ COPY CAST of ORIGINAL

☐ INCISAL EDGES MEET DEFINITE STOP
☐ NO ANTERIOR CONTACT



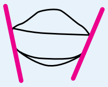
INCISAL EDGES CONTOUR

☐ OUTLINED BY LINE ANGLES

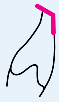


☐ INCISAL EDGE HIGHER ON LINGUAL

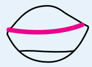
☐ INCISAL EDGE WIDER AT LINGUAL



☐ DEFINITE LABIO-INCISAL LINE ANGLE

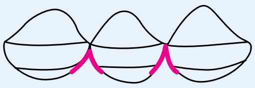


☐ LINGUAL STRAIGHT or SLIGHTLY CONCAVE



LABIAL EMBRASURES

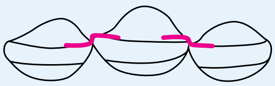
☐ FORMED BY CONVEX PROXIMAL SURFACES



☐

LABIAL SILHOUETTE

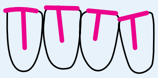
☐ FORM SLIGHT OFFEST OF INCISAL EDGES



☐

INCISAL EDGES SILHOUETTE

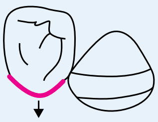
☐ FORM SLIGHT ANGULATION OF FLAT EDGES
☐ PATIENT WANTS EVEN



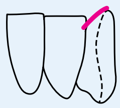
☐

CUSPID

☐ MES-LAB LINE ANGLE POINTS FORWARD



☐ SHOW LINGUAL OF CUSPID FORM LABIAL VIEW



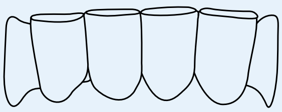
EMERGENCE CONTOUR

☐ RELATE TO SOFT TISSUE MODEL
☐ NO METAL EXPOSED
☐ PORCELAN MARGIN
☐ METAL EXPOSURE OK

LABIAL CONTOUR

☐ RELATE LABIAL CONTOUR TO E/O
☐ TO CAST OF ORIGINAL
☐ TO CAST OF TEMPS
☐ NO BULGE AT MARGIN

☐ SPECIAL INSTRUCTIONS



☐ SHADE INSTRUCTIONS

☐ CHECK CONTACTS ON SOLID MODEL

Esthetic Checklist ©1984 Peter E. Dawson, DDS

UPPER POSTERIORS

FOR ______________________

DUE ______________________

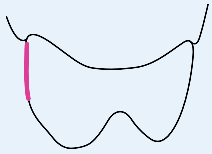
DR. ______________________

PLANE OF OCCLUSION

☐ ALIGN with BENCH
☐ COPY CAST of TEMPS
☐ COPY CAST of ORIGINALS
☐ ______________________

EMERGENCE CONTOUR

☐ USE TISSUE MODEL
☐ NEARLY VERTICAL
☐ STRAIGHT or SLIGHTLY CONVEX

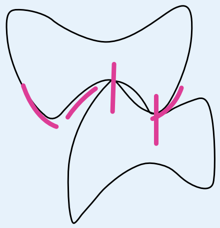


BUCCAL CONTOUR

☐ OVERJET for CHEEK BITING PROTECTION
☐ TAPER BUCCAL CONTOUR IN
☐ CUSP TIP CONTACT (NO SURFACE to SURFACE)

LINGUAL CONTOUR

☐ TAPER LINGUAL INTO OCCLUSAL
☐ PROTECTION for TONGUE BITING



OCCLUSAL CONTOUR

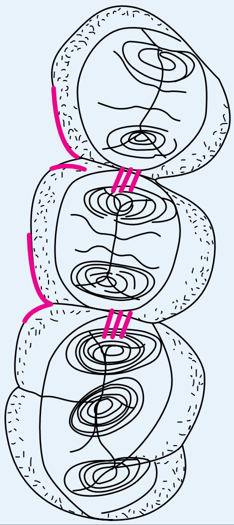
☐ CONTOURS TAPER IN TO OCCLUSAL TABLE

☐ DEFINITE GROOVES

☐ MARGINAL RIDGES ALL EVEN

☐ BUCCAL SURFACES ALL ALIGNED

☐ FOSSAE OPENED FOR CUSP TIP

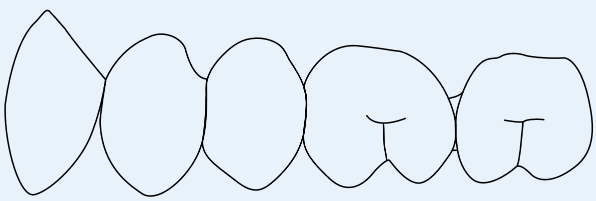


☐ SPECIAL INSTRUCTIONS

CONTACTS

☐ CHECK on SOLID CAST
☐ EACH CONTACT PROTECTS INTERDENTAL PAPILLA

☐ SPECIAL INSTRUCTIONS



☐ SHADE INSTRUCTIONS

☐ INDIVIDUALIZED CUSPS
☐ SHOW NO METAL in INTERPROXIMAL
☐ SHOW NO METAL at MARGIN
☐ METAL DISPLAY AT MARGIN OK
☐ CLOSE SPACES

FOR ____________________

DUE ____________________

DR. ____________________

LOWER POSTERIORS

PLANE of OCCLUSION

☐ COPY CAST of TEMPS
☐ ALIGN WITH BENCH
☐ DON'T ALTER
☐ USE FLAG
☐ ____________________

CUSP TIP POSITION

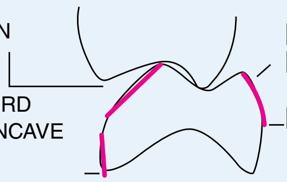
☐ AS MARKED ON UPPER CAST
☐ ALGIN with CENTRAL GROOVE OF UPPER
☐ ____________________

FOSSAE CONTOUR

☐ CR CONTACT ONLY
☐ USE FOSSA GUIDE
☐ ____________________

BUCCAL CONTOUR

☐ TAPER IN FOR CHEEK BITING PROTECTION
☐ HEIGHT OF CONTOUR AT JUNCTION of LOWER THIRD
☐ STRAIGHT or SLIGHTLY CONCAVE EMERGENCE CONTOUR
☐ VERTICAL EMERGENCE

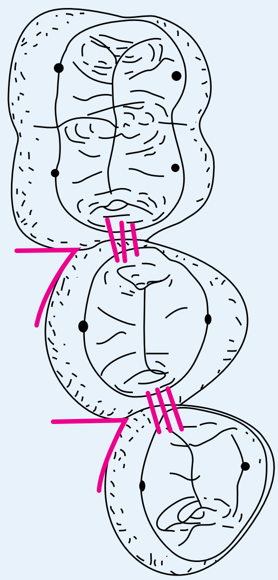


LINGUAL CONTOUR

☐ TONGUE BITING PROTECTION
☐ TAPERED IN/ON LINGUAL
☐ CORRECT LINGUAL HEIGHT of CONTOUR

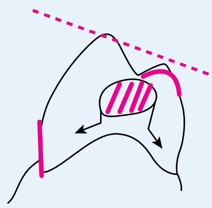
OCCLUSAL CONTOUR

☐ CONTOURS TAPER IN TO OCCLUSAL TABLE
☐ DEFINITE GROOVES
☐ MARGINAL RIDGES ALL EVEN
☐ FOSSAE OPENED FOR CUSP TIP CONTACT ONLY
☐ BUCCAL SURFACES ALIGNED and PARALLEL
☐ MESIAL 1/3 ALIGNED FACING FORWARD



FIRST PREMOLAR

☐ LINGUAL CUSP of FIRST PREMOLAR KEPT LOW

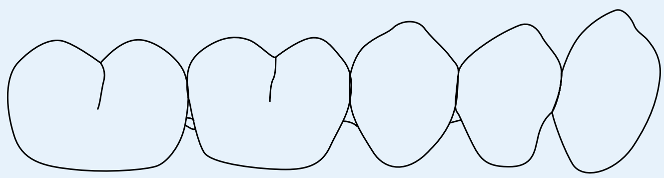


CONTACTS

☐ EACH CONTACT PROTECTS INTERDENTAL PAPILLA
☐ CHECK on SOLID CAST

☐ SPECIAL INSTRUCTIONS

☐ SHADE INSTRUCTIONS



☐ INDIVIDUALIZED CUSPS
☐ SHOW NO METAL IN INTERPROXIMAL
☐ SHOW NO METAL AT MARGIN
☐ METAL DISPLAY AT MARGIN OK
☐ CLOSE SPACES

THE FUNCTIONAL-ESTHETIC ANALYSIS

Are the TM Joints stable and healthy? Can they comfortably accept maximal load testing?	If '**Yes**' proceed with checklist.
	If '**No**' treat joint first.

5 Requirements for Occlusal Stability	Yes/No	Treatment Options
When in centric relation are there stable stops on **all teeth** or a substitute?		
Is the anterior guidance in harmony with the envelope of function? (CR contact to incisal edges)		
Is there immediate disclusion of the posterior teeth in protrusion?		
Do all the posterior teeth on the balancing side disclude during excursion toward the midline?		
Do all teeth on the working side disclude with the anterior guidance? ☐ *Group function may be indicated in cases of a compromised working side cuspid or implant in the cuspid site.*		

6 Elements of Global Esthetics	Yes/No	Treatment Options
Does the patient have an acceptable maxillo-mandibular relationship in centric relation (Face, Airway, Bite)?		
Is the embrasure between the centrals parallel with the midline and perpendicular to the occlusal plane?		
Is the lower posterior occlusal plane in harmony with the lower incisal plane?		
Are the vertical and horizontal edge positions of the maxillary central incisors related to the **inner** vermillion border (wet/dry line) of the lower lip?		
Is the buccal corridor (transverse relationship) within normal limits?		
Is the display of gingiva acceptable when smiling?		

6 Macro Esthetic Goals	Yes/No	Treatment Options
Is the gingival architecture appropriate and balanced?		
Are teeth 6-11 in proper proportion and contra-lateral balance?		
Is the width-to-length ratio of the central incisors 75-85%?		
Is the papillary position acceptable (without black triangles)?		
Are the axial inclinations of the anterior teeth acceptable esthetically?		
Is the depth of the incisal embrasures appropriate and do they graduate from anterior to posterior?		

Treatment options: Reshape, Reposition, Restore, Reposition a boney segment

Appendix C Laboratory Checklist

LABORATORY CHECKLIST

M. FRADEANI G. BARDUCCI

Patient ______ Age ______ Date ___ / ___ / ___ ☐ Male ☐ Female

ESTHETIC INFORMATION

PATIENT'S PHOTOGRAPH

PATIENT'S PHOTOGRAPH

PATIENT'S PHOTOGRAPH

PHOTOGRAPHS ☐ Old ☐ New

SMILE LINE ☐ Average ☐ Low ☐ High

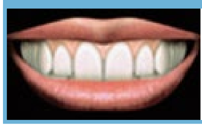
ALIGNMENT ☐ Yes ☐ No

APPEARANCE ☐ Youth ☐ Adult ☐ Mature

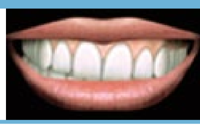
TOOTH TYPE  ☐ Ovoid  ☐ Triangular  ☐ Square

TEXTURE **Macro** ☐ None ☐ Slight ☐ Pronounced **Micro** ☐ None ☐ Slight ☐ Pronounced

OCCLUSAL PLANE vs COMMISSURAL LINE – HORIZON

 ☐ Parallel

 ☐ Slanted right — Maintain ☐ Modify ☐

 ☐ Slanted left — Maintain ☐ Modify ☐

Indicate modifications: Mark with + to lengthen and – to shorten

(mm) 16 ___	15 ___	14 ___	13 ___	12 ___	11 ___	21 ___	22 ___	23 ___	24 ___	25 ___	26 ___	(mm)
(mm) 46 ___	45 ___	44 ___	43 ___	42 ___	41 ___	31 ___	32 ___	33 ___	34 ___	35 ___	36 ___	(mm)

Notes ______

COLOR

Shade Guide

☐ Vita ☐ 3D Master

☐ Ivoclar ☐ Other ______

Spectrophotometer

☐ Yes ☐ No

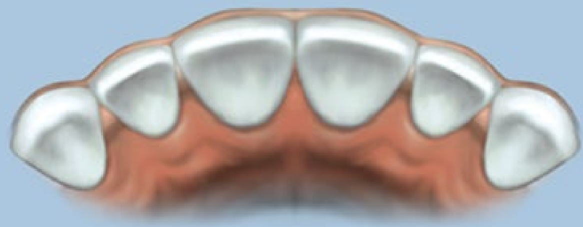
Value

High ☐ ☐ ☐ ☐ ☐ Low

Notes ______

This Laboratory Checklist is courtesy of Mauro Fradeani, MD, DDS; and Giancarlo Barducci, MDT
From: "Esthetic Rehabilitation in Fixed Prosthodontics" Vol 2, Quintessence Pub. 2008.

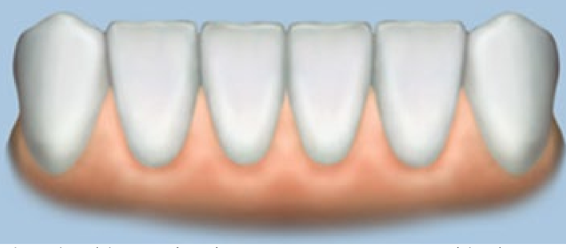
SHAPE	Modifications	POSITION

13 lengthen/shorten (mm)	widen/narrow (mm)	labial/palatal (mm)
12 lengthen/shorten (mm)	widen/narrow (mm)	labial/palatal (mm)
11 lengthen/shorten (mm)	widen/narrow (mm)	labial/palatal (mm)
21 lengthen/shorten (mm)	widen/narrow (mm)	labial/palatal (mm)
22 lengthen/shorten (mm)	widen/narrow (mm)	labial/palatal (mm)
23 lengthen/shorten (mm)	widen/narrow (mm)	labial/palatal (mm)

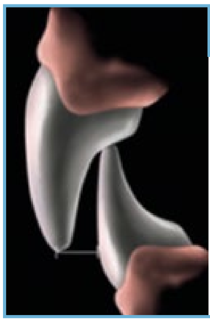
Notes

SHAPE	Modifications	POSITION



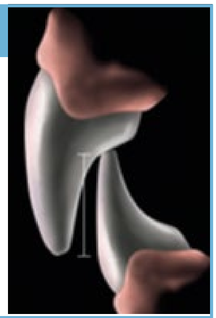

43 lengthen/shorten (mm)	widen/narrow (mm)	buccal/lingual (mm)
42 lengthen/shorten (mm)	widen/narrow (mm)	buccal/lingual (mm)
41 lengthen/shorten (mm)	widen/narrow (mm)	buccal/lingual (mm)
31 lengthen/shorten (mm)	widen/narrow (mm)	buccal/lingual (mm)
32 lengthen/shorten (mm)	widen/narrow (mm)	buccal/lingual (mm)
33 lengthen/shorten (mm)	widen/narrow (mm)	buccal/lingual (mm)

Notes



OVERJET	Modifications	OVERBITE
☐ Confirmed		☐ Confirmed
☐ Decreased (mm)		☐ Decreased (mm)
☐ Augmented (mm)		☐ Augmented (mm)

Notes



FUNCTIONAL INFORMATION

STONE CASTS

- ☐ **Previous**
  - ☐ Maxillary ☐ Mandibular
- ☐ **Diagnostic**
  - ☐ Maxillary ☐ Mandibular
- ☐ **Provisional**
  - ☐ Maxillary ☐ Mandibular

OCCLUSAL RECORDS

☐ MI ☐ CR ☐ Protrusive interocclusal record ☐ Lateral interocclusal records

VERTICAL DIMENSION

- ☐ Unchanged
- ☐ Increase (mm) ______
  - ☐ Maxillary (mm) ______
  - ☐ Mandibular (mm) ______
- ☐ Decrease (mm) ______
  - ☐ Maxillary (mm) ______
  - ☐ Mandibular (mm) ______

FACEBOW

☐ Arbitrary ☐ Kinematic

Reference lines

☐ Horizon ☐ Interpupillary ☐ Commissural ☐ Other ______

ARTICULATOR SET-UP

- ☐ **Semi-adjustable**
  - ☐ Condylar inclination (degrees) ______ OR ☐ Protrusive interocclusal record
  - ☐ Progressive mandibular lateral translation (degrees) ______ OR ☐ Lateral interocclusal records
  - ☐ Immediate mandibular lateral translation (mm) ______
- ☐ **Fully adjustable**
  - ☐ Mechanical pantograph
  - ☐ Electronic pantograph

DISOCCLUSION

☐ Incisal guidance ☐ Canine guidance ☐ Group function ☐ Balanced occlusion

IMPRESSION

Recorded on_____/_____/_____ Time _____:_____ Disinfected with ______

Impression materials

- ☐ **ALGINATE**
  - ☐ Maxillary ☐ Mandibular
- ☐ **POLYETHER**
  - ☐ Maxillary ☐ Mandibular
- ☐ **ADDITION SILICONE**
  - ☐ Maxillary ☐ Mandibular
- ☐ **POLYSULFUR**
  - ☐ Maxillary ☐ Mandibular
- ☐ **CONDENSATION SILICONE**
  - ☐ Maxillary ☐ Mandibular
- ☐ **OTHER** ______
  - ☐ Maxillary ☐ Mandibular

DOCUMENTATION

CASE HISTORY

- ☐ Contagious diseases
- ☐ Confirmed allergies
- ☐ Other medical device present
- ☐ Psychomotor handicap
- ☐ Bruxism
- ☐ Other ______

Notes ______

ATTACHMENTS

☐ Slides/Photographs ☐ Esthetic Checklist ☐ Other ______

LABORATORY WORK ORDER

Dr name ______	Dental lab name ______
Address ______	Address ______
City ______ State ______	City ______ State ______
Telephone ______	Telephone ______

Date____/____/____ **Work order no.**______

Patient/Code______ **Age**______ ☐ Male ☐ Female

TYPE OF WORK

☐ Diagnostic waxing ☐ Indirect mock-up ☐ Provisional ☐ Fixed prosthesis ☐ Removable prosthesis

Description ______

SCHEMA

o = *Natural abutment* ☐ = *Implant* **X** = *Missing tooth*

❶ 18	17	16	15	14	13	12	11	21	22	23	24	25	26	27	28 ❷
❹ 48	47	46	45	44	43	42	41	31	32	33	34	35	36	37	38 ❸

PFM: *Porcelain-fused-to-metal*
MCM: *Metal-ceramic margin*
AC: *All-ceramic*
PS1: *Presoldering*
CS: *Ceramic shoulder*
RB: *Resin-bonded*
PS2: *Postsoldering*
PC: *Post and core*
V: *Veneer* **IN:** *Inlay*
MM: *Metal margins*
ABU: *Abutment*
ON: *Onlay*

Alloy: ______

Ceramic: ______

COLOR

Shade Guide

☐ Vitapan
☐ 3D Master
☐ Ivoclar
☐ Other ______

Value

High ☐ ☐ ☐ ☐ ☐ Low

TRY-INS

Try-in ______	Date____/____/____	Notes: ______	☐ Attachment No. ______
Try-in ______	Date____/____/____	Notes: ______	☐ Attachment No. ______
Try-in ______	Date____/____/____	Notes: ______	☐ Attachment No. ______
Delivery ______	Date____/____/____	Notes: ______	☐ Attachment No. ______

Dentist's signature ______

Appendix D Pincus Principles

Dedication

Dr Charles L. Pincus and I met for the first time in 1959 at the International Symposium in Knokke-Sur-Mer, Belgium, where we were the only Americans lecturing. From the beginning, a rapport was established and a friendship began that was to grow and endure until the day of Charlie's death on September 4, 1986.

As mentor as well as friend, Charlie nurtured my interest in esthetic dentistry in the early years of our friendship. In fact, had it not been for my strong family ties in Atlanta, I might have accepted his early invitation to enter practice with him in Beverly Hills. I did manage, however, to attend every course he taught and received much personal instruction.

Some 10 years later, I suggested to Charlie the need for a multidisciplinary organization comprising people who shared an interest in esthetic dentistry and who envisioned the important role it would play in the future of the profession. Together, we identified a group of approximately 50 leading dental educators and founded the American Academy of Esthetic Dentistry. That academy became the inspiration and stimulus for a worldwide expansion in esthetic dentistry, including the establishment of numerous other academies focusing on the same discipline, as well as the International Federation of Esthetic Dentistry.

In view of the pioneering contributions of this leader in the field, it is appropriate that we include some of the important principles that Charles Pincus taught the profession over the years. At the end of this chapter, Dr Pincus's autobiographical history, "The Development of Dental Esthetics in the Motion Picture Industry," appears. Thus, it is with a great deal of pride, nostalgia, and fond memories that I present this chapter.

Early contributions

Although his first published article appeared in a 1938 issue of the *Journal of the California Dental Association*,[1] Dr Charles Pincus actually began pioneering esthetic dentistry techniques some 10 years earlier when he was asked to solve a threefold problem presented to him by the heads of the makeup departments at Twentieth Century Fox and Warner Brothers Motion Picture Studios (see end of this appendix).

The problem stemmed from the emerging technology of talking movies, a technology that focused the camera and thus, the audience's attention, on the actors' mouths to a much greater extent than in silent movies. The makeup executives needed procedures for: (1) improving the photographic appearance of the actor's mouth; (2) developing appliances that would change the visual appearance of the performer, such as when playing Count Dracula or Frankenstein; and (3) creating esthetic restorations that would not degrade the quality of speech or be a hindrance to the actor. Although some work had been done in the area, it was altogether useless in the new "talkies."

Thus, Charles Pincus began the work that would consume much of his career and launch the field of esthetic dentistry. One of Dr Pincus's major contributions was to recognize the important principles of how teeth play a role in mouth personality. He also realized the vital role played by light reflection, surface texture, and tooth contour. He taught the basics of these theories throughout his career, constantly reminding us of how important they are in preventing esthetic failure. The remainder of this chapter is a distillation of the legacy he bequeathed to us.

Ronald E. Goldstein's Esthetics in Dentistry, Third Edition. Edited by Ronald E. Goldstein, Stephen J. Chu, Ernesto A. Lee, and Christian F.J. Stappert.

Creation of mouth personality

Typically, dentists emphasize patient treatment outcomes related to function, articulation, and the like, with significantly lesser regard for the esthetic outcomes that affect the patient's visual personality. Said another way, many in our profession perceive the role of dentistry as functioning in three dimensions to achieve rehabilitation of the mouth. Factors associated with the dimensions of physiologic, biologic, and mechanical functions are the traditional concerns. The fourth dimension of effective mouth rehabilitation includes those psychologic factors that can be critically important to the self-concept of the patient.

Although their devotion to technical perfection is commendable, most dentists need to develop a greater sensitivity to the value of an attractive smile and the benefits it may hold for the patient. The opposite of the positive personality resulting from a smile that shows an even row of natural, white teeth is the inferiority felt by those with crooked, unattractive teeth. They tend to cover their mouths during speech or move their lips unnaturally to cover their teeth. This lack of confidence frequently accounts for the difference between success and failure in the lives of many people.

The importance of mouth personality is exemplified by the movie industry. Stars are provided with state-of-the-art makeup and costumes to maximize their attractive faces and figures. Writers and directors develop scripts for them that enable them to achieve precisely the desired dramatic effect. Yet, the entire illusion can be lost when those perfect lines proceed from a mouth full of crooked, protruding, or ill-spaced teeth. In realizing this, motion picture executives require that every prospective star have his or her mouth personality brought up to a level comparable to the actor's dramatic ability. Thus, while the need for attractive dental features among movie stars is obvious, the less obvious fact is that the same benefits are appreciated by the public. The effective dentist is the one who combines sensitive understanding of patient needs with knowledge of the principles of esthetic technique.

The importance of light

Basic to the practice of successful esthetic dentistry is a working knowledge of the properties of light. Unfortunately, there seems to be too little consideration given to this critically important factor. We must consider three characteristics of light if we expect to achieve superlative results with porcelain:

1. Direction of light
2. Movement of light
3. Color of light.

The direction and movement of light cast shadows and are the basic factors in the creation of cosmetic illusions. By varying the contour and facets on tooth surfaces we alter and affect the direction of light reflection. Shadows are created that are the basis of tooth illusion, as they affect porcelain restorations. As an example of the character of direction in light reflection, the shadows created are varied by the silhouette form of the teeth and the concavities and convexities of the enamel surface. Variation in the silhouette form can alter the color of the background by variation in the angle of lighting. The concavities and convexities of the enamel surface determine, partly, the surface texture, which influences the intensity and character of the reflected light by the way the surface absorbs or reflects the light. Shadows are used to dramatize a lighted area. The general lighting in one area may be deliberately played down by a darker shade of tooth or by darkening the interproximal areas as they curve into the contact areas. As an illustration, for an anterior fixed partial denture restoration, where insufficient depth can be attained interproximally to create the desired depth of shadow, the porcelain shade should be darkened interproximally to simulate the shadow, and thus create an illusion of depth.

Surface texture

Porcelain crowns and bridges should be fabricated so that the surface texture, including the convexities and concavities, matches the enamel surfaces of the adjacent natural teeth. This reproduces the characteristics of light reflection inherent in the patient's natural dentition (Figure D.1A and B). One of the very important things accomplished is lowering the value of the shade to the correct value for those teeth.

The character of color in light reflections

Tissue color—the color of the lips, cheeks, tongue, palate, and gingiva—reflects against and affects the color of the teeth. This causes variations in the appearance of the color and shade of the teeth. A high palatal vault will increase the translucency of a tooth with a thin incisal edge. With anterior porcelain restorations we grind away the linguoincisal and replace it with a translucent porcelain to simulate this very natural appearance when appropriate. When taking the shade, the hue, value (brilliance or amount of gray), and chroma (saturation) should be differentiated and matched. Concentrate on the tooth for only 5 s intervals, so as not to allow the phenomenon of adaptation of the retina of the eye to induce fatigue wherein all the shades tend to gray into one another. A florid (reddish) complexion will induce your judgment toward a green cast, while the patient with a sallow (yellowish-green) complexion will influence you toward a red cast. Also remember that the gingival color will influence your selection as well. With a dark gingiva you are apt to pick a shade that is too light. A light gingiva will usually result in a darker shade by contrast. The gingival tooth shade must be adapted to the influence of the gingival color. Pure north light or color-corrected fluorescent lighting is believed to reproduce shades and colors more accurately (Figure D.2). The final shade in the mouth should be checked with the patient in dynamic action. This is because a speaking patient affects the light reflections from the tooth surfaces differently (see Chapter 10).

The character of movement in light reflection

The movements of the lips, cheek, and tongue strongly influence light reflection. It varies with the differences in the width of the arch form of the teeth and the width of the vestibule. The narrower the arch form, as a rule, the wider the vestibule of

Figure D.1 **(A)** This patient with occlusal problems and broken teeth needed a metal framework to reinforce the porcelain.

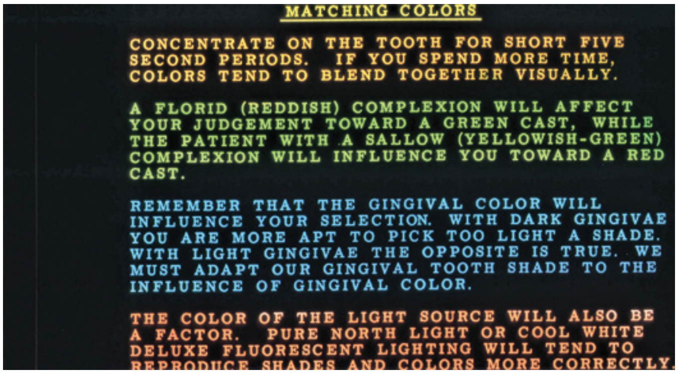


Figure D.2 Dr Pincus used bright colors in his teaching slides to illustrate his principles. Here, four tips were offered about matching colors.

the cheek; and the light reflections will create more shadows posteriorly, so that the shade of the posterior porcelain teeth should be lightened. The wider the arch form, the narrower is the vestibule, so that very little or no shadows are produced by the light reflections on the teeth. As an example, a decalcified, whitish area added to a bicuspid crown in a narrow arch with a wide vestibule should be boldly placed, as otherwise it will not be visible in the mouth. The same addition in a mouth with a wide arch and a narrow vestibule requires a delicate placement to preclude it standing out role like a headlight. This explains why so often the insert, which looked so good on the model, defeats its purpose in the mouth. All of these factors must be communicated to the knowledgeable technician to ensure a superlative porcelain result.

Influence of contours on esthetic results

The contours affecting appearance

We create illusions to obtain the appearance of larger, smaller, longer, or shorter teeth in the same place. This is achieved in part by varying the outline or silhouette form, thus changing the character of light as the result of the direction and movement of light. To illustrate what is meant by the outline or silhouette form, consider that the mesial and distal highlights or marginal ridges of a maxillary central incisor tooth curve lingually from the ridges to the contact areas, reflecting light mesially or

Figure D.1 **(B)** Four ceramometal crowns were constructed by Dr Pincus for this patient. Note how the delicate texture breaks up the light reflection for a more natural light.

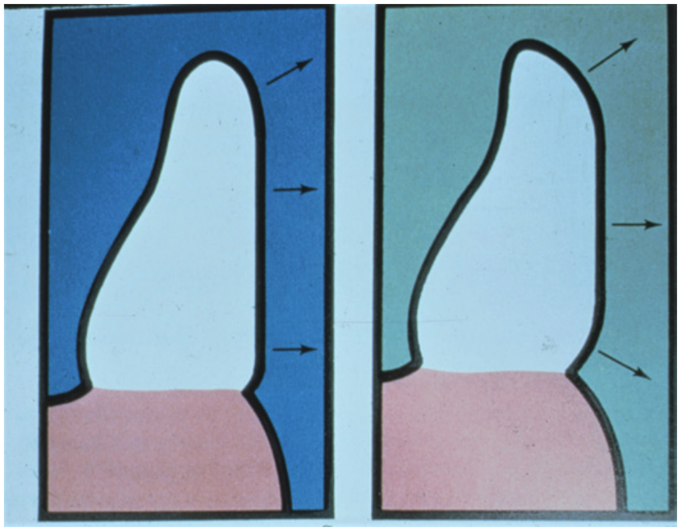


Figure D.3 This illustration shows how changing the contour of the labial surface alters the light reflection to make the tooth appear longer.

distally to the sides. The cervical one-fifth of the tooth curves lingually into the gingival sulcus, reflecting light upward. The incisal one-fourth curves lingually, reflecting and shadowing the light downward. When we speak of the outline or silhouette form of a tooth we describe that portion of a central incisor that reflects light forward or anteriorly. By reducing the portion of the tooth reflecting light forward, the silhouette form, we create the illusion of a smaller or shorter tooth in the same space. By enlarging the portion of the tooth reflecting light forward, the silhouette form, the illusion of a larger or longer tooth results (Figure D.3).

Incisal edge contour should conform to the dynamic action of the lips. This is checked in the mouth with the wax try-in. If one side of the lip raises more in speaking and smiling, the incisal line should also be raised on that side to make certain the teeth do not appear longer. Also check the median line. At the initial appointment, well before the restoration is started, it should be observed and noted whether the patient has a low, medium, or high lip line to determine how much gingiva is revealed.

Covering the exposed roots of the teeth can transform a simple case to one so difficult as to tax to the utmost the ability of the most skilled cosmetic dentist to obtain a superlative result.

The surface texture of the enamel

The convexities and concavities of the porcelain break up the surface and vary the reflection of light to a brilliance (value) that can be compared to the facets on a diamond. An actress with protrusive teeth, for example, photographed normally on screen because in dynamic action the lower anterior teeth did not allow the lower lip to fall under the upper teeth during speaking and smiling. Another actress with the same amount of protrusion photographed on screen with teeth extremely protrusive due to the lower anterior teeth being retrusive; this allowed the lower lip to hook under the upper teeth, thus exaggerating the defect. Contours have much effect on not only esthetic results but also on biologic and physiologic results, making it important not to overlook this area.

Basic cosmetic principles to achieve ultimate beauty in porcelain

a. Do not build on quicksand. Treat and resolve all inflammatory reactions and unstable periodontal conditions and allow healing before preparations are started. Sometimes it may require only a prophylaxis, other times several periodontal treatments.
b. Create models. In the parlance of the theatre, full-mouth casts should act as a "dress rehearsal" for the exact mouth preparations. Prepare the teeth on plaster or stone models as though you are working on a vital tooth, keeping in mind the relationship of the pulp to the preparation so as to retain vitality. After preparing, wax-up the correction on the study model. Very often it will be found that too much tooth structure was eliminated where it was not necessary, and not enough where it was important for the correction. In this way, we will know in advance each step in the preparation in the mouth to conservatively achieve the ideal porcelain correction.
c. Avoid tissue insults. In other words, do not injure the gingival tissues or periodontal fibers in preparation, impression taking, or treatment with chemicals before cementing. Otherwise, you may start a pattern of tissue recession that, once started, is difficult to stop. There are, of course, times when the preparation will include removing the epithelial lining of a periodontal pocket as part of the treatment plan. In most cases there should be "bloodless cutting"; no hemorrhaging during preparation.
d. Adapt the movement, color, and direction of light reflections to achieve the necessary illusions through varying the outline or silhouette form. Achieve the correct surface texture of the enamel for value in color. Adapt the placement and intensity of characteristic inserts to the presence of a wide or narrow vestibule of the cheeks.
e. Use a cast of soft resilient plastic to enable you to reproduce the gingival tissue and thus achieve the correct contour that will be biologically compatible with the soft tissues.
f. Have a wax try-in in the mouth to verify the fit of the pontics, the contact points, the length of the teeth, and arch form in relation to the dynamic action of the lips and illusions created.
g. The margins of the restoration should fit perfectly with appropriate contours to adequately deflect food and to provide support, not pressure, to the sulcular tissues (pressure would initiate a pathologic reaction). All of the margins and contours should be biologically compatible with the surrounding tissues.
h. The articulation should be free of prematurities, with the correct centric relation, and should not produce trauma to either the hard or soft tissues. To avoid additional stress on the investing tissues of the teeth by ceramometal restorations, create narrow occlusal tables with occlusal markings parabolic in form for minimal surface contact.
i. Proper maintenance, including a balanced diet (low in refined carbohydrates, high in protein), proper brushing, plaque control, vitamin and mineral supplements, and regular check-ups are vital to long-term success. The objective is good resistance and reparative ability, which is the greatest preventive factor of all.
j. The proximal surfaces should be properly contoured to allow a sufficient gingival papilla to regenerate or to be maintained (Figure D.4A). As much as possible, the crown contours should simulate the ideal physiologic pattern that existed, hopefully, before tooth preparation (Figure D.4B).

    Three faults that can commonly occur during tooth preparation are illustrated in Figure D.4C:

    1. Insufficient reduction of finish line.
    2. Insufficient reduction on gingival half.
    3. Insufficient rounding of buccal surface and linguo-occlusal line angle.

Interdisciplinary communication

Dentistry in general, and esthetic dentistry in particular, can greatly benefit from assuming an interdisciplinary perspective. There are many benefits that could result from a knowledgeable dialogue between the various disciplines. Some examples are:

1. Where a short lip would expose the entire gingival area in speech and smile, a knowledgeable dentist can try to prevent a future gingivectomy by recommending a conservative subgingival curettage or a conservative flap operation first.
2. When you have a short upper lip and maxillary anterior protrusion, correct the protrusion rather than extract the teeth. This will avoid the loss of the maxillary anterior ridge and prevent the creation of another dental cripple. Many of us have sweated blood and tears trying to arrive at an esthetic result on a similar case that had been irreparably ruined.

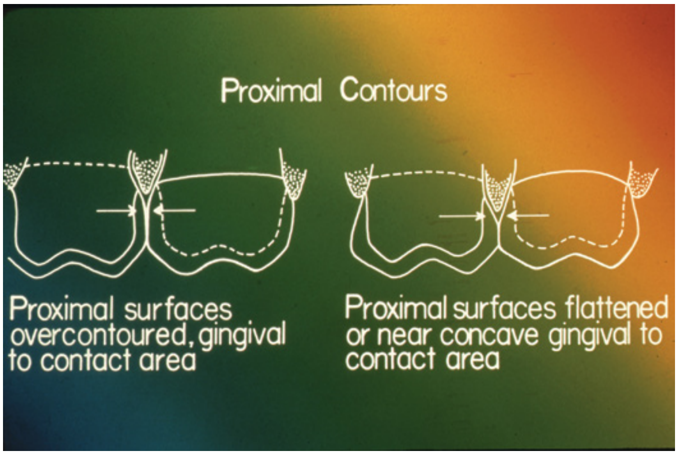


Figure D.4 **(A)** The proximal surface must be carefully planed and contoured to avoid impinging upon the gingival papilla.

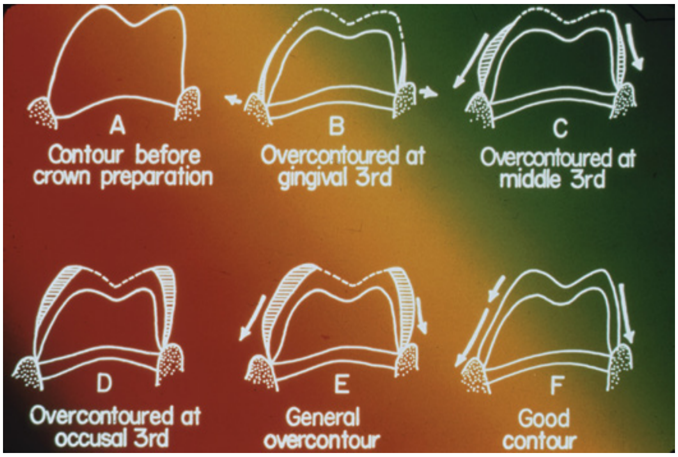


Figure D.4 **(B)** One of the most difficult tasks is to properly contour a full-crown replacement. This illustration shows proper contouring and the four common types of overcontouring.

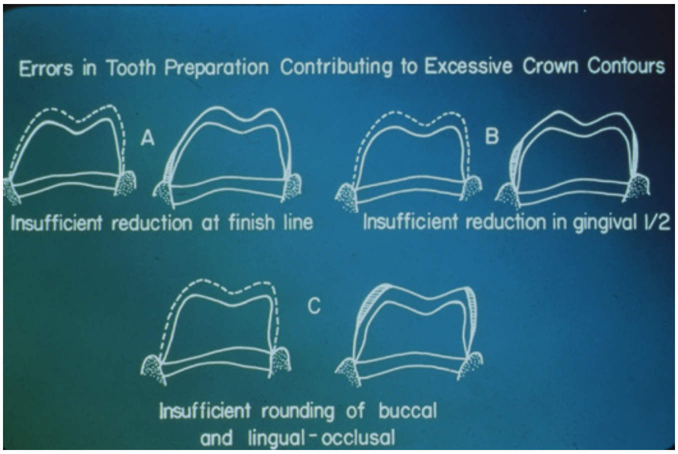


Figure D.4 **(C)** Errors in tooth preparation are a major factor in excessive crown contours.

We must stress cooperation and discussion among the various disciplines in advance of work being done! Intelligent discussion between experts from various disciplines could result in several additional choices for the cases described above; for example:

1. If the patient has sufficient time, adult orthodontics would be a good choice.
2. If the patient does not have the time for adult orthodontics and there is enough pulp recession to sufficiently shorten the teeth so that proper preparation can restore a cosmetic arch form, then crowning the teeth would be the restoration of choice.
3. In extreme cases, it would be good dentistry to treat the teeth endodontically, building the dowels lingually, so that the crowns may be placed in an esthetically pleasing arch form.

In these ways, a cosmetic result is achieved while retaining all the alveolar bone to keep normal lip support and actions.

Porcelain or plastic?

The use of porcelain crowns has been criticized by some dentists because of the frailty of the material. The reason for such frailty is that most dentists resort to porcelain only when the tooth has been badly broken down. By failing to build up the tooth with a casting in order to achieve a normal preparation to support the porcelain against stress, these dentists encounter breakage. Porcelain is only as strong as its underlying support. In contrast, acrylic crowns are much stronger and more resistant to breakage. When used on broken teeth, the preparation should be built up with a platinized gold casting.

Attention to detail

The single most important consideration when building mouth personality is attention to detail. The superior dentist, whose work stands apart from that of his average peers, is one who pays particular attention to every small detail, and it is this that explains why two dentists using exactly the same procedure will produce outcomes that are perfect in one case and marginal or unacceptable in the other. Although in the latter case we may believe we are following the procedure exactly, we may actually miss several tiny items, the sum of which results in a product that is less than we could have achieved had we painstakingly addressed each one.

Procedures for building mouth personality

Building mouth personality includes using one or more of the following five procedures:

1. **Porcelain or acrylic veneers.** Porcelain or acrylic veneers are thin facings that improve the appearance of incorrectly spaced, short, rotated, protruded, or retruded teeth. They were used exclusively in motion picture work, as they have very little strength to withstand the stresses induced by eating and other functions of daily living. In addition to improving the appearance of the actor's teeth, veneers are also used to build up teeth for the purpose of filling out narrow, sunken cheeks.
2. **Fixed porcelain or acrylic crown and bridge restorations (full-mouth reconstruction).** Although dentists may use the word "permanent" to describe porcelain or acrylic crown and bridge restorations, its use is misleading. Experienced clinicians understand that there are simply too many uncontrolled variables that can break down these esthetic restorations, such as a sudden and sustained craving for sweets that results in widespread caries in a patient who had been heretofore relatively free of caries, or psychosomatically induced breakdowns in healthy mouths brought on by anxiety and stress. Although these variables and others like them are the patient's responsibility, it is only ethical for the dentist to inform the patient when such a situation exists that might tend to break down esthetic restorations. They may prefer choosing a stronger, albeit less esthetic, material.
3. **Improving arch appearance.** Improving arch appearance is achieved through a combination of restorative procedures and cosmetic reshaping of the natural teeth (rounding cusp angles, shortening tooth lengths, etc.).
4. **Orthodontia.** Orthodontia may be easily accomplished with good results in children and adolescents in whom alveolar bone tissue is quick to regenerate. In general, adults do not respond as well, due in part to faulty bone regeneration that creates a predisposition to periodontosis. It is imperative for dentists, therefore, to identify the need for orthodontia during childhood. Patients who experienced previous root resorption secondary to orthodontia, hypothyroidism, or unknown causes usually can be esthetically corrected with porcelain crowns.
5. **Full or partial denture restorations.** Full and partial denture restorations constitute the final category of esthetic procedures that can be employed to build mouth personality. The emphasis in this appendix is on crown and bridge restorations and improving arch appearance, so if you want to study the various techniques included in this category, they are described in detail elsewhere in the dental literature.

The use of study models in treatment planning

The recommended starting point for patients needing esthetic treatment is to make a thorough diagnosis and treatment plan. The next step is taking an impression from which casts of both upper and lower jaws are poured and mounted for study. As mentioned earlier, the involved teeth are prepared and then correctly built up in wax in order to study the results that might be achieved and to ascertain the need for additional preparation. In this way, you can avoid excessive and unnecessary destruction of tooth structure. Full-mouth X-rays are always obtained at the start of the process; and in more extreme cases, additional radiographs are obtained at intervals in order to note the ever-closer proximity to the pulp as tooth structure is removed.

Frequently, 2–3 mm or more of tooth structure may be removed, especially in cases of excessive overbite with a short lip and recessive pulp. In contrast, patients with abnormally high and wide pulps may require shallow preparation in order to prevent death of the pulp. In these cases, the temporary crowns may be worn for as long as 2 years, during which time the pulp has time to safely recede, before making the final preparations.

A common mistake when treating widely spaced teeth with porcelain or acrylic crowns is to fill the entire space with only one crown, which typically results in a more unsightly outcome than the original problem. To create the best mouth personality, we must strive for a perfect, natural appearance that defies detection (Figure D.5A–C). Thus, just as abnormal spaces should be corrected by working with the teeth on either side of the space, protrusion should be corrected by bringing the protruded tooth in lingually and the adjacent retruded tooth (or teeth) out labially. Multiple tooth correction requires careful advance planning. One tooth may require more reduction on the distal surface to make room for a normal-sized tooth adjacent to it. Often the central incisor on one side is normally positioned with respect to the median line, and the other is responsible for most of the space. Again, with advanced planning and common sense, these situations can easily be corrected.

Conclusion

In addition to the benefits that accrue to the patient through the use of esthetic procedures, the benefit of an enhanced practice accrues to the dentist. Even simple procedures, such as rounding off long, sharp cusps to create a "softer" effect, will generate much enthusiasm in the patient. Such enthusiasm cannot help but result in loyalty and referrals. Thus, the clinician can enjoy expanded financial rewards and derive the personal satisfaction that comes from knowing that a patient's deep concern for his or her appearance has been met.

Figure D.5 **(A)** Dr Pincus taught that spaced teeth need to each be proportionally restored rather than create teeth that are too wide by treating only one or two of the teeth. Here, a patient with multiple spaces is shown.

Figure D.5 **(B)** Four teeth were ideally prepared for full crowns. This patient was treated years before more conservative restorations (such as bonding with composite resin or porcelain/laminates) were available.

Figure D.5 **(C)** The final result shows four symmetrically placed, full porcelain crowns. Note how good the tissue response was to well-performed esthetic dentistry.

The development of dental esthetics in the motion picture industry[1]

Charles L. Pincus, DDS

Esthetic or cosmetic dentistry is actually the fourth dimension in addition to the biologic, physiologic, and mechanical factors—all of which must be achieved for the successful result. As one of the individuals responsible for the initial concepts and growth of esthetics, it might not be amiss for me to detail how it came about. Cosmetic dentistry was first brought to my attention around 1928 by Ern and Perc Westmore, who were then the executive heads of the makeup departments of Twentieth Century Fox and Warner Brothers Motion Picture Studios, respectively. They were referred to me with their problems by the top executives of the Max Factor makeup company who were patients of mine. Talking pictures were being born. Great dramatic stars were being imported from the legitimate stage and later from Europe. Quality in every phase of motion picture production was being stressed. Their requests were threefold:

1. They needed to know how to improve the photographic appearance of the mouth.
2. They wanted some form of appliance to change the visual appearance of the performer where a characterization (Dracula or Frankenstein) or dual role was required.
3. Most important was the fact that restorations could not interfere with speech or make the performer conscious of something foreign in the mouth, thereby affecting his dramatic ability.

Some crude work had been done in the past. However, this was completely unacceptable with the advent of sound and the emergence, as from a chrysalis, of motion pictures as a true art form. To solve their dilemma I pioneered and refined the "false front" we called veneers, now known as "Hollywood facings." These were very thin porcelain facings that were baked in a contour to cover the spaced, turned, or twisted teeth, so as to give the appearance of well-rounded arch form with normally positioned teeth, thus preventing the teeth from photographing black on screen. They were placed upon the teeth before the

[1] Originally written as an appendix for *Esthetics in Dentistry*, first edition, this section is reprinted here for its historical value.

actor appeared on camera, for interviews, or for personal appearances and were removed afterward. Ern and Perc Westmore were joined in their problems with me by a number of executive makeup heads (Jack Pierce of Universal Pictures, Jack Dawn of Metro-Goldwyn-Mayer, Clay Campbell of Columbia Pictures, and Mel Burns of RKO Studios). These men were the creative giants among the pioneers whose basic techniques formed the cornerstones that are responsible for so many of the makeup advances to date. We were called upon to look at screen tests at the studios and to recommend and produce the necessary changes. These improvements allowed the audience to focus on the beautiful performance presented by the actor or actress instead of being distracted by the defects in the mouth. Knowledge and techniques advanced with each challenge. For example, we learned that it was a simple matter to correct the arch form by placing facings on the two maxillary central incisors where they were in extreme lingual retrusion. Unfortunately, in covering the teeth to the incisal edge they would appear unduly long because the entire surface reflected light forward instead of only the gingival half, as before. Hence, it became necessary to bevel the incisal portion of the veneer from about 4 mm gingivally to the incisal edge of the natural central, so that a portion of the light would be reflected downward, thus creating the needed shorter appearance. This was the basis for all our subsequent work on illusions, varying tooth contours to change the light reflections and silhouette form, thereby making teeth appear longer, shorter, wider, or narrower in the same approximate space. It was also found that it was possible to cover short protrusive maxillary teeth from the lingual, lengthening the teeth without additional protrusion, and sometimes the correction of sibilation when it was present. Techniques were also evolved for shortening, evening, and recontouring teeth through judicious grinding with carborundum stones and Joe Dandy discs followed by polishing with fine sandpaper and crocus discs. In many instances this allowed mandibular buckled teeth to photograph normally on screen. Because of the time factor for performers, and the fact that "adult orthodontics" was not a technique of orthodontists in those days, a need arose for replacing long-term orthodontic therapy with simple and rapid techniques of illusion; hence, techniques for contouring turned or twisted anterior teeth or correcting diastemas were developed. The sum of all these experiences led to improved jacket crown restorative contours.

In Warner Brothers' *Man of Two Faces*, Edward G. Robinson played a dual role. In order to maintain suspense, a Frenchman had to be unrecognizable until the final scene. This posed quite a problem because of the short, square jaw, and thick lips that showed no teeth during speech or smile that were so unmistakably Robinson. Maxillary and mandibular removable castings were fabricated, opening the vertical dimension to create an elliptical face and longer teeth. Porcelain facings were placed so that teeth would show when he spoke and smiled. The makeup artist took over from there. Metro-Goldwyn-Mayer was in much the same difficulty with Lionel Barrymore in *Devil Doll*. He was to be disguised as a woman in a portion of the picture. The difficulty lay in the fact that the Barrymore characteristics were so strong that, in the screen test in his female disguise, he looked exactly like his sister, Ethel Barrymore. (As a matter of fact, as he was walking from the makeup department to the sound stage in female costume a mutual acquaintance who had just arrived from New York, rushed across the street calling him Ethel!) Impressions had to be taken on the set at the studio, as the picture was in production. A denture was constructed that modified the appearance of the lower third of his face. Much of the knowledge of what to avoid during contouring for natural-looking teeth was gleaned from these radical departures.

We were under contract to Twentieth Century Fox to ensure that Shirley Temple's mouth personality photographed the same in every film while she was a child star, regardless of the stage of primary tooth loss or eruption of the permanent teeth. It was vital that no picture production time be lost, as this would cost many thousands of dollars. The replacements varied from temporary dentures or very thin gold castings for retention with porcelain facings replacing missing teeth, to porcelain facings completely covering the partially erupted dentition. The latter were changed to labial facings as the teeth finally erupted.

Some motion pictures required character restorations to lend authority. A Twentieth-Century-Fox production *This Is My Affair* was about Theodore Roosevelt and his era. To create Roosevelt's protrusive and toothy appearance, and so create character authenticity, an appliance was constructed to overlay Sydney Blackmer's perfect arch of teeth. Thus, the teeth were lengthened and the arch widened without making him look too grotesque or stagey on camera and without interfering with his speech. Another character was built for Henry Hull in Universal Studios' *Great Expectations*, from the Charles Dickens classic. In this instance it was vital that there be a protrusive, bulldog effect of the lower jaw. For Paramount Studios' *The Years Are So Long*, starring Beulah Bondi and Victor Moore, we created a typical mouthbreather type of tooth protrusion for a brother and sister who were supposed to possess the same family characteristics. We were called upon to make the teeth for Frankenstein, Dracula, and the Wolf Man, and from the grotesque learned what not to do for the beautiful. Out of this motion picture proving ground emerged so many of the principles that contribute to the many beautiful results achieved today by the competent esthetic dentist.

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PART 4
ESTHETIC PROBLEMS OF INDIVIDUAL TEETH

Chapter 21 Management of Stained and Discolored Teeth

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Discoloration and staining is a topic of special interest to many dental patients; however, it has not received as much attention in the contemporary scientific literature. Much of the discussion about dental diseases and discolorations dates back to the middle of the last century, and the latest review on the topic was published in 2001 by Watts and Addy, being the only readily available review since 1975.[1] This only highlights the importance of dentists being able to answer the numerous questions that are posed by patients seeking whiter teeth.

Each year, millions of individuals change toothpaste, purchase ineffective preparations, and even change their dentists in their quest for "whiter teeth." Many an attractive smile is marred by some discoloration or stain, either on an individual tooth or on all teeth (Figure 21.1A and B). There are many causes and

Ronald E. Goldstein's Esthetics in Dentistry, Third Edition. Edited by Ronald E. Goldstein, Stephen J. Chu, Ernesto A. Lee, and Christian F.J. Stappert.

Figure 21.1 **(A)** The first line of defense for staining is bleaching.

Figure 21.1 **(B)** Bleaching plus bonding with direct composite resin was done to improve this lady's smile.

corresponding treatments for these stains and discolorations. The dentist needs to be able to correctly diagnose the cause of discolorations, as it is crucial for a successful treatment outcome. Some treatments must be performed in the dental office, some can be performed at home by patient, and some are a combination of home and office treatments.

Types of stains: causes and treatment options

Generally, stains can be divided into extrinsic (located on the outside of the tooth) and intrinsic (located within the tooth). Moreover, extrinsic stains can become intrinsic over time. Hence, stains can originate from the outside in or from the inside out. The clinical appearance can be in a variety of colors. Table 21.1 provides a summary of tooth discoloration and associated conditions. Some examples of these different discolorations can be seen in Figures 21.2A and B, 21.3, and 21.4. In addition, the discoloration can be either of a generalized nature or specific to one tooth or one location on a tooth (Table 21.2).

A number of treatment options should be considered, in order of increasing aggressiveness (Table 21.3).

Stains and discolorations caused by tooth defects

Dental Caries

Dental caries is one of the chief causes of unsightly tooth stains. The progress of caries can be evaluated visually, tactually, and radiographically. In direct lighting, incipient lesions may appear as dull, chalky white areas where the enamel has been decalcified and has lost its translucency. Interproximal decay may be seen as a gray area deep to the marginal ridge of the affected surface. Recurrent decay may also be seen as a gray area adjacent to the margin of a defective restoration. Viewed with transillumination (Addent), proximal lesions on anterior teeth can be seen as shadows.

As the lesion progresses, the decalcified area becomes stained with food and bacterial debris. The discoloration can vary from light to dark brown (Figure 21.5). The degree of discoloration depends on how long the decay process has been active in the tooth. Therefore, the earlier the treatment, the smaller the chance of tooth staining. For this reason, radiographs should be taken, periodically, of all patients.

Discolored deep grooves

Diagnosis for decay is difficult in deep grooves. If there is a possibility, first use an air-abrasive or hard-tissue laser (Solea) to remove the organic pellicle and any caries present and then either fill or seal the tooth rather than merely watch the area.[2] Patients who complain about discolored grooves will be better served with a highly filled tinted or opaque sealant rather than a clear sealant through which the groove can be seen. In addition, clear sealants that were chemically cured may exhibit an amber or yellow discoloration over time and require replacement (Figure 21.6). Prior to the placement of a sealant, the grooves should be cleaned of organic matter.[3] The cleaning of grooves can be mechanically accomplished by use of a #1/4 round bur in a high-speed handpiece, hard-tissue laser or air abrasion. Placing 3% hydrogen peroxide in the grooves is a chemical option to debride the grooves.[4] If peroxide is used, the cessation of bubbling will indicate that the grooves are clean. A caries detection agent (Seek Caries Indicator, Ultradent Products), a laser (DIAGNOdent, KaVo; Cariescan), or a high-intensity light illuminator can all aid in detecting caries. A sealant should then be placed to prevent further staining. Some sealants have acetone water chasers to improve the bond to the enamel (UltraSeal, Ultradent Products).

Stains caused by leakage around restorations

Stains around restorations are usually the result of simple leaks (Figure 21.7A and B). These restorations should be replaced. Unfortunately, dentists tend to leave in amalgam and other restorations entirely too long, perhaps to satisfy the patient's desire for a "permanent restoration" or out of fear of the patient's displeasure at having to spend additional fees to replace restorations. Many patients arriving for examination have the same request: "Don't find anything." Most patients have as little desire

Table 21.1 Common Discolorations and Associated Causes

Tooth Discoloration	Associated Condition
Yellow	Aging Calcific metamorphosis Loss of vitality Tetracycline ingestion Amoxicillin syrup Stannous fluoride Imipenem for cystic fibrosis Amelogenesis imperfecta
Opaque	Fluorosis Sickle cell anemia Osteogenesis imperfecta
White	Fluorosis Chronic kidney failure Hypomineralization
Brown	Fluorosis Smoking Coffee Soy sauce Cola Tea Calcific metamorphosis Loss of vitality Chlorhexidine ingestion Iron Tetracycline ingestion Antitartar toothpaste Osteogenesis imperfecta Chlorhexidine glucamate (Hibitane) disinfectant Tannic acid Ochronosis Dental materials
Black	Occupational: glass blowers Betel nut chewers Pipe/cigar smokers Dental materials (pins) Caries
Blue	Tetracycline ingestion Osteogenesis imperfecta
Green	Hyperbilirubinemia Congenital biliary atresia Occupational: brass factory Marijuana smoking Nasmyth's membrane
Orange	Poor oral hygiene Chromic acid fumes Chromogenic bacteria
Red	Internal resorption Congenital erythropoietic porphyria Periapical granuloma in lepromatous leprosy Death
Gray	Tetracycline ingestion for cystic fibrosis Minocycline for acne in adults Dentinogenesis imperfecta Amalgam restorations Cyclosporine

to spend money for the replacement of dental restorations as they do to maintain cars, appliances, and other parts of their bodies (Figure 21.8).

Always make the patient aware of the limited life of restorations. Phillips has said, "leakage causes as much pain and pulpal inflammation as do the materials themselves."[5] Therefore, leakage should be avoided if at all possible, and if it occurs, the restorations must be replaced. In general, dentistry needs to change its philosophy and provide patients with functional esthetic restorations and be realistic when it comes to replacement.

One major advantage of composite resin restorations is the ability to easily see future microleakage. The brown stain signifies beginning microleakage that can be easily refinished or be treated with air abrasion and resealed with flowable or conventional composite resin restoration to extend the life of the original composite (Figure 21.9A–D).

Extrinsic stains

Extrinsic discoloration occurs after the completion of the fully eruption of a tooth and is defined as stains located on the outer surface of the tooth structure and caused by topical or extrinsic agents.

Nathoo classification and causes

The Nathoo classification system of extrinsic dental stain describes three categories as follows:[6]

- **Nathoo type 1 (N1):** N1-type colored material (chromogen) binds to the tooth surface. The color of the chromogen is similar to that of dental stains caused by tea, coffee, wine, chromogenic bacteria, and metals (Figure 21.10A–F).
- **Nathoo type 2 (N2):** N2-type colored material changes color after binding to the tooth. The stains actually are N1-type food stains that darken with time (Figure 21.10G).
- **Nathoo type 3 (N3):** N3-type colorless material or prechromogen binds to the tooth and undergoes a chemical reaction to cause a stain. N3-type stains are caused by carbohydrate-rich foods (e.g., apples, potatoes), stannous fluoride, and chlorhexidine (Figure 21.11A and B).

Certain factors predispose children and adults to extrinsic stains, including enamel defects, salivary dysfunction, and poor oral hygiene.[7] Microscopic pits, fissures, and defects in the outer surface of the enamel are susceptible to the accumulation of stain-producing food, beverages, tobacco, and other topical agents.

Since saliva plays a major role in the physical removal of food debris and dental plaque from the outer and interproximal tooth surfaces, diminished salivary output contributes to extrinsic discoloration. Decreased output may be caused by local disease (e.g., salivary obstructions and infections), systemic disease (e.g., Sjögren syndrome), head and neck radiation therapy for cancer, chemotherapy, and multiple medications (e.g., anticholinergics, antihypertensives, antipsychotics, antihistamines).

Figure 21.2 **(A)** An example of severe extrinsic stains, including discolored restorations.

Figure 21.2 **(B)** A good example of severe tetracycline staining.

Figure 21.3 Total neglect resulted in the green stain and gingival inflammation.

Figure 21.4 Staining can occur in tooth defects such as the vertical crack line on the central incisor, which can be difficult and almost impossible to remove by just polishing.

Table 21.2 Clinical Appearance and Causes of Discoloration

Clinical Presentation	Consideration
Single dark tooth (radiograph needed for diagnosis of pathology)	Vital: blood-borne pigments from trauma, calcific metamorphosis, internal resorption Nonvital: blood stains during endodontic therapy, remaining pulp material in chamber, restoration type (amalgam) or leaking, internal resorption
Generalized discoloration of all of the teeth	From smoking (extrinsic or intrinsic), chromogenic foods, drugs (tetracycline), diseases, aging, or genetically inherited
Localized discoloration to one tooth	White spots: surface or subsurface fluorosis, white surface demineralization Brown spots: fluorosis, formation defects
Localized discoloration to one area on all of the teeth	Chromogenic foods, chlorhexidine, smoking (extrinsic), often associated with plaque and poor oral hygiene
Discoloration associated with a restoration	Amalgam: show-through because of thin enamel, stained dentin Composite: staining of margins, staining beyond margins, complete discoloration of restoration
Discoloration associated with caries	Aproximal and occlusal stained additionally by food or saliva
Tooth defects: pitted, poorly formed	Facial, lingual, or incisal defects from fever or trauma during development, genetics (peg laterals or deep grooves)
Translucency: dark incisal	Finger test on lingual to determine translucency; may appear darker with bleaching due to loss of further color

The most common cause of extrinsic stains is poor oral hygiene.[7] The inability to remove stain-producing materials and/or the use of dentifrices with inadequate cleaning and polishing actions cause discolorations.

Table 21.3 Treatment Options for Stained Teeth

Treatment Options	Intrinsic	Extrinsic
Prophylaxis		✓
Air polisher		✓
Bleaching external with 10% or more CP	✓	✓
Bleaching external with 35% HP	✓	
Bleaching internal with 10% CP	✓	
Bleaching internal with 35% HP	✓	
Sealant or preventive resin	✓	
Macroabrasion: handpiece, burs, disks		✓
Microabrasion: rubber dam and acid		✓
Resurface and seal restoration		✓
Replace restoration	✓	✓
Replace portion of restoration (composite to mask over amalgam)	✓	✓
Veneer (partial or complete, composite or ceramic)	✓	
Crown (PFM, porcelain butt, all ceramic)	✓	

CP, carbamide peroxide; HP, hydrogen peroxide; PFM, porcelain fused to metal.

Extrinsic stains can be caused by various drugs, mouthwashes, foods, and drinks. A complete list of staining agents can be found in Table 21.2. Extrinsic discoloration was further classified as direct and indirect,[1] or metallic and nonmetallic.[1] Direct or nonmetallic staining occurs when the stain from a chemical compound gets incorporated into the acquired pellicle.[1] It is often associated with chromogens found in dietary sources, such as coffee, tobacco, red wine, and chromogenic bacteria. Indirect or metallic staining occurs by the means of metal salts and cationic antiseptics that stain the tooth's surface by a chemical reaction.[1] In either case, such superficial discoloration can be removed by tooth brushing, bleaching, or professional cleaning (Figures 21.11A and B and 21.15A and B). One extrinsic stain hard to remove occurs in microcracks. These microcracks can be caused by trauma, chewing ice, or even severe tooth grinding.

Prior to diagnosis of the stain or discoloration, a complete prophylaxis should be performed to remove minor surface staining. For instance, an air polisher can be used on the posterior occlusal surfaces to help diagnose whether the grooves are stained or carious. The diagnosis of occlusal decay is better done by visual means rather than by tactile sensation with an explorer. Proponents of the visual method explain that some grooves will not "stick" but will have decay, whereas others will stick mechanically due to their surface topography but will contain no decay.

Extrinsic stains can also be caused by the use of a mouth rinse containing chlorhexidine (refer to Figure 21.11A and B). This product is often prescribed to promote gingival health. The dark stain resulting from the product's use is a major disadvantage to an otherwise very beneficial product. There is an ongoing debate in the scientific literature regarding the mechanism of stain

Figure 21.5 Dark brown advanced caries is the result of total neglect.

Figure 21.6 Some clear sealants that were chemically cured tend to yellow over time, becoming unesthetic.

Figure 21.7 **(A)** Stains around restorations are usually a result of simple leaks around the margins of the old restoration.

Figure 21.7 **(B)** Replacement with composite resin is usually the best solution.

formation by chlorhexidine and other mouthwashes.[1] Most in-vitro and in-vivo evidence supports the mechanism of precipitation of dietary chromogenic anions onto the areas of absorbed cations. Chlorhexidine and other antiseptics act by absorption into the enamel, and once absorbed they form complexes with other ions in the oral cavity, such as polyphenols, thus forming a stain.[4] Some patients are able to overcome this disadvantage by employing 10% carbamide peroxide in a bleaching tray periodically (Figure 21.11A and B). This approach is possible only if the patient is a reasonable candidate for bleaching or if their teeth are already as light as they can become. Otherwise, more frequent prophylaxis is required for esthetics.

Types of stains

Green stain

Green stain is most often found in children, in association with remnants of Nasmyth's membrane, the primary dental cuticle. It ranges in color from light- or yellowish-green to very dark green (Figure 21.12). It is most frequently seen on the cervical one-third to one-half of the labial surfaces of the maxillary incisors; however, it may cover the entire labial surface of the teeth involved. Green stain is composed of inorganic elements as well as decomposed hemoglobin and chromogenic bacteria and fungi; it is associated with poor oral hygiene. As the epithelial tags are often attached to surface irregularities in the enamel, the stain is quite tenacious and can be removed only with some difficulty by scaling and polishing. If left untreated, the remnants of the dental cuticle and the adherent stain will be abraded from the surface by frictional forces of mastication and muscle movement.

Orange stain

Orange stain appears as a thin, brick-red, orange, or yellow line on the cervical third of the teeth involved, usually the incisors (Figure 21.10A and B). Although rare, it is most frequently seen in children and is thought to be caused by chromogenic bacteria. It is easily removed by prophylactic procedures, but may return. A yellow or black stain can also be caused by the ingestion of iron over time.

Black line stain

Also known as black or brown stain, black line stain is a continuous thin band along the free gingival margin on the enamel surface that follows the crestal contour of the tooth on the lingual and proximal surfaces. It is seen in patients of all ages and has some predilection for female patients. The cause is thought to be chromogenic bacteria, coupled with the patient's natural tendency to form a mucinous plaque, for which the bacteria haven an affinity. Tobacco use and poor oral hygiene are not blamed for staining of this sort. However, the stain is more extensive if home care is inadequate. Scaling will remove the stain, but it tends to recur.

Figure 21.8 Too many patients leave their old amalgam restorations too long. Although the original restoration was done to protect the tooth, it now serves as the source of decay and microcracks.

Tobacco stain

Discolorations are seen as a yellowish-brown to black diffuse plaque along the cervical one-third to one-half of the teeth, mainly on the lingual surfaces. It may also be deposited in the pits and fissures of the occlusal, facial, and lingual surfaces. It can be removed by scaling and polishing. Heavy deposits, especially from chewing tobacco, may penetrate the enamel surface and become intrinsic. Patients who smoke a great deal and tend to accumulate stain should be told to use the more abrasive tooth powders or pastes. Figure 21.10C shows permanent staining due to dipping snuff for 15 years. Discoloration in a 68-year-old man due to cigar smoke is shown in Figure 21.13.

Food stain

Certain foods can cause extrinsic staining. Developmental grooves, pits and fissures, and other acquired enamel defects can harbor dark stains. Patients who drink excessive amounts of coffee (Figure 21.14A and B) or tea often have stained teeth.

Metal stains

Metallic dusts from various industries or metals used in compounding medications tend to impart characteristic color to dental plaque. Iron yields a brown to greenish brown color; copper or brass yields green or bluish-green; nickel yields green; and cadmium yields yellow or golden brown. Unless the stain penetrates the enamel surface and becomes intrinsic, it can be removed by scaling or polishing.

Amalgam stain

One of the most common causes of stained teeth is amalgam restorations. There are two ways an amalgam may impart a stained appearance to the tooth: (1) show through and (2) penetration of corrosion products. Correct preparation and an opaque base or liner can prevent these.

If the cavity preparation necessitates leaving a thin labial or proximal wall supported by little dentin, the darkness of the amalgam metal may show through the relatively translucent

Figure 21.9 **(A)** The brown stain around this composite restoration is evidence of microleakage.

Figure 21.9 **(B)** The overlay technique makes it easy to refinish areas where stain later occurs either using a 30 blade carbide or 15 μm diamond (DET6EF Brasseler, USA).

Figure 21.9 **(C)** Final polish can be with discs or impregnated cups or points.

Figure 21.9 **(D)** The final result shows how the restoration can achieve years more life due to the ability to continue repolishing or repair as needed.

enamel. This may be unavoidable, owing to the extent of decay, but the possible consequences should be recognized.

After removing an old amalgam from a tooth, you may notice that the dentin has become severely discolored and even softened. This greenish black pigment permeating the dentin is predominately corrosion products of tin. The mechanism of discoloration is a slow diffusion of metal ions into the dentin. These ions are liberated under the influence of galvanic currents within the restoration and sulfides that presumably originate from saliva. The use of a copal resin cavity varnish will prevent this discoloration. It has been shown that the carboxylic acid groups in the varnish react with the tin corrosion compounds, thus absorbing and retaining them. Therefore, the varnish works not by forming a "membrane" impermeable to the pigments, but by reacting to impede the diffusion of tin compounds. When amalgam stains become an esthetic problem, crowning may be necessary to completely mask teeth that are broken down (Figure 21.10D and E).

Figure 21.10 **(A)** Orange stain appears as a thick brick-red, orange, and yellow line on the cervical third of the teeth involved, usually the incisors, and is associated with poor oral hygiene and chromogenic foods.

Toothpastes that help maintain whiteness

Once the dental officer has removed the extrinsic stains, the patient can use a toothpaste to maintain the whiteness of the teeth. There are a number of toothpastes on the market advertised for whitening, and patients are always seeking something

Figure 21.10 **(B)** Orange–brown stain may cover more of the facial area due to poor oral hygiene and ingestion of chromogenic foods.

that they can use at home to obtain whiter teeth. The US Food and Drug Administration allows any toothpaste that removes stains to make claims as a whitening toothpaste. However, the mechanism of action of the different toothpastes is generally divided into three categories:[8, 9]

- **Abrasive toothpastes:** The original whitening toothpastes, commonly referred to as the "smoker's toothpaste," remove extrinsic stains by mechanical abrasion, which can make the tooth appear whiter. However, overuse of these toothpastes will eventually reduce enamel, causing the teeth to appear more yellow due to the show-through of the dentin. These toothpastes are not recommended, especially in persons who are already aggressive with their tooth brushing technique or use a hard toothbrush.
- **Chemical toothpastes:** Some toothpastes attempt to remove stains by changing the surface chemistry of the tooth so that plaque and tartar will not adhere. These types of "tartar control" toothpaste act much like Teflon on a frying pan, and if there is no plaque or tartar on the tooth, there is less substrate to be stained. One of the problems with this approach is that, in some patients, these types of toothpastes cause marked sensitivity. Another class of chemical toothpastes that have become popular since the advent of bleaching are those that contain peroxide. Many of these products also contain baking soda. Baking soda is a mild abrasive, but the peroxide acts by chemical means. The problem with the use of a peroxide dentifrice for whiter teeth is that the contact time on the tooth is too short to produce any noticeable whitening. However, a peroxide-containing toothpaste may be useful in color maintenance after the dentist has whitened the teeth.

Figure 21.10 **(C)** Black tobacco stain from dipping snuff for 15 years.

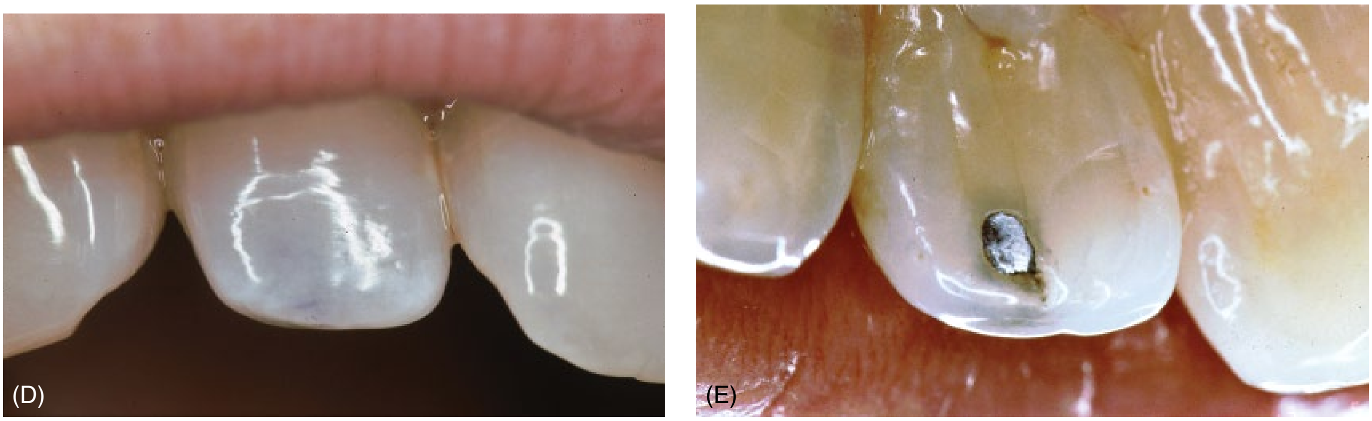

Figure 21.10 Gray stain on lateral incisor **(D)** is a result of an amalgam restoration on the lingual surface of the tooth **(E)**.

Figure 21.10 **(F)** Black stain from chewing betel nuts over time.

Figure 21.10 **(G)** Extensive use of chlorhexidine can cause a black stain on the teeth surface.

Figure 21.11 **(A)** Patient on regular use of chlorhexidine rinse for gingival treatment shows marked staining of teeth.

Figure 21.11 **(B)** Stains were removed, and the patient continued with chlorhexidine use while simultaneously bleaching the maxillary arch. After 3 months of treatment, there is markedly less staining on the maxillary teeth.

Figure 21.12 Green stain associated with poor oral hygiene and gingival inflammation.

Figure 21.13 This 68-year-old man presented with black tobacco stain due to cigar smoking.

- **Cosmetic toothpastes:** Most of the whitening toothpastes should be classified as a cosmetic, in that they apply something to the surface of the tooth. Most whitening toothpastes contain titanium dioxide, which is essentially a "sticky white paint." This "paint" then adheres to the cracks and crevices on the tooth and to the embrasures, giving the illusion of whiter teeth. However, cosmetic toothpastes are only temporary and do not change the inherit tooth color.

Matching color to individual patient

The color of make-up, lipstick, or clothes can also impact the perceived color of a patient's teeth. Just as certain colors of clothing make the complexion look either whiter or more tanned, so do certain redder colors of lipstick make the teeth appear whiter. In the same manner, a whiter complexion (or white makeup, as used by a circus clown) makes the teeth appear more yellow. Some patients may wish to consult with a color or makeup specialist to improve other aspects of their appearance than their teeth. Improvements in areas of the face and head will, in turn, have an impact on the color of the teeth. Although some experts feel the color of the teeth should closely match the color of the sclera (white part) of the eye for a natural appearance, Goldstein says many patients disagree. They ask for shades much whiter than the white parts of their eyes.[9–11]

Intrinsic stains

Several factors may be responsible for intrinsic or endogenous staining of the teeth. Congenital defects may result in the faulty deposition or calcification of enamel that allows the enamel rods to be penetrated by chromogenic substances. Trauma during the eruption of a developing tooth can cause hemorrhage within the pulp chamber, resulting in extravasations of blood into the dentinal tubules, with subsequent blood breakdown. Such stains would reflect the progressive degradation of the red blood cells. Systemic disease and medications can interrupt the normal sequence of dentinal and enamel formation and will be reflected in various stains. Endogenous stains can be said to be a form of vital staining. External materials can cause intrinsic stains when defects in the enamel surface allow chromogens to become embedded in the surface irregularities.

Intrinsic stains result from the change in structural composition or the thickness of hard dental tissues, which can be drug induced or associated with a health condition or injury.[1, 12] In addition, teeth defects that facilitate staining can be acquired throughout lifetime. For instance, tooth wear thins the enamel, making it more transparent and causing dentin to show and the tooth to appear darker.[1] Gingival recession also exposes dentine,

Figure 21.14 **(A)** The severe black stains in this patient are a result of drinking eight cups of coffee per day.

Figure 21.14 **(B)** Polishing with coarse pumice, the stains were removed and the patient was advised to severely reduce his coffee intake.

allowing the chromogens to enter the body of the tooth.[1] Some of the materials used in restorative dental treatment also have an effect on the color of teeth. For instance, root canal therapy can cause intrinsic stains if eugenol and phenolic compounds are employed. Also, amalgam restorations can cause staining of gray to black color, which is caused by the migration of tin into the tubules of dental tissues.[1] A complete list of drugs and health conditions causing intrinsic discoloration can be found in Table 21.1. These factors are well known to interfere with dental processes, causing discoloration as a consequence.[12]

Enamel hypoplasia

According to Bhaskar and coworkers,[13] enamel hypoplasia is a reduction in the thickness or amount of enamel formed and is not associated with the calcification process. It is a defect in which the tooth enamel is hard but thin and deficient in the amount. The etiology may be local, systemic, or hereditary.

In its mildest form, enamel hypoplasia is seen as horizontal grooves, or waves, on the labial surfaces of affected teeth. As it progresses, the grooves increase in depth, and there is often pitting and discoloration. Hypoplastic teeth may be grossly deformed. Hypoplasia is associated with systemic diseases that occur at the time of tooth development, affecting the teeth bilaterally and symmetrically. The incisors, cuspids, and first molars are most frequently involved. The regions of the teeth usually affected are the incisal and middle thirds of the central incisors, the incisal one-third of the lateral incisors, the tips of the cuspids, and the occlusal one-third of the first molars (Figure 21.15). When groups of teeth are affected, the hypoplasia can be attributed to severe and prolonged debilitating disease, chronic metabolic and/or endocrine abnormalities, or prolonged antibiotic therapy. However, if isolated teeth are affected, irradiation, trauma, or infection is usually the cause. Cosmetic contouring, microabrasion, bonding resins, veneering, or crowning can be used to treat hypoplastic defects.

Figure 21.15 In enamel hypoplasia, the incisal and middle thirds of the central incisors are affected most frequently.

Amelogenesis imperfecta

This is a form of enamel hypoplasia or agenesis, which is a heterogeneous genetic disorder that is characterized by defective enamel formation. It is inherited as an autosomal dominant, autosomal recessive, and X-linked disorder in which both the baby teeth and permanent teeth are affected. This developmental disorder causes the teeth to be covered with a thin, soft, abnormally formed enamel that appears yellowish brown and is easily damaged. The appearance may be similar to that shown in Figure 21.16. If the patient feels an esthetic need for treatment, either acid-etch bonding to the labial surface or full crowing can be done. Bleaching is difficult because the dentinal layer shows through, and it is usually painful because of the thinness of enamel.

Enamel hypocalcification

A condition of diminished calcification of the enamel, which is not associated with enamel thickness. It can occur locally as a white spot (Figure 21.17A and B) or systemically on several teeth (Figure 21.18A–D). Treatment can be cosmetic contouring, if the surface layer is not too deep, microabrasion, bonding, or porcelain veneers.

Dental fluorosis

Mottled enamel may be a developmental defect caused by the ingestion (during the period of enamel calcification) of water or foods containing excessive amounts of fluorine. The concentration of fluorine is believed to cause a metabolic alteration in the

Figure 21.16 This patient presented with a case of moderate amelogenesis imperfecta in which the yellowish‐brown enamel is thin, soft and easily damaged and sensitive.

Figure 21.17 **(A)** This patient illustrates a good example of enamel hypocalcification on a single tooth.

Figure 21.18 **(A)** Patient presented with enamel hypocalcification throughout her upper teeth.

ameloblasts during enamel formation, which results in a defective matrix and improper calcification.[14] Fluorosis is classified as mild, moderate, or severe, depending on the amount of fluorides ingested during amelogenesis. Mild fluorosis is seen as flat gray or white flecks on the enamel surface. Most of all, the enamel surface is dull, unglazed, or chalky white in moderate fluorosis; there may also be pitting, with or without stains. Severe fluorosis causes marked tooth deformity; abnormally shaped crowns that show severe pitting and staining are also seen. Enamel opacities due to fluoride ingestion are poorly demarcated, and at the time of the eruption of affected teeth these opacities are not stained. In contrast, non‐fluoride opacities are usually round or oval and well demarcated in the center of the enamel surface. Treatment usually consists of a series of bleaching treatments (see Chapter 11), composite resin bonding, porcelain veneers, and even crowning at times (Figure 21.19A, B and C).

Dentinogenesis imperfecta

This is a genetic disorder that is characterized by defective dentin, resulting in opalescent teeth. Like amelogenesis imperfecta, dentinogenesis imperfecta is dominant and not sex linked in which both the baby teeth and permanent teeth can be affected.

Figure 21.17 **(B)** Direct composite bonding was done to mask the localized white spot.

Figure 21.18 **(B)** Microabrasion was first attempted to remove as much of the white hypocalcification as possible.

Figure 21.18 **(C)** Many of the white spots were diminished after the microabrasion.

Figure 21.18 **(D)** Direct composite bonding masked the remainder of the white spots to produce a better - looking smile.

Figure 21.19 **(A)** This patient was embarrassed to smile due to her fluorosis staining.

Figure 21.19 **(B)** Composite resin bonding was selected to mask the stain and improve her smile.

Figure 21.19 **(C)** This man was diagnosed with severe fluorosis and staining which would require orthodontics, bleaching and possibly bonding and veneers.

The dentin is stained gray, brownish-violet, or yellowish-brown and the pulp chamber and canal are usually greatly reduced in size and are sometimes undetectable on radiographs. Severe attrition is associated with the disease (Figure 21.20). The teeth appear opalescent.

Blood-borne pigment

Pigments circulating in the blood are transmitted to the dentin from the pulp capillaries. Although rare, some of these discolorations are worth noting.

Figure 21.20 Severe attrition and yellowish-brown stained teeth are most frequently seen in dentinogenesis imperfecta.

Erythroblastosis fetalis, or hemolytic disease of newborns

This is due to incompatibility between Rh-negative red blood cells of the mother and Rh-positive ones of the fetus. Maternal antibodies destroy fetal blood cells, and the concentration of blood pigments circulating in the fetus's bloodstream increases. The primary dentition is markedly discolored—erupting teeth are bluish-black, greenish-blue, tan, or brown.

Hepatic–biliary disorders

Conditions such as intense, prolonged jaundice, cause bile pigments to be deposited into forming dental tissues, thus causing green or yellow discoloration of the teeth.

Porphyria

Abnormal metabolism or porphyrins may be congenital or secondary to infection. This disorder affects primary and secondary teeth, causing red or brown stains.

Pulp injury

Hemorrhage in the pulp chamber may allow red blood cells and blood pigments to penetrate the dentinal tubules and degenerate, causing discoloration of the crowns of teeth involved. Soon after the injury, the crown is pink; with time, the pink becomes orange, brown, or black, indicating the progressive breakdown of the blood.

Internal resorption

Chronic irritation or injury to the tooth induces a chronic granulomatous reacting in the pulp. Pressure from proliferating tissue on the dentin causes dentinal resorption in the crown or root of the affected tooth. When the resorption nears the enamel surface, a pinkish discoloration is seen.

Stains of various medications

Medicaments and materials used in dental procedures often induce staining. These include: silver amalgam, causing gray to black stain; silver nitrate, causing black or bluish-black discoloration; volatile oils, giving yellowish brown; iodine, leading to brown, orange, or yellow: aureomycin, causing yellow discoloration; root canal sealer containing silver, giving a black discoloration; and pins, leading to a blue-grayish stain (Figure 21.21).

Figure 21.21 This patient illustrates a good example of tooth stains and decay associated with various medications that cause xerostomia.

Single dark teeth

A single tooth may become dark either from trauma, after completion of endodontic therapy, or from internal resorption. The first step in the treatment of this tooth is to take a radiograph to determine whether there is any periapical pathology and to pulp test the tooth for vitality.[15]

If the single dark tooth tests vital, there are two options for treatment. One option is when the patient wishes to lighten the other teeth as well. The other option is when the patient only wants to bleach the single tooth. If the patient wants to lighten all teeth, a conventional bleaching tray is fabricated, and carbamide peroxide is placed on all the teeth. When the unaffected teeth cease to lighten, treatment is continued by placing the material only on the darkened tooth until it matches the color of the other teeth.

If a single dark tooth does not test vital, the radiograph is negative for periapical pathology, and the patient has had no symptoms; the treatment can be the same as a single dark vital tooth without initiation of endodontic therapy. However, the patient should be informed that there is a chance that the tooth may need a root canal treatment should symptoms eventually occur.

Other situations for dark teeth occur after the tooth had received endodontic therapy. If the tooth has not been restored, or if the treating dentist is not certain that all of the remaining pulp material had been removed from the tooth, then some form of inside bleaching should be performed (Figure 21.22A–E).

Localized brown discoloration

Typically, a brown discoloration is associated with high fluoride ingestion.[16] The discoloration is generally localized to sporadic areas on the tooth. Usually, microabrasion is considered the primary treatment.[14] Microabrasion is the application of acid and pumice to selectively remove the enamel surface discolorations.[2] However, Nightguard vital bleaching has been shown to successfully remove brown discolorations.[17–19] It is estimated that 80% of these brown discolorations are amenable to bleaching with 10% carbamide peroxide.[20] More recent articles have shown removal of brown discoloration after 4–6 weeks of bleaching, with no return or need for additional treatment at seven years recall.[21]

Figure 21.22 **(A)** This patient presented with a single dark tooth following endodontic treatment.

Certainly, attempting bleaching first avoids the removal of the fluoride-rich enamel layer, and microabrasion[22] or macroabrasion[23] can be attempted should bleaching not be successful.[24, 25] When time is of the utmost importance to the patient, a combination approach can be most effective (Figure 21.23A and B).

Localized white discoloration

As with brown discolorations, white discolorations are often associated with high fluoride ingestion, high fever, or other disturbances during enamel formation. Bleaching does not remove white spots and may occasionally make them lighter during treatment, but it does lighten the surrounding tooth so as to make the white spot less noticeable (Figure 21.24A and B).[26] During bleaching, the white spot may get whiter, but on termination of the bleaching, it generally turns to its original color. It is thought that these white spots are differently formed portions of enamel that respond differently to the bleaching material. Teeth with white spots undergoing bleaching often develop a "splotchy look" during the first or second week of bleaching. However, patients should be encouraged to continue through this stage, so that the darker portions of the teeth can "catch up." Often, malformed parts of enamel below the surface of the tooth contribute to this splotchy appearance. On termination of bleaching, the white spots return to their original color. Bleaching with 10% carbamide peroxide is still the first treatment of choice because it can lighten the other portions of the tooth, so that the white spot is no longer as noticeable.

Tetracycline staining

Tetracyclines lead to permanent tooth staining if ingested by an expectant mother or by a child during the developmental period of primary or secondary teeth. Tetracycline-/minocycline-induced discoloration is one of the most difficult stains to remove. The ability of tetracycline to intrinsically stain teeth during odontogenesis has been well known for five decades.[5, 14, 27–29]

One of the side effects of tetracycline is incorporation into tissues that are calcifying at the time of their administration. They pass through the placenta and can have toxic effects on the developing fetus. Toxic effects on the developing fetus include dental discoloration, enamel hypoplasia, and a 40% depression of bone growth. They have the ability to chelate calcium ions and to be incorporated into teeth, cartilage, and bone, resulting in a discoloration of both primary and permanent dentitions.

The major factors impacting the amount of tetracycline deposition are dosage, duration of treatment, stage of tooth mineralization, activity of the mineralization process,[30] and the type of the specific drug.[1, 31] The discoloration, which is permanent, varies from yellow or gray to brown depending on the dose or the type of drug received in relation to body weight (Figure 21.25A and B). After tooth eruption and exposure to light, the fluorescent yellow discoloration gradually changes over a period of months to years to a non-fluorescent brown color.[32] The labial surfaces of yellow-stained anterior teeth will darken in time, while the palatal surfaces and buccal surfaces of posterior teeth will remain yellow.[33] The staining of the permanent teeth creates an esthetic and psychological concern for which patients may look for advice and treatment to improve their appearance.[34]

The drug diffuses into the tooth and binds irreversibly with calcium ions, forming a stable complex in the hydroxyapatite crystals located in dentin and enamel.[1, 31] In-office bleaching is a possible treatment method but is generally contraindicated due to the number of treatments required and the concurrent high fee and patient discomfort. With the advent of at-home bleaching, these tetracycline stains can be managed more easily.[35–37] Treatment times may vary from 2 months to 1 year (Figure 21.26A–C). Patients are seen monthly to replenish solutions and evaluate for continuing color change. Patients should

Figure 21.22 **(B–D)** An access opening was created, gutta percha sealed with glass ionomer base, and internal and external bleaching with 35% hydrogen peroxide (Opalescence Endo, Ultradent Products Inc.).

agree to a minimum of 2 months of nightly treatment before deciding to proceed to more aggressive treatment. Fees are generally the cost of a monthly office recall visit and additional material. Once lightening is observed, patients should continue treatment until a month has passed with no obvious color change.

Dark tetracycline stains located in the gingival third of the tooth or dark blue or gray stains have the least favorable prognosis. However, even in these situations, there can be some improvement. This improvement may be sufficient for a patient's esthetic demands. If not, bleaching for up to a year can be quite successful. However, compliance by the patient is necessary for success.

Figure 21.22 **(E)** Final result shows the matching of the single tooth to the rest of the teeth.

Figure 21.23 **(A)** Dark brown spots associated with high fluoride ingestion are present in this young boy.

Figure 21.23 **(B)** Individual in-office bleaching was effective in eliminating the stain and producing a more pleasant smile.

Figure 21.24 **(A)** White spots on the incisal edges are accentuated by the yellow of the teeth.

Figure 21.24 **(B)** After 5 weeks of nightly treatment with 10% carbamide peroxide, the white is less noticeable because the yellow has been removed.

Figure 21.25 **(A)** This patient illustrates moderate tetracycline staining.

Figure 21.25 **(B)** This patient is a good example of severe tetracycline staining.

Figure 21.26 **(A)** Patient with moderately tetracycline-stained teeth is considering bleaching or veneers. Bleaching is initiated to either resolve the issue or provide a lighter base onto which the veneers can be placed.

Figure 21.26 **(B)** Four months of bleaching of the maxillary arch using 10% carbamide peroxide produces a remarkable shade change.

Figure 21.26 **(C)** The mandibular arch is subsequently lightened.

Patients with tetracycline staining often view the at-home bleaching regime similar to a weight loss or an exercise program. Application of the bleaching material at night becomes a regular part of their routine. There is no increase in side effects with this long-term bleaching since most side effects occur in the initial weeks of treatment. Two other therapies that are helpful in removing the spots are microabrasion and/or masking with composite resin bonding and porcelain veneers.

Treatment

Correction of defects caused by intrinsic staining depends on the amount of tooth structure affected. In mild forms of enamel hypoplasia, for example, simple procedures may be all that is necessary: superficial selective grinding and polishing of the affected surface or acid-etch and bonded composite resin restoration of the area. In more severe defects, such as systemic drug-induced discolorations and congenital defects, full crown coverage may be necessary to improve the appearance of the teeth.

Bleaching

Typically, bleaching with 20% carbamide peroxide in a custom-fitting tray easily treats discolorations due to aging, smoking, or chromogenic foods and beverages. Although these types of stains generally require only 2–6 weeks of bleaching treatment, some are more stubborn. Nicotine staining of long-term duration may require as long as 3 months of nightly treatment.[9] Tetracycline staining may take anywhere from 2 to 12 months of nightly treatment.[35] Patients must be counseled regarding realistic expectations for the outcomes of bleaching. Long-term treatment is best presented as one that is worthwhile but may not produce the desired results.[10]

Bleaching as a stepping-stone to veneers

Bleaching may not produce an acceptable result on all tetracycline-stained teeth, but it can provide the patient with a better idea of how their smile will appear with whiter teeth. Often, bleaching is the stepping-stone to veneers. Once the patient has seen what a little color change will do for their appearance, they are often more excited about completing the restorative process. Even when veneers are the ultimate goal, bleaching lightens the underlying tooth, decreasing the masking needs of restoration. If the tooth shade regresses after the placement of the veneers, the teeth can sometimes be rebleached through the lingual surfaces. However, it would be wise to use a more opaque shade of cement for the veneers.

Figure 21.27 **(A)** Comparison of masking of feldspathic porcelain on the left versus lithium disilicate on the right with the same amount of porcelain thickness.

Bleaching and other restoration procedures

Bleaching does not change the color of other restorations. In fact, existing restorations tend to appear darker as the adjacent teeth lighten. Patients should be informed of the possible need for replacement of restorations in the esthetic area should there be a color mismatch posttreatment. However, the color stability of restorations can also be a benefit to the clinician. Usually, crowns that match adjacent natural teeth are placed. Over time, the teeth may have darkened to the point where they no longer match the crowns. Rather than replace the otherwise acceptable crown with a darker shade crown, bleaching is the treatment of choice. In these instances, the patient can carefully bleach the teeth until the natural teeth return to the shade they were when the crowns were fabricated. To avoid overbleaching of the teeth, patients are instructed to apply the whitening solution for only 1–2 h a day until they see how responsive the natural teeth will be to the process. This avoids a color mismatch, where the teeth become lighter than the crowns from bleaching, which might require replacing the crowns with a lighter shade.

Tetracycline-stained teeth often require significant tooth reduction to provide the dentist and the laboratory technician an adequate space for the restorative material to mask the discoloration. Some suggest the use of an opaque resin to mask the discolorations prior to the cementation of the porcelain veneers.[12]

Lithium disilicate veneers

The masking of tetracycline staining with the use of lithium disilicate (e.max) is compared with feldspathic porcelain in Figure 21.27A, showing that masking can be achieved with less amount of tooth structure removal. However, it is still essential to take the stump shade of the prepared teeth for the ceramist to be able to visualize the amount of masking needed.

The 48-year-old man shown in Figure 21.27B presented to the office with tetracycline staining. He had a brown discoloration on his teeth, which represents a heavy ingestion of tetracycline compared with yellow or gray discolorations.

A wax-up (Figure 21.27C) was done with the ideal desired final contours of the veneers prior to prepping the teeth. Thus, additive wax-up can be done to evaluate whether veneered teeth can tolerate the additive porcelain material that would lead to

Figure 21.27 **(B)** This 48-year-old man presented to the office with tetracycline staining.

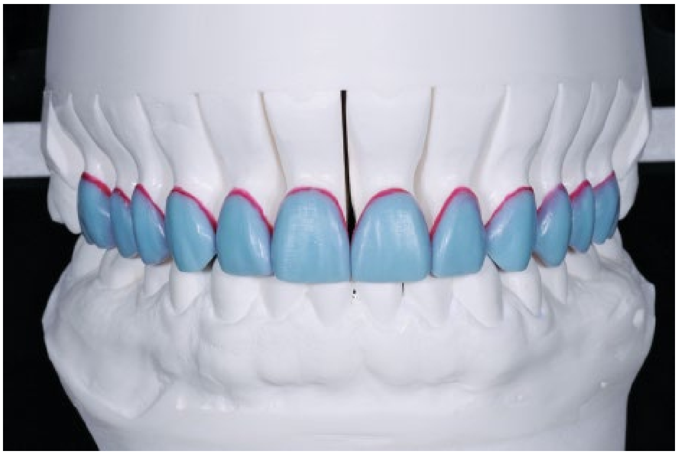

Figure 21.27 **(C)** A wax-up has been done with the ideal desired final contours of the veneers prior to tooth preparations.

Figure 21.27 **(D)** The matrix was fabricated from the wax-up that will be utilized as the reduction guide at the time of the tooth preparation.

Figure 21.27 **(E)** The preparation of the teeth completed for the lithium disilicate veneers.

Figure 21.27 **(F)** The amount of masking of the tetracycline stain is portrayed with lithium disilicate veneers.

Figure 21.27 **(G)** The veneers were bonded with the recommended etching and bonding guidelines.

less tooth structure removal. The matrix was fabricated from the wax-up that would be utilized as the reduction guide at the time of teeth preparation (Figure 21.27D). The preparation of the teeth was completed for the lithium disilicate veneers (Figure 21.27E), the final impression was made, and the teeth were provisionalized with the direct provisional technique.

At the laboratory site, full contour wax-up was done prior to pressing the lithium disilicate porcelain. A 5% cutback was performed on the incisal edge for the layering (Figure 21.27F). The veneers were bonded with the recommended etching and bonding guidelines for lithium disilicate with the help of rubber dam isolation. (Figure 21.27G).

Figure 21.28 **(A)** This dentist was concerned about her aging composite resin veneers and wanted to have them rebonded for better esthetics.

Figure 21.28 **(B)** Direct bonding with a microfilled composite was utilized for maximum polish.

Discoloration of composite resin restorations

Stains to composite resin restorations can occur in the body of composite, on the surface of the composite, or at the restoration margins. Bulk discoloration of chemically cured composites was common before the advent of light curing. Benzoyl peroxide, which is the chemical initiator in all chemically cured composites, is not color stable and will cause the restoration to darken over time. This phenomenon may necessitate the replacement of many otherwise serviceable restorations (Figure 21.28A and B). Darkening of light-cured composites is a result of extrinsic stains from food, drink, or oral habits. Orange stain can be the result of chromogenic bacteria. If these stains recur after thorough prophylaxis, refer the patient to an oral pathologist for culture, which will help determine a specific antibiotic to help prevent the recurrence of the bacteria. These stains can often be removed by merely repolishing the restoration. Care must be taken not to use certain aggressive cleaning devices during prophylaxis (i.e., Prophy-jet air polisher, Dentsply Professional) because these technologies can roughen the surface finish of composite restorations.[38]

It is not uncommon for staining to occur at the margins of composite restorations as the restorations age. If the staining is superficial, it can often be removed by bleaching, air abrasion, or the use of diamond or carbide finishing burs. After stain removal, the composite's margins should be etched for 15 s with 32–37% phosphoric acid, rinsed, and resealed with a bonding agent or surface sealant. When a marginal stain is not easily removed by conservative finishing techniques, the affected area should be mechanically removed because of the possible presence of recurrent decay. If, on penetration and exploration, the stain is found to be superficial, the restoration's margins can be repaired with fresh composite. If the stain is extensive, the entire restoration should be replaced. The postfinish application of a surface sealant (Fortify, Bisco, Optiguard, KerrDental) has been shown to improve the composite's marginal integrity over time and can provide a more esthetic restoration by sealing surface irregularities.

Discolorations around porcelain veneers

Marginal staining of porcelain veneers may necessitate the replacement of otherwise acceptable restorations. Marginal staining can result from any of these clinical situations, as follows:

- The cement line may become obvious after several years if a dual-cured or chemically cured composite luting agent was used instead of a more color-stable, light-cured resin cement. Also, unsightly margins may develop when extensive stains accumulate on improperly polished margins. However, the eventual esthetic failure of veneers may be due to advance marginal staining. The final potential cause of unsightly margins is marginal leakage. This occurs when the tooth–composite bond becomes compromised. Although the first two margin discolorations present only an esthetic concern, staining as a result of leakage may signal a problem with decay under the restoration. As stated earlier, Nightguard bleaching with 10% carbamide peroxide may be helpful as both a therapeutic and a diagnostic procedure. If the stain around the veneer is removed by the at-home bleaching, the margin can be refinished[39] and/or resealed and the veneer salvaged.
- Discoloration can be microleakage due to failure of the adhesive cement or an inadequate bond at virtually any part of the veneer. Because of the physiologic problems associated with maintaining an adequate bond in the cervical area, this leakage is most often seen associated with the cervical portion of the veneer. Treatment of this problem generally consists of replacement of the veneer. However, it is sometimes possible to repair the gingival aspect with composite resin (refer to Chapter 14). If this treatment option is selected, it is advisable to use abrasive technology with a metal strip to avoid any unnecessary trauma or injury to the remaining porcelain. Often, jet-black stain caused by chromogenic bacteria is found underneath the defective part of the veneer.

- Both vital and endodontically treated teeth under veneers may darken over time. Bleaching may be a conservative treatment for this condition. In this instance, the bleaching material is applied to the surface of the tray that contacts the lingual surface of the tooth. The bleaching of the underlying tooth may return the veneered tooth to an acceptable shade.

Esthetic considerations for facial composite restorations

There are several factors that should be kept in mind when esthetically restoring the Class V restoration.

- **Color match:** For most patients, the objective will be to correctly match the present tooth shade. If using composite resin, a microparticle restorative material is preferred rather than a hybrid composite since there will be usually no occlusal force with which to deal and the polishability of a microfilled composite will be of benefit to the patient. Generally, a slightly darker shade should be applied first at the cervical-most portion of the restoration, followed by either a blending body tone or translucent shade to help create a natural look to the tooth. If the patient is bleaching their teeth first, wait 2–3 weeks following termination of bleaching before appointing the patient for the restoration procedure.
- **Gingival seal:** Perhaps the most difficult procedure to accomplish is obtaining an effective gingival seal when bonding a Class V restoration. However, failure to obtain proper gingival adhesion will eventually result in either the restoration becoming debonded or subsequent microleakage can result in a gray–black stain that can, in time, be detected. Use of a rubber dam is the best way to avoid contamination. If a rubber dam is not used, then the placement of a gingival retraction cord 10–15 min prior to restoring the tooth may help prevent crevicular contamination.
- **Shape:** After color, the shape of the restoration becomes the most important element of an esthetic restoration. Using the overlay technique (see Chapter 14), be sure to slightly overbuild the restoration so that sufficient material remains to finish and polish the restoration. Both building up and contouring of the restoration should be accomplished by viewing the tooth not only from the facial aspect but also occlusally and laterally to best obtain the correct silhouette form.

Although the patient may tend to focus on specific discolorations or stains, it is important for the dentist to remain objective and view the stains in the context of the entire smile and face. In other words, will removal of the stain truly satisfy the patient's quest to look better, or will a more comprehensive approach not only improve the tooth color but also provide a smile that would better improve their self-image? The answer to this question may be found in esthetic computer imaging or even a Trial Smile. Actually showing your patient the difference in just removing the stains and changing the smile provides the truest form of informed consent.

Summary

The staining or discoloration of teeth can be indicative of a variety of clinical situations, ranging from severe systemic conditions that may be life threatening to the mere buildup of extensive stains as a result of oral habits. Therefore, the first step in the treatment of a patient whose chief complaint is stains or discolorations is the diagnosis of the cause of the discoloration. The diagnosis will dictate the appropriate treatment options from which to choose. It is incumbent on the dentist to select the most conservative treatment option for the specific stain, while preparing the patient for subsequent treatments should the selected one not be effective.

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Chapter 22 Abfraction, Abrasion, Attrition, and Erosion

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In contemporary life, cervical and occlusal tooth wear has become part of dentists' regular assessments, and providing information to patients about tooth wear is growing in importance. Throughout the years, the dental profession has held a variety of theories about the causes of tooth wear, including chemical wasting of the teeth, the effects of tooth brushing, and lateral forces. Tooth wear may present as abfraction, abrasion, attrition, and erosion.

During their lifetime, many people will experience the effects of one or more of these conditions. The stress of today's fast-paced lifestyle may lead to various habits that can directly cause or contribute to these problems. The etiologies of abfraction, abrasion, attrition, and erosion may be interrelated; therefore, multiple conditions may be seen in a single patient (Figure 22.1A–K).

A review of the literature frequently reveals confusion, controversy, and contradiction concerning the terminology and etiology related to the loss of tooth structure due to noncarious processes. For example, even though the term erosion is frequently used in the dental literature to denote loss of tooth structure due to chemical dissolution, the actual definition of erosion is the abrasive destruction of a material that occurs as a result of movement of liquid or gas, with or without solid particles, over the surface of the material. So possibly, the term "erosion" could be called "corrosion" more accurately, as it describes the chemical dissolution of teeth. However, in this text we will utilize the term "erosion" as it is commonly known in the profession.

Often, the lines between the chemical and physical forces that cause noncarious tooth structure loss are blurred. When the etiologic factors of more than one of these conditions are simultaneously present, the resultant loss of tooth structure will be accelerated or magnified. As an example, bulimics who brush their teeth immediately after regurgitation may increase the rate of enamel loss. This is due to the greater effect of abrasion on acid-etched enamel. In assessing these various conditions, the possibility of multifactorial etiology should always be kept in mind.[1]

* Deceased

Ronald E. Goldstein's Esthetics in Dentistry, Third Edition. Edited by Ronald E. Goldstein, Stephen J. Chu, Ernesto A. Lee, and Christian F.J. Stappert.

Figure 22.1 **(A)** This 48-year old male became concerned about his tetracycline stained teeth that had become darker but especially the tooth abrasion and erosion that had occurred over the years.

Figure 22.1 **(B)** The treatment plan called for porcelain veneers to solve both the labial defects plus the tetracycline stained teeth. Ten teeth were prepared for porcelain veneers plus one molar for a full all-ceramic crown.

Figure 22.1 **(C)** Cotton retraction cord (Ultradent) displaced the gingival tissue to obtain an accurate vinyl polysiloxane impression. (Aquasil, Dentsplyl).

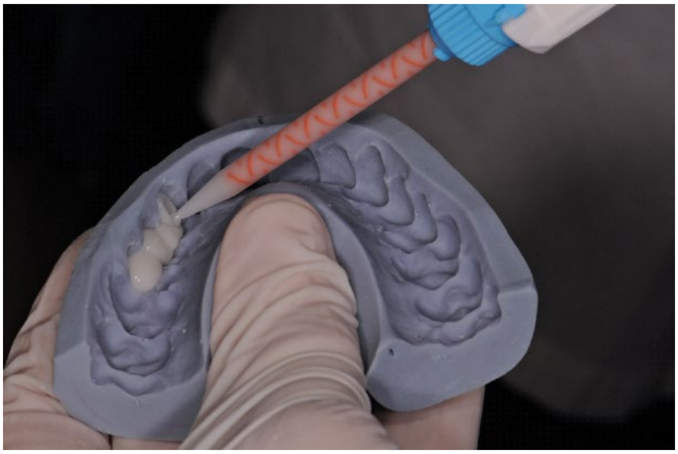

Figure 22.1 **(D)** A siltek matrix formed from the patient's waxed model is being loaded with temporary acrylic material (Luxatemp DMG) to make the interim veneers.

Figure 22.1 **(E)** The temporary veneers are bonded together for strength in the patient's chosen shade to act as both tooth protection and as a trial smile for shape and shade.

Figure 22.1 **(F)** A special color corrected light was utilized to verify shade. (AdDent).

Figure 22.1 **(G)** The final veneers are first fitted individually one by one and then as a group.

Figure 22.1 **(H)** The two central incisors are bonded to place first, followed by the lateral incisors and then the 2nd and 1st bicuspids. Finally, the cuspids are refitted and bonded.

Figure 22.1 **(I)** The final restorations have all been cemented and any residual cement removed.

Figure 22.1 **(J–K)** The before and after smile showing good blocking the underlying discolored teeth. The patient did not feel he showed his lower discolored teeth much so he postponed veneers on these teeth. An alternative plan is in place to restore the mandibular cervical eroded defects with composite resin bonding.

It is important to recognize that wear of the dentition has been present since the origin of humankind. Young provides an extremely interesting summary of the literature relating to dental wear in the aboriginal populations of Australia and New Zealand.[2] The anthropologic studies of the University of Adelaide Dental School show the gamut of “development, progressive modification, and adaptability of the human occlusion to the demands of the environment before Western culture shock.”[2] Through these studies, it was shown that human dentition was better able to withstand wear against the plaque-induced diseases that are primarily related to modern diets. In essence, these data support the fact that wear enhances the efficiency of teeth for the purposes for which they were intended: incising, shearing, crushing, and grinding foods. Begg wrote a series of articles on his analysis of prehistoric dentitions.[3–6] These articles provide insight into the orthodontic implications of dental wear as it relates to the preservation of dental arch integrity. Barrett determined that Australian aborigines with abrasive diets did not have significant malocclusion from a functional perspective.[7]

In 1958, Barrett noted that teeth in modern populations rarely exhibit the patterns of wear seen occurring in a natural fashion in aboriginal civilizations.[8] Herein lies part of the dilemma faced by the profession today. Radical changes in our environment and diet over the past few centuries have altered the extent and type of wear present in teeth.[9] These same dietary alterations have increased the prevalence of plaque-related dental diseases and the subsequent effects of such diseases.[10] Further compounding the picture are cultural shifts that have led to heightened awareness and the demand for esthetic dentistry.[11] Ultimately, as a profession, it is important that we recognize that anthropologic evidence related to tooth wear and the consequences of basic stomatognathic function on the longevity of teeth and restorations.

Attrition

Attrition is the loss of tooth structure by mechanical forces from opposing teeth. The wear from attrition may be seen on the occlusal surfaces of posterior teeth, the palatal surfaces of maxillary anterior teeth, and the labial surfaces of mandibular anterior teeth. The affected surfaces are usually hard, smooth, and shiny. However, the teeth may be sharp and jagged in certain cases. The areas of attrition may exhibit a yellowish-brown discoloration if the wear has penetrated the enamel. Wear may also occur interproximally, causing mesial drifting and broadening of proximal contacts.

Young mouths typically do not exhibit severe attrition. However, wear may be seen in the primary and mixed dentitions (Figure 22.2A). Numerous articles have reported on wear in children and adolescents.[12–19] As expected, increasing wear is seen with increasing age. This, as well as the fact that men exhibit more wear as they age, was demonstrated in a study of 586 subjects aged 45 and older[20] (Figure 22.2B–D).

It is well established that the most common cause of attrition is bruxism. Functional habits, such as chewing and swallowing, rarely result in tooth contact, and when contact does occur it

Figure 22.2 **(A)** This young girl demonstrated severe wear and attrition in her mixed dentition.

Figure 22.2 **(B–D)** It is so important for both hygienist and dentist to diagnose early bruxism habits as soon as possible to prevent from further tooth loss.

results in very little force. On the other hand, parafunctional habits, such as clenching and bruxism, result in significant forces on opposing teeth. This will be discussed at greater length in the bruxism section. There are numerous etiological factors that contribute to attrition. These include malocclusion, environmental factors, and genetic factors. Considering occlusion, we see greater wear in teeth that are in crossbite, both anteriorly and posteriorly. Environmentally, chronic exposure to dust and dirt can also cause increased wear in humans. This can occur in agricultural areas[21] or be associated with various industrial settings, such as cement factories.[22] Genetic factors should also be considered, such as dentinogenesis imperfecta, a disorder that affects the collagen protein causing deformities in dentin,[23–36] or amelogenesis imperfecta, which is a hypoplastic enamel. Both of these conditions make the teeth more susceptible to wear at an increased rate. When first examining a patient and diagnosing tooth wear, it is important to remember that the tooth wear may not be actively occurring at the time of exam. In other words, the current damage may be present from historical behaviors. It is important to monitor the progression of the tooth loss over time. This can be done by making casts and taking digital photographs of the teeth with wear, and repeating this process at different intervals. The same wear facets can be measured on the different casts to determine the continued activity of tooth wear. Likewise, if care is taken to replicate the same positioning in the photographs, one can visualize the progression of exposed dentin. To quantify the amount of tooth structure that has been lost due to wear, several authors have created indices. One of the most frequently cited is the tooth wear index published by Smith and Knight in 1984 (Table 22.1).[37]

Table 22.1 Smith and Knight's Tooth Wear Index

Score	Surface	Criterion
0	B/L/O/I	No loss of enamel surface characteristics
	Cervical	No change in contour
1	B/L/O/I	Loss of enamel surface characteristics
	Cervical	Minimal loss of contour
2	B/L/O	Loss of enamel exposing dentin for less than one-third of surface
	Incisal	Loss of enamel just exposing dentin
	Cervical	Defect less than 1 mm deep
3	B/L/O	Loss of enamel exposing dentin for more than one-third of surface
	Incisal	Loss of enamel and substantial loss of dentin, but not exposing the pulp
	Cervical	Defect 1–2 mm deep
4	B/L/O	Complete loss of enamel, pulp exposure, or exposure of secondary dentin
	Incisal	Pulp exposure or exposure of secondary dentin
	Cervical	Defect more than 2 mm deep, pulp exposure, or exposure of secondary dentin

Bruxism

Bruxism is a condition in which persons grind, gnash, or clench their teeth. This can include unconsciously clenching of the teeth during the day or clenching or grinding them at night (sleep bruxism).[122] Sleep bruxism is considered a sleep-related movement disorder. Mild bruxism may not require treatment, but bruxism can be frequent and severe enough to lead to jaw disorders, headaches, damaged teeth, and other problems. Bruxism can lead to extreme loss of occlusal and incisal tooth structure (Figures 22.3 and 22.4). For example, a young woman was treated for her defective restorations in 1968. Although she continued with routine maintenance appointments for a few years, she never accepted the advice to have a bite appliance constructed to treat her bruxism habit. Thirty-one years later, she returned with extremely worn dentition, as seen in Figure 22.4C–E. Crown lengthening and full crowns were necessary to restore this patient's smile (Figure 22.4 F and G).

Bruxism may also produce abfractions in the cervical regions.[38] It was suggested that bruxism and malocclusion generate occlusal forces on the tooth of sufficient duration and magnitude to cause tooth flexure, which is followed by lesion formation.[39,40] Patients suffering from bruxism may also experience symptoms of myofacial pain dysfunction syndrome or related disorders.[41,42] It is imperative to look closely at wear patterns in patients suspected of bruxism and evaluate for other signs and symptoms of occlusal dysfunction.

Owing to the gradual loss of tooth structure that most commonly occurs with bruxism, there is rarely loss of the vertical dimension of occlusion. This is due to the continued eruption of the teeth and their surrounding alveolar bone, as the teeth maintain their occlusal stops. The typical thought process would suggest that vertical dimension should be increased restoratively by opening the bite, thereby creating space for restorative materials to lengthen the worn teeth. This approach, however, may be ill advised. Often, the patient's posterior teeth are unworn and in occlusion. If this is the case, alternative treatment options, including orthodontic movement and crown lengthening, should be considered in conjunction with the prosthetic rehabilitation of the worn teeth.

When treating a patient with worn dentition, it is essential to first diagnose the cause and the type of wear, and whether restorative space is available. Turner proposed a classification system for occlusal wear in 1984, which has since become the standard for clinical and academic discussions regarding this topic. Three categories of wear patients are described:[43]

Category 1: excessive wear with loss of occlusal vertical dimension (OVD) (Figure 22.5A–K).

Category 2: excessive wear without loss of OVD but with space available.

Category 3: excessive wear without loss of OVD but with limited space.

First, one must establish if there has been a loss of OVD by clinical examination. If there has been a loss, the patient is assigned to the first category. For these patients, opening the vertical dimension of occlusion is indicated and will create the necessary space for restorative materials. If there has not been a

Figure 22.3 This case illustrates the severe damage that can be caused by bruxism. The patient is a 56-year-old man who reports that his wife tells him he grinds his teeth while sleeping. He is also a farmer and is exposed to dust for extended periods of time for much of the year. The combined bruxism and environmental factors have likely contributed to the extreme wear present. As is most commonly seen with cases in which the wear progresses slowly, there has been no discernible loss of vertical dimension, as evidenced by lip position and speech patterns. Note the traumatic occlusal relationship when the patient is in complete intercuspation **(A)**. Views of the severe wear of the maxillary and mandibular arches. Note the calcified, exposed pulp chambers and caries **(B and C)**.

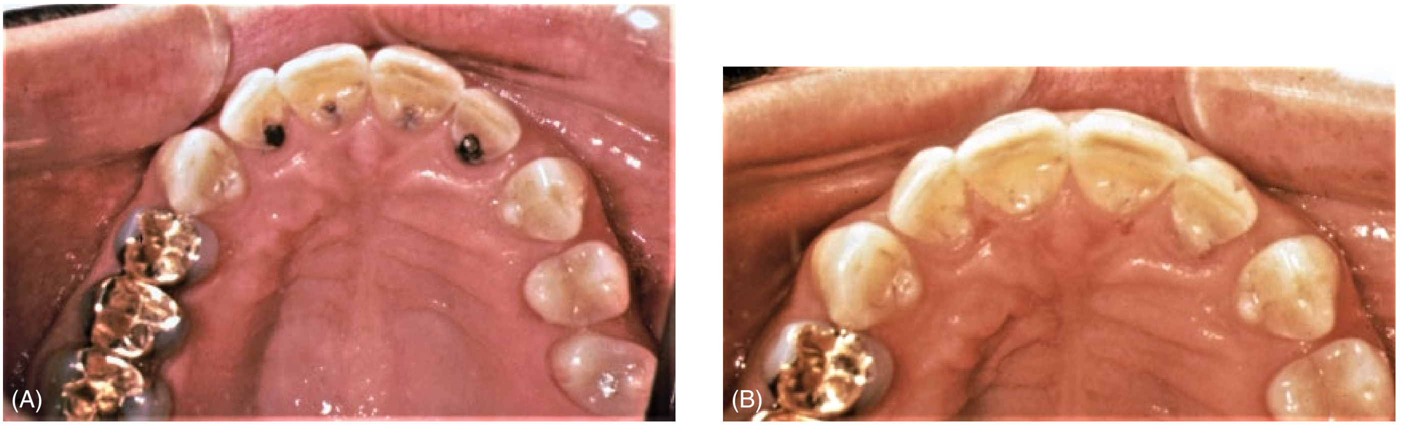

Figure 22.4 **(A, B)** This young woman's defective amalgam restorations were replaced in 1968 with tooth-colored restorations. At that time, and during the ensuing few years of maintenance recalls, she was advised to have a bite appliance constructed for her severe bruxism habit.

loss of OVD, one must determine whether space is available for restorative materials. This can be done by clinically evaluating the closest speaking space or by having the patient wear an occlusal splint made at the desired vertical opening. If it is determined that restorative space is unavailable, then space must be gained either with orthodontic intrusion or periodontal crown lengthening. Nel et al. described a variety of techniques that can be used in restoring wear from bruxism.[44]

Figure 22.4 **(C–E)** She returned 31 years after her first appointment with an extremely worn dentition.

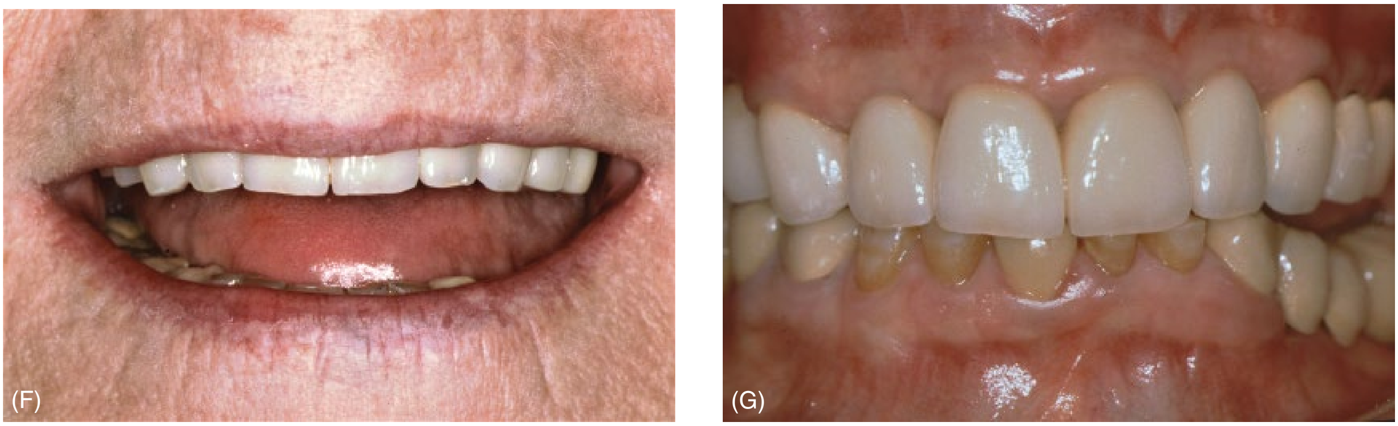

Figure 22.4 **(F, G)** Treatment consisted of crown lengthening and full crowns, which restored the patient's smile and her self-confidence. The lower left arch was treatment planned to replace the fixed bridge, but in unideal occlusion to occlude with the new maxillary restoration.

Once the patient's Turner classification has been identified, treatment planning can begin with a diagnostic wax-up. Dawson[45,46] recommends the following sequence:

1. Develop maxillary incisal edge position.
2. Develop mandibular incisal edge position.
3. Develop maxillary occlusal plane.
4. Develop mandibular posterior occlusal plane.

Following this sequence, you can determine from the diagnostic wax-up if the treatment will require orthodontics, esthetic and/or functional crown lengthening, as well the extent of the restorative rehabilitation. As you are beginning your diagnostic process with the maxillary incisal edge position, the patient's incisal display must be evaluated. As previously mentioned, the lost tooth structure is often compensated with continuous eruption of the tooth, along with its alveolar bone and gingival tissues. If this is the case, the incisal edge is often in the correct position, even though the teeth may be significantly worn down. The length needed to achieve esthetics in this situation needs to come from the gingival direction rather than the incisal. Osseous crown lengthening is frequently needed.

Orthodontically[47,48] repositioning the teeth should be the first treatment option when both functional and esthetic improvements can be achieved. Although patient motivation may not be easily obtained, the slow eruption or intrusion of anterior teeth combined with functional orthodontic intervention can many times result in the ideal solution to this problem. Therefore, it is wise to seek an orthodontic consultation before providing the patient with alternative treatment plans.

Turner Class I patients have the most straightforward treatment planning; teeth have excessive wear and there is also space

Figure 22.5 **(A)** The 56-year-old woman shown was not aware of her bruxism habit.

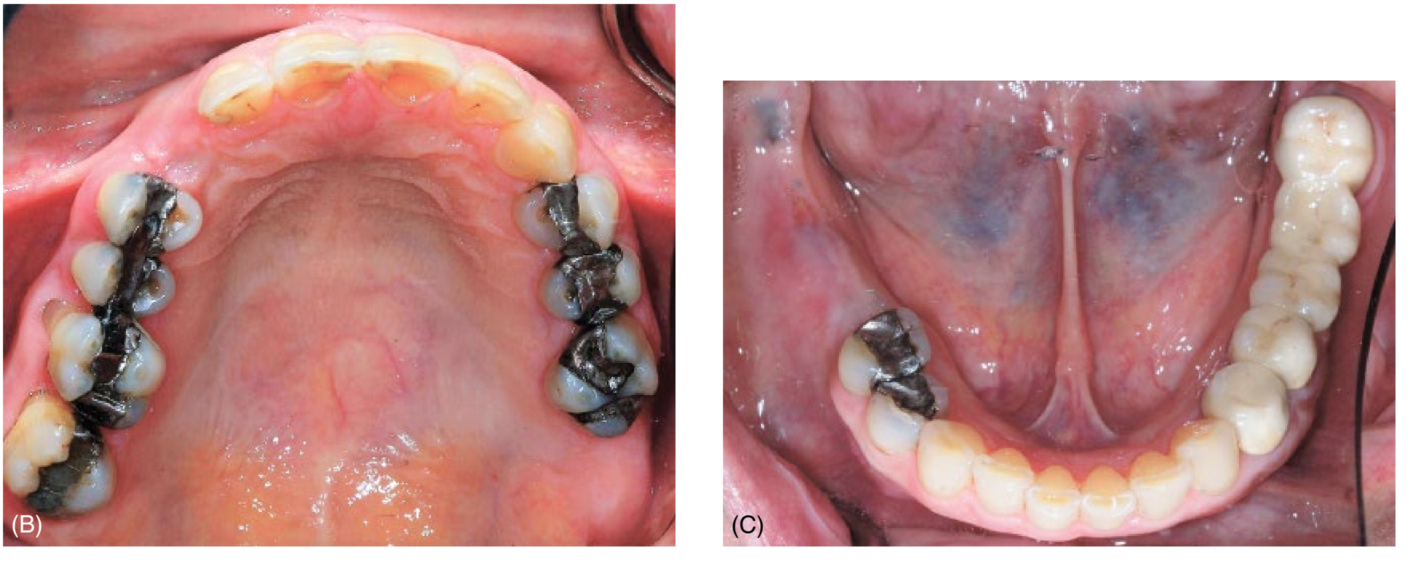

Figure 22.5 **(B, C)** The patient presented with severe wear on the lingual surfaces of teeth #8 and #9, moderate wear on the lingual and incisal surfaces of teeth #7, #10, and #11 as well as mandibular anterior teeth due to bruxism. Cupping areas were also detected on the occlusal surfaces of the teeth #4, #5, #12, #13, #28, and #29 probably due to combined effect of erosion and attrition.

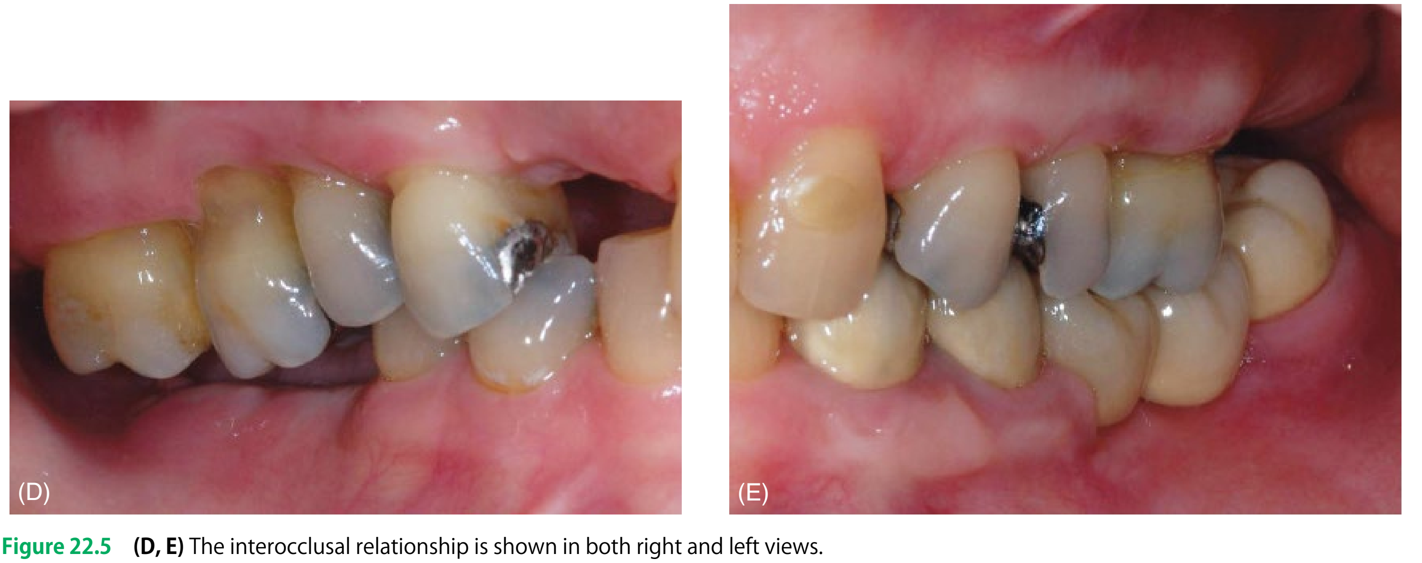

Figure 22.5 **(D, E)** The interocclusal relationship is shown in both right and left views.

Figure 22.5 **(F–K)** Extraction of a supererupted tooth, surgical implant placement, crown lengthening, and full coverage crowns were necessary to restore this patient's smile as well as proper function.

available to restore the dentition. This type of patient typically presents with:

- posterior teeth missing and anterior teeth flared out;
- erosion on teeth that caused tooth wear at a rate that continuous eruption could not occur;
- genetic disorders such as dentinogenesis imperfecta or amelogenesis imperfecta.

With these patients, a new OVD should first be determined. In the literature, different methods have been discussed, including facial proportion method, phonetic evaluation (closest speaking space), Niswonger's freeway space evaluation, and transcutaneous electric neural stimulation.

Another method that has been discussed is utilization of an occlusal splint. With this technique, patients need to wear an acrylic appliance made to replicate the targeted amount of opening. This is typically worn for about three months as a way to evaluate whether the new OVD is acceptable. After determining the proper OVD, the diagnostic wax-up should be completed. Possible orthodontic treatment with an esthetic crown lengthening should be considered. Prosthetic rehabilitation should be completed as a final treatment following the provisionals being tested esthetically and functionally.

Clinical case study 22.1

A 56-year-old woman (shown in Figure 22.5A) was not aware of her bruxism habit. She presented with severe wear on the lingual surfaces of teeth #8 and #9 and moderate wear on the lingual and incisal surfaces of teeth #7, #10, and #11 and mandibular anterior teeth due to bruxism. Cupping areas were also detected on the occlusal surfaces of the teeth #4, #5, #12, #13, #28, and #29 probably due to combined effect of erosion and attrition (Figure 22.5B and C). The interocclusal relationship is shown in Figure 22.5D and E.

A functional occlusal analysis revealed a first centric occlusal contact between teeth #14–#18 and #19 with approximately 0.1 mm forward and 0.3 mm right lateral slide into maximum intercuspation. There was also a protrusive interference between teeth #14 and #17. This might have precipitated the grinding habit. Extraction of a supererupted tooth, surgical implant placement, crown lengthening, and full coverage crowns were necessary to esthetically restore this patient's smile and proper function (Figure 22.5 F–K).

Clinical case study 22.2

The treatment planning for Turner Class II patients tends to be more complex due to the continuous eruption that frequently takes place. Because of this, the tooth size is compromised but the OVD is maintained. Like Class I patients, the restorative OVD needs to be determined. Subsequently, the diagnostic wax-up will help determine whether to restore the worn dentition more apically or incisally. Again, both orthodontic treatment and esthetic crown lengthening should be considered, and provisional restorations must be used to verify esthetics and function before proceeding with final restorations. However, there are exceptions where palliative treatments may suffice (Figure 22.6A–C).

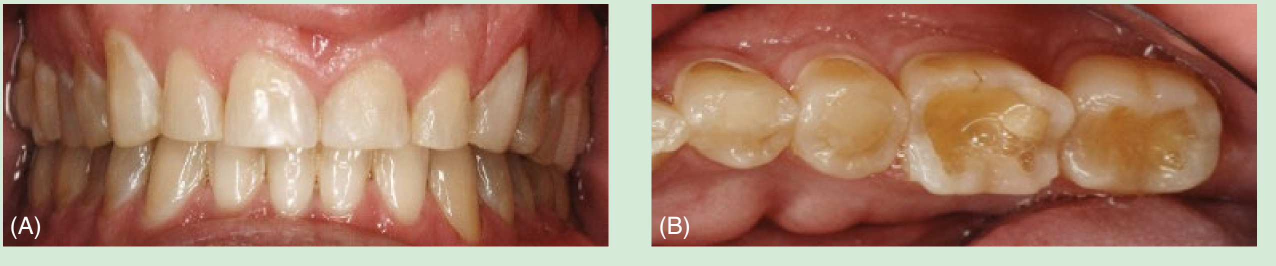

Figure 22.6 **(A, B)** Patient presented with moderate/severe attrition without loss of vertical dimension but with space available. Patient was not interested in esthetic improvement of the anterior teeth and nor was he complaining of any symptoms other than sensitivity in the posteriors.

Figure 22.6 **(C)** The decision was made to a restore the excessive wear on the molars with composite resin bonding, and a bite guard was fabricated to help control his bruxism.

Clinical case study 22.3

In the case of a Turner Class III patient, there is no space available to restore the worn dentition. This type of patient typically presents with wear on the anterior teeth, with no signs of bruxism on the posterior teeth. These patients should be diagnosed immediately, and the OVD does not need to be opened. Depending on the incisal display and the need for restorative space, orthodontic intrusion and osseous crown lengthening also should be considered. Finally, the restorative rehabilitation should be completed after testing the new function and esthetics of the teeth with provisionals. An alternative treatment would be to alter opposing incisors in order to regain tooth length (Figure 22.7A–J).

In any bruxism/attrition patient, once the prosthetic rehabilitation is completed, an occlusal guard should be fabricated.

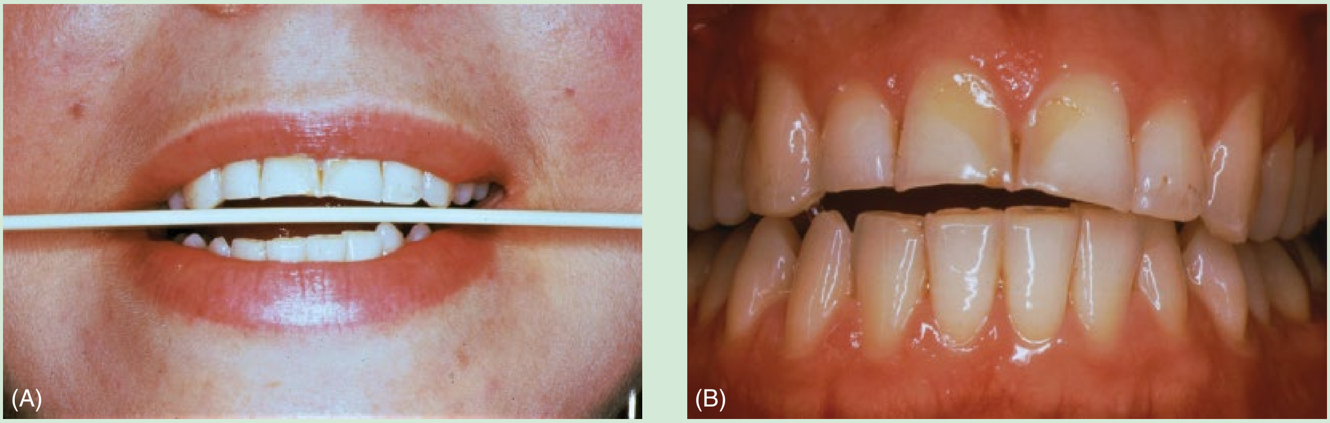

Figure 22.7 **(A, B)** This 23-year-old woman presented with advanced anterior incisal wear.

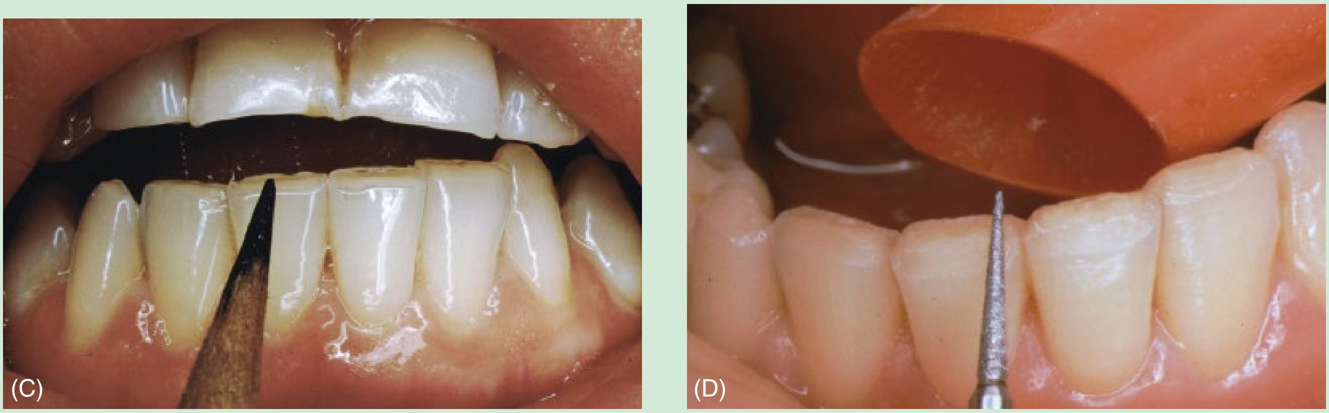

Figure 22.7 **(C, D)** The lower incisors were shortened and slightly beveled with a diamond bur.

Figure 22.7 **(E)** The maxillary right lateral and central incisors were etched and veneered with composite resin to add length.

Figure 22.7 **(F)** The final result shows a younger-appearing incisal plane.

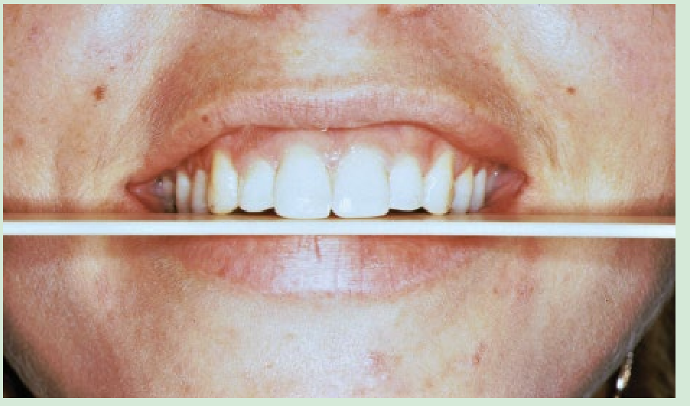

Figure 22.7 **(G)** Note the improvement of the smile line by comparing this figure with Figure 22.7A.

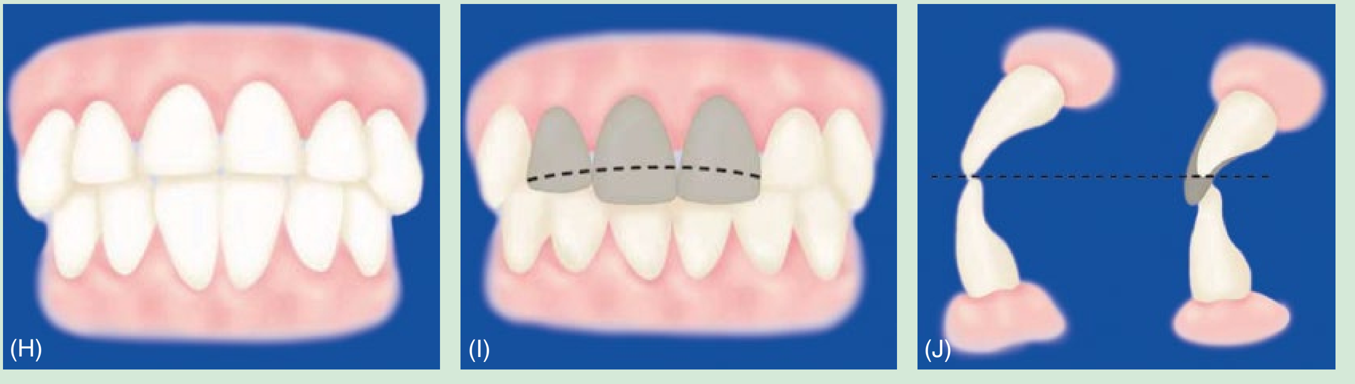

Figure 22.7 **(H–J)** These diagrams show how this procedure was accomplished. A balance was achieved by shortening and beveling the mandibular anteriors (J) to compensate for the lengthening of the maxillary incisal edges.

Abfraction

Abfraction, a type of noncarious cervical tooth loss, is a poorly understood condition. Other terms have also been suggested for this phenomenon, including noncarious cervical lesions (NCCLs) and stress erosion. Clinically, abfraction is represented by a wedge-shaped cervical lesion that results from repeated tooth flexure caused by occlusal loading (Figure 22.8). Although these lesions have been recognized for years, their etiology had been debated. Numerous hypotheses were put forward over time to explain the cause of these lesions. The most common theory was that of toothbrush abrasion occurring independently or in conjunction with erosion.[49] However, the sharp angles and frequent subgingival location of these cervical lesions cannot be adequately explained by any of the previous hypotheses. It was not until the early to mid-1980s that the concept of tensile stress as the etiology of these lesions came into the forefront.[50–52] Grippo originated the term abfraction to describe this pathologic loss of both enamel and dentin caused by biomechanical loading

Figure 22.8 This patient shows typical signs of abfraction lesions due to his constant clenching and grinding.

forces. He stated that the forces could be static (such as those produced by swallowing and clenching) or cyclic (as in those generated during chewing action). The abfractive lesions were caused by flexure and ultimate material fatigue of susceptible teeth at locations away from the point of loading. The breakdown was dependent on the magnitude, duration, direction, frequency, and location of the forces. Sufficient experimental and clinical evidence has now been gathered to establish the primary etiology of these lesions as tensile stress of occlusal origin.[41,53–63] However, even in light of strong scientific evidence, this topic remains highly controversial.

An abfraction can be commonly found on any tooth that has an exceptionally heavy occlusal marking on an inclined plane. Abfractions are also found quite frequently on patients with slight anterior open bites for the same reason—guidance coming from the bicuspids, rather than the cuspid. The open bite is usually the result of an abnormal motor action of the tongue. If damaging lateral forces are not obvious during excursive motions, then one needs to evaluate the position and motion of the tongue. The hypothesis is basically simple and easily tested in any dental office. Abfractions are not generally found on teeth of calm, nonstressed individuals with a natural and ideal (noncrowded, nonortho) Class I occlusion. These individuals with a noncrowded natural Class I occlusion will normally have a good cuspid rise during lateral excursions. With cuspid rise, the loading forces of the excursive movement will be directed onto the cuspid. Abfractions are frequently found, however, on cases where maligned cuspids cause initial lateral guidance forces to be exerted on the lingual incline of the buccal cusp of the first maxillary bicuspid (or whichever tooth bears the initial lateral guiding force of excursion). Dawson[45,46] described the requirements for a stable occlusion. These included: (1) having stable stops on all teeth when the condyles were in centric relation, (2) having anterior guidance in harmony with border movements of the envelope of function, and (3) disclusion of all posterior teeth in protrusive and excursive movements, including posterior teeth on the nonworking (balancing) and working side. If a tooth has an abfraction, the occlusal loading on the tooth can be tested in centric occlusion and in excursive movements with occlusal marking paper. There is a good chance that the tooth with the abfraction will have a heavy marking on one of the inclines of a cusp. This damaging lateral force produces stress lines in the tooth and results in tooth breakdown as described by Lee and Eakle.[50,64] McCoy[51,52] suggested that, to resolve the problem, the tooth needed to be reshaped. To prevent Class V abfractive restorations from falling out, however, one needs to treat the cause of the abfraction before restoring it.

As lateral and occlusal forces are generated during mastication and parafunction, flexure of the tooth occurs at the cervical fulcrum (Figure 22.9). This flexure concentrates tensile stresses that disrupt the chemical bonds of the crystalline structure of enamel and dentin. Small molecules then enter the microfractures and prevent the reformation of the chemical bonds. Loss of tooth structure ultimately occurs in the regions of concentrated stresses. After the initiation of these lesions, they may be accelerated by erosion and/or abrasion. In particular, if the lesion progresses so that dentin gets exposed, the tooth becomes highly

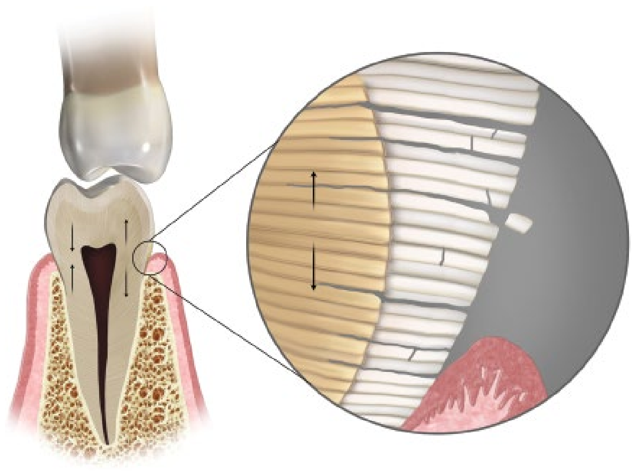

Figure 22.9 Model of tensile stress etiology of abfraction. Lateral forces create tension and compression in the cervical region, as indicated by arrows. Magnified section shows disruption of hydroxyapatite crystals of enamel and microfractures of dentin. When small molecules enter microcracks, reestablishment of chemical bonds is prevented. These areas are more susceptible to destruction from factors such as abrasion and chemical dissolution. *Source:* Reproduced with permission from Lee and Eakle.[64]

susceptible to further mechanical and chemical wear. Thus, there are additional factors that accelerate the impact of abfraction, such as tooth brushing pressure that can enhance microfractures and reduced salivary flow and salivary quality due to xerostomia and aging that will increase the amount of food particles in contact with teeth, especially on the buccal side.[40,65]

The concept of abfraction is supported only by studies conducted in vitro, where teeth were subjected to occlusal forces, while being stored in water.[39] These studies are unable to simulate the biomechanical dynamics of teeth and their supporting structures, as well as the changes that take place as teeth are exposed to the intraoral environment. The common findings of these studies suggest no differences in the location of the lesion with the direction of the forces applied, while clinically abfraction preferably occurs on the facial side rather than lingual. Furthermore, an applied force is never maintained in clinical situations. Hence, the results of in vitro studies should be interpreted with caution.

Some findings are consistent with the concept of abfraction and suggest tooth structure loss due to occlusal forces acting on the high stress cervical area. Indeed, cervical enamel is more brittle and vulnerable than occlusal enamel due to scalloping.[66] Human dentinoenamel junction (DEJ) scallop varies greatly between different tooth types, with larger and more pronounced scallops in teeth subjected to higher masticatory loads, such as molars, and anterior teeth having smaller scallops. Scalloping is the process taking place during tooth formation and is largely determined by the genetics of an individual. Thus, some people may have a stronger DEJ scallop, which provides more resistance to axial and nonaxial forces, while in others the DEJ may be more vulnerable to microcracking (Figure 22.10A–C).

Figure 22.10 **(A)** The buccal surfaces of the mandibular teeth have lesions that possess components of both abfraction (sharp margins in the occlusal regions) and abrasion (concave geometry and gingival recession in the cervical regions).

Figure 22.10 **(B)** The buccal aspects of the maxillary posterior teeth show smooth, concave configurations that are consistent with toothbrush abrasion and/or erosion.

Figure 22.10 **(C)**The palatal cervical regions of the maxillary anterior teeth exhibit sharp, wedge-like lesions that are characteristic of abfraction. These areas would be difficult, if not impossible, to have resulted from toothbrush abrasion.

Figure 22.10 **(D, E)** This lady wanted to improve her smile because she was embarrassed about the discoloration and abfraction lesions in her teeth.

Figure 22.10 **(F, G)** All ceramic crowns and veneers were combined to restore the defects and improve the esthetics of her smile.

According to only a few clinical studies, cervical wear was related to erosion and abrasion rather than abfraction or occlusal loading.[36,39] These clinical studies were based on individual assessments and questionnaires. There is only one study that has investigated the progression of cervical lesions over time.[67] This 6-year longitudinal clinical study reported the results for 55 people with cervical wear, and the authors observed that both consumption of dietary acids and frequency of tooth brushing correlated to increased wear, suggesting synergistic effects of abfraction and abrasion or erosion.

From the clinical data combined, abfraction is unlikely to lead to cervical lesion formation independently. Instead, it may be a part of a more complex process that leads to the formation of v-shaped cervical lesions. It was suggested that mechanical microcracks on cementum and dentin may act as the initial contributor to the formation of cervical defects. Abfraction has a possibility of being the initial factor and the dominant progressive modifying factor in producing cervical lesions[68] (Figure 22.10D–G). Perhaps the best summary regarding causative factors was stated by Heymann in his excellent 2016 presentation on NCCLs at the annual meeting of the American Academy of Esthetic Dentistry.[69]

Restoration defect

When NCCLs are restored, there tends to be relatively high failure rates if the occlusal problems that initiated the lesions are not corrected. This is true for both bonded and nonbonded restorations.[47,62,70–77] Although not reported in the literature, some clinicians suspect that the occasional case of facial porcelain debonding in ceramo-metal crowns used to restore teeth with abfractions is caused by the same stresses that caused the original lesions. This apparently occurs when the facial crown margin has been placed at the same level as the apical aspect of the abfraction and the occlusal disharmony has not been corrected. Again, the key to restorative success for abfraction is control of the destructive occlusal forces that initially caused the lesions.

Glass ionomer cements (GICs), resin-modified GICs (RMGICs), a GIC/RMGIC liner/base laminated with a resin composite, resin composite in combination with a dentin bonding agent and microfilled composites, which are slightly more flexible than conventional hybrid composites, represent restorative options.[78] Problems with restoring cervical lesions include difficulty in obtaining moisture control, gaining access to subgingival margins, loss of retention, secondary caries, discoloration, and sensitivity.[78] Cervical restorations may also contribute to increased plaque accumulation, potentially leading to caries and periodontal disease.

In cases when the root surface gets exposed and the outcome is an elongated clinical crown, a soft tissue graft or coronally positioned flap are possible treatment options for improved esthetics.[79] Typically, if the loss of tooth structure is relatively deep, an advanced flap will provide the necessary thickness of healed tissue and serve as a tissue barrier against possible future breakdown from inflammation due to bacterial plaque or traumatic toothbrush/toothpaste abrasion.

To prolong the life of cervical restorations, the lateral stress issue needs to be addressed. Occlusal adjustment and/or occlusal splints can be used to reduce heavy contacts and bruxism, as well as nonaxial forces on teeth.[80]

Clinical case study 22.4

A 42-year-old man presented with a complaint related to the space between the maxillary left central and lateral incisors. He reported that the space had been present as long as he could remember, but it had increased over time. Although he was aware of the notching defect on the central incisor, he could not recall how long it had been present. The abfraction extended from the midfacial to the distolingual line angle. There was significant gingival recession, particularly on the distal aspect of the left central incisor that was accompanied by gingival inflammation and a probing defect of 4–5 mm. Further, there was a marked right shift of the dental midline and the solid contact between the maxillary and mandibular left central incisors in protrusion (Figure 22.11).

Figure 22.11 This 42-year-old man has a space between the left lateral and central incisors. It is easy to see that traumatic occlusion could have played a role in the development of the cervical lesion on the distolabial area.

Clinical case study 22.5

A 70-year-old man presented with an extreme loss of tooth structure owing to abfraction (Figure 22.12A). Figure 22.12B shows the severe nature of the abfractions on the palatal surfaces of all posterior teeth on the right side. Both molars had exposures of the pulp chambers due to abfractions. The pulp tissue in the second molar was clearly visible and vital, but the first molar was necrotic. Neither tooth was symptomatic. The maxillary left region was similarly involved. The mandibular arch also had generalized abfractions, but they were not as severe as those in the maxilla (Figure 22.12A and B).

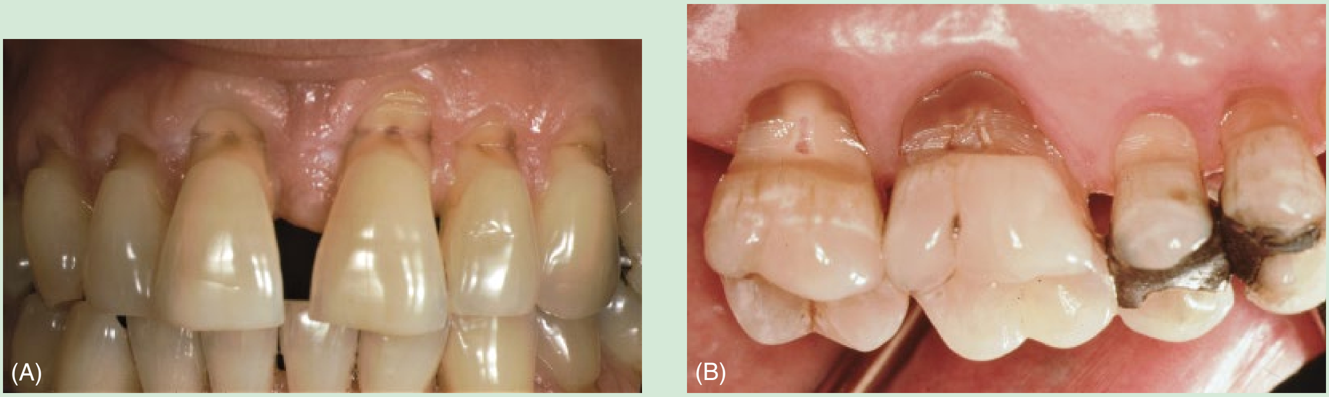

Figure 22.12 **(A, B)** These two photos are excellent examples of how extreme loss of tooth structure due to abfraction can exist and invade the pulp chamber without causing any symptoms.

Abrasion

The loss of tooth structure due to repeated mechanical contact with objects other than teeth is termed abrasion. Any object placed against the teeth can cause abrasion. If this tooth loss begins at the cemento-enamel junction, then progression of tooth loss can be rapid since enamel is very thin in this region of the tooth. Once past the enamel, abrasion quickly destroys the softer dentin and cementum structures. Evidence exists of various forms of abrasion in prehistoric populations.[81–85] A number of dental specimens recovered from the Sima de los Huesos Middle Pleistocene cave site in Spain exhibited a particular type of interproximal groove between the posterior teeth. The grooves were found only in adults and were apparently caused by the habitual probing of the interdental spaces with rigid objects (i.e., prehistoric toothpicks). Particles in the diet likely enhanced this abrasive phenomenon.[86] This same condition is seen in present-day societies. Other articles present information on various forms of tooth sharpening.[87,88]

Numerous oral habits cause abrasion; these are further discussed in Chapter 25. Examples of these habits include the localized occlusal defects in some pipe smokers who clench the pipe stem or individuals who chew on pens and pencils. Incisal notching is fairly common among seamstresses who hold pins or needles between the anterior teeth. Abrasion also can be produced by the clasps of partial dentures.[89] If teeth are worn on their occlusal surface and incisal surfaces by friction from the food bolus, this wear is termed "masticatory abrasion"[89] or "demastication." Masticatory abrasion also can occur on the facial and lingual aspects of teeth as coarse food is forced against these surfaces by the tongue, lips, and cheeks during mastication.[89] Abrasion can occur as a result of overzealous toothbrushing or improper use of dental floss. Toothbrush abrasion in particular has a characteristic appearance of a v-shaped lesion with horizontal striations from the bristles, as is most often seen on the canines and premolars. As a treatment modality, modification of the causative oral hygiene habit is important to prevent further progression. Existing defects caused by abrasion can be restored with composite resin or glass ionomers (Figure 22.13A and B). For severe abrasion that involves pulp of the tooth, root canal treatment may be needed.

The most conservative restoration of Class V defects is composite resin bonding. It generally requires little or no tooth reduction, thereby retaining as much tooth structure as possible to an already compromised tooth. A typical procedure can be seen in Figure 22.14, which shows a 45-year-old man with evidence of gingival and incisal abrasion, erosion, and abfraction. It is important to convey to patients that, by treating these types of defects as early as possible, less tooth structure is lost and more enamel is present to enable a stronger bonded restoration.

Figure 22.15A shows a 29-year-old woman who has abrasion and gingival recession confined to the anterior left segment, involving the canine and two incisors on that side. Closer examination revealed the smooth, rounded nature of the abraded areas (Figure 22.15B). Although she could not recall her specific age at the time, she reported that she was told by a hygienist that her brushing technique was improper when she was a teenager. She stated that she was instructed in brushing and flossing by this hygienist and had noted no progression of the recession since that time. For the past 8 years, she had been a patient in the same dental practice, and the clinical charting indicates that there had been no worsening of the problem. She had been informed about gingival surgery to correct the defects but has declined since she does not show her teeth when smiling.

Figure 22.13 **(A)** This is an example of abrasion, most commonly seen in canines and premolars as a result of improper tooth brushing technique.

Figure 22.13 **(B)** The abrasion defect was restored using composite resin. It is important to educate the patient on proper tooth brushing technique to prevent further destruction.

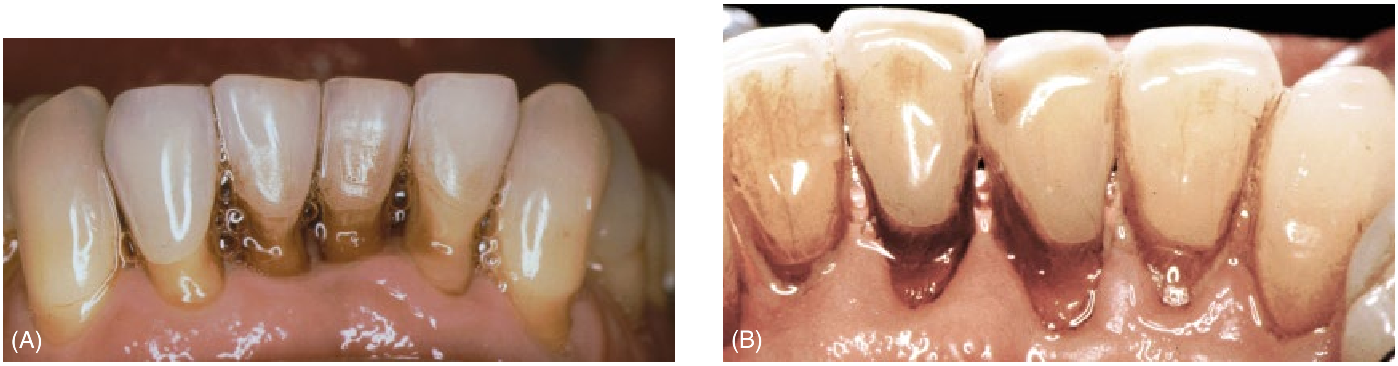

Figure 22.14 **(A, B)** This 45-year-old man shows extreme tooth loss due to combination lesions both gingivally and incisally of abrasion, erosion, and abfraction.

Figure 22.14 **(C)** A dentin/enamel bonding agent is applied, then a dentin/enamel resin, and finally an appropriate tooth-colored microfilled composite resin is placed using a Goldstein #3 composite instrument (Hu-Friedy, Chicago, IL).

Figure 22.14 **(D)** Careful shade selection and attention to detail should produce an invisible margin. Warning: Research shows that ultrasonic scaling on teeth with Class V direct composite resin bonding may cause microleakage at the cervical margins.[123]

Erosion

Erosion is a perplexing and frustrating problem. It is defined as the noncarious loss of tooth structure due to chemical dissolution not related to acids produced by the dental plaque. Erosion can present as a solitary lesion or involve a significant number of teeth. In certain medical conditions, such as gastroesophageal reflux disease (GERD) and bulimia, the corrosive lesions have a characteristic pattern.[90–98]

There have been a number of theories regarding the etiology of erosion, and they suggest two categories: intrinsic and extrinsic causes.[89,99–104] Extrinsic causes include environmental, dietary, medication, and lifestyle factors. Chronic contact with acidic fumes in factories that produce or use acids has been cited as a

Figure 22.15 **(A)** A 29-year-old female with abrasion confined to the maxillary left canine and lateral and central incisors.

Figure 22.15 **(B)** Close examination reveals smooth, rounded, abraded areas that are suspected to be the result of improper brushing.

Figure 22.16 **(A)** This patient presented with erosion on her two central incisors but was not positive of the cause.

Figure 22.16 **(B)** The treatment of this patient consisted of direct bonding with composite resin.

notable cause of erosion.[83,105–108] Another environmental cause of erosion is prolonged swimming in pools with a low pH. Certain medications[109] and oral hygiene products have also been implicated in the development of dental erosion. It is well known that a drop in oral pH below 5.5 initiates demineralization. Salivary flow rates and the buffering capacity of saliva also affect demineralization. In addition, it has been postulated that extreme alkaline conditions promote chelation of calcium out of teeth.

Dietary factors receive widespread attention and likely affect the greatest number of people.[52] Wine has been shown to lead to erosion in wine makers,[110] wine tasters,[111] and wine merchants.[112] Carbonated soft drinks and other acidic beverages play a major role in the development of erosive lesions and dental caries.[113–118] Many patients are unaware of the damaging effects of these dietary factors (Figures 22.16 and 22.17). Tables 22.2 and 22.3 list the pH of foods and beverages that may be implicated in tooth erosion. Whether the causes are acidic foods or beverages, the frequency and time of consumption are major lifestyle factors that contribute to erosion. Before treatment, it is important to identify the destructive foods or beverages in the diet and counsel the patient on the harm that is occurring to their dentition as a result (Figure 22.18).

Figure 22.17 This patient had a habit of sucking lemons, which caused typical erosion patterns on her anterior upper teeth. But even after the dentist restored her tooth, she continued her habit, which caused more erosion.

Treatment of these types of lesions should be done only when the causative problem is under control. Otherwise, restorations will have too short a lifespan, ending in esthetic failure. It is acceptable, however, to use provisional restorations during the corrective phase. During the corrective phase, measures should

Table 22.2 The pH Values of Acidic Beverages

Beverage	pH
Cranberry juice	2.3–2.5
Wine	2.3–3.8
Coffee	2.4–3.3
Sprite	2.6
Pepsi and Coke	2.7
Gatorade	3.3
Beer	4.0–5.0
Black Tea	4.2

Source: From Ren.[119]

Table 22.3 The pH Values of Acidic Foods

Food	pH
Lemons and limes	1.8–2.4
Pickles	2.5–3.0
Apples	2.9–3.5
Strawberries	3.0–4.2
Italian salad dressing	3.3
Tomatoes	3.7–4.7
Yogurt	3.8–4.2

Figure 22.18 **(A)** This young lady presented with severe occlusal erosion.

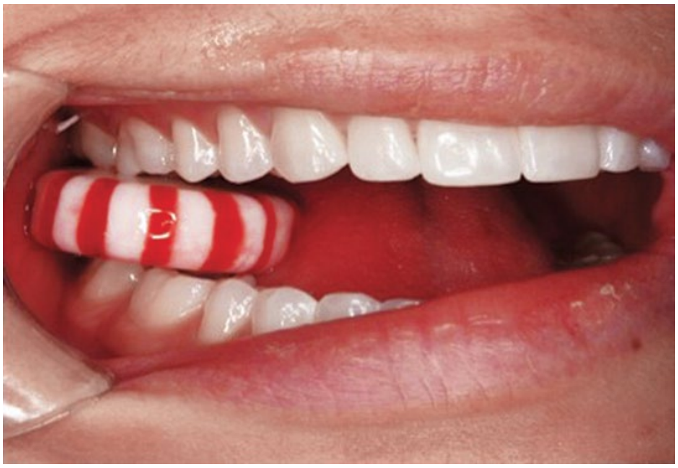

Figure 22.18 **(B)** When reviewing the patient's history, it was discovered that she had a habit of biting peppermint candy and holding it in place in between her posterior teeth while working at her desk.

Figure 22.18 **(C)** The defects were prepared and restored using a microhybrid composite resin.

be taken to keep the patient comfortable (in the case of dentin hypersensitivity) and try to remineralize the teeth. The patient should drink plenty of water and modify their diet if deemed necessary. Products to promote remineralization should also be considered, such as RECALDENT (MI Paste and MI Paste Plus, GC America).

Differential diagnosis

Proper diagnosis is required to achieve successful treatment outcomes. As noted at the beginning of this chapter, patients may simultaneously have more than one of the conditions described. Thus, when occlusal or incisal changes are noted, the cervical regions of the teeth should also be closely examined. Likewise, the occlusal scheme should be fully evaluated for cervical notches or defects.

When evaluating a patient who has any of these lesions, it is necessary to correctly diagnose the condition and address the etiologic factors. Many patients with these conditions may be asymptomatic and/or unaware of them. In addition, they may have received "routine" dental care in the past and be surprised when these conditions are brought to their attention. In the case of bruxism, some patients are so surprised that they actually deny the problem. If this is the case, the best way to demonstrate to them that they have a bruxing problem is through visual images. A variety of means are available to illustrate the problem, including intraoral photographs, diagnostic study casts, surgical microscopes, and intraoral or extraoral video images. With the aid of even simple visual references, the patient can be shown the extent of the damage that has been done and how they are causing it.[120] Once the patient is convinced of the problem, the next step is attempting to determine when it is occurring. If it occurs primarily during waking hours, the patient may be able to control or correct the problem.[122] If not, you may need to construct a daytime appliance for the patient until the habit is controlled. Generally, this will consist of a removable acrylic appliance fabricated on the lower arch that will not inhibit speech. If it occurs during sleep, a nighttime appliance will be necessary to control bruxing and/or prevent further damage to the dentition.

Although some of the aforementioned mechanisms do act independently, many additive or synergistic combinations of mechanisms may occur simultaneously, sequentially, or alternatively, leading to the progression of Class V cervical lesions.[89] The possible combinations include attrition–abfraction (lateral stress due to tooth-to-tooth contact; e.g., in bruxism or clenching), abrasion–abfraction (friction from abrasive material in the area where stress concentration due to loading forces may wear tooth substance), erosion–abfraction (chemical dissolution on areas of excess stress concentration), attrition–erosion (chemical dissolution in the areas of tooth-to-tooth contact), and abrasion–erosion (action of an acid together with abrasive particles).[89] In such situations, enamel may be lost rapidly and extensively.

Clinical case study 22.6 Severe tooth erosion in a woman with history of bulimia

A 28-year-old woman had a severe bulimic condition over the course of many years (Figure 22.19A–C). After years of therapy and overcoming her illness, she desired to restore her smile. Since so much tooth structure had been eroded, it was necessary to place provisional restorations followed by crown lengthening (Figure 22.19D) and eventual replacement with the final ceramo-metal restorations (Figure 22.19E–G).

A key criterion when examining a suspected abfraction is the presence of lateral occlusal stresses during mastication or parafunctional movements. Thus, signs of attrition in the form of notable wear facets and/or loss of anterior guidance are highly probable when abfraction is present. The orientation of the long axis of the tooth in relation to occlusal loading should also be evaluated. The physical characteristics of abfraction are that of a sharp, angular defect, and these lesions may be located completely beneath the gingival margin. Abrasion in the cervical region can be usually distinguished from abfraction by the smooth, rounded nature of the lesion. Minimal to extreme gingival recession, with or without mucogingival defects, will likely accompany abrasion. Gingival recession may also be seen with abfraction, but it is not a hallmark of these defects.

A novel method of determining the progression of cervical lesions over time is to undertake a scratch test.[39] A number 12 scalpel blade is used to superficially scratch the tooth surface. Visual observation of the scratch will give an indication of the rate of the tooth structure loss. Loss of scratch definition or loss of the scratch altogether signifies active tooth structure loss. Another indicator of the factors contributing to lesion progression is the staining of teeth.[121] Stained teeth suggest that the acid erosion is inactive, whereas stain-free teeth suggest that the erosive process is taking place. The rationale behind this is that persistent acid exposure removes the outer layer of enamel or dentin, creating a stain-free surface.

Teeth that exhibit any kind of cervical lesion need to be monitored over time, and preventive measures should be taken to avoid interventive operation. These include educating the patient about proper toothbrushing technique to prevent excessive pressure and abrasion to the teeth. Dietary advice would include consuming acidic foods in moderation and, preferably, during meal times, or drinking using a straw to minimize contact between beverage and tooth surfaces to reduce dissolution of enamel. Patients should be discouraged from brushing their teeth immediately after consuming acids, but instead wait for at least 30 min, as studies have shown that the time needed for softened enamel and dentin to reharden after an erosive challenge ranges from 2 to 30 min. Fluoride treatments help to harden enamel surfaces and promotes remineralization.[121]

Dental practitioners should have a high level of suspicion when they see generalized lingual erosion of the maxillary anterior teeth. Bulimia or GERD will be the likely cause. It is important to carefully obtain a history that will allow proper diagnosis. Individuals with GERD will more readily provide information that will assist in the diagnosis. Patients who suffer from bulimia may be reluctant to reveal their condition and are sometimes outwardly defensive when questioned concerning the issues related to their eating disorder. Often, however, a dentist may be the first medical professional to recognize signs of bulimia and can be instrumental in initiating an appropriate referral to address the overall condition.

Dentists must be diligent when they examine patients. They must look beyond the routine of caries, periodontal diseases, and missing teeth and closely evaluate patients for the loss of tooth structure due to noncarious processes. When these conditions are found, dentists must take time to assess potentially interrelated conditions and perform a thorough clinical examination.

Figure 22.19 **(A)** Severe occlusal erosion in a woman with history of bulimia.

Figure 22.19 **(B)** Labial erosion also contributed to discoloration.

Figure 22.19 **(C)** Her smile demonstrated severe labial erosion on the posterior teeth.

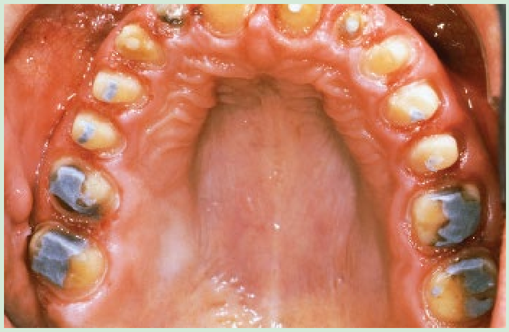

Figure 22.19 **(D)** Crown lengthening and buildups with composite resin were necessary before making the impressions for the final restorations.

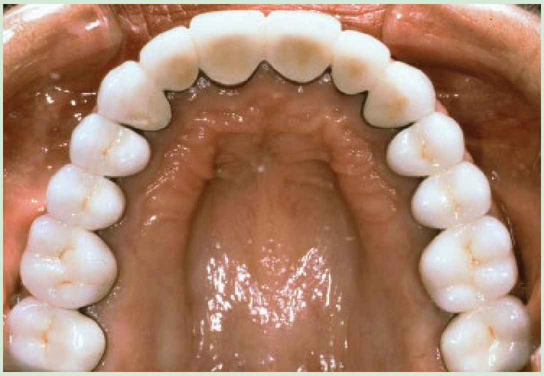

Figure 22.19 **(E)** The final splinted restorations were constructed using ceramo-metal.

Figure 22.19 **(F)** The five splinted crowns restored this lady's smile. Note the lighter shade the patient selected.

Figure 22.19 **(G)** The new, improved shapes and shade helped to achieve the smile the patient desired.

Discovering and helping to identify destructive habits, such as bruxism, needs to be a team effort. Frequently, the dental hygienist or assistant can be the observant individual who calls attention to a potential problem before it becomes an esthetic deformity. Team educational meetings are useful in teaching staff exactly what signs to observe. Knowing the correct anatomy of anterior and posterior teeth is of considerable value in being able to recognize even minor cusp or incisal edge changes that are a result of bruxism. Thus, the esthetics of the patient's smile not only depends on good oral hygiene but also becomes a shared team responsibility to keep it looking as good as possible throughout life.

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Chapter 23 Chipped, Fractured, or Endodontically Treated Teeth

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New caries prevention and health measures and improved oral care will help more patients keep more of their teeth disease free for a lifetime. However, one thing in "dental life" is almost a certainty: teeth will continue to fracture. Although sports injuries can be greatly reduced with proper protective gear, our daily lives are conducive to all sorts of accidents causing patients to fracture their teeth. The frequency of permanent incisor fractures in children is reported to range from 5 to 20%.[1,2] The loss of tooth substance in these situations is likely to be more horizontal than vertical.

Most tooth fractures are minor and seldom involve pulp. This chapter discusses such simple fractures, as well as treatment of teeth with pulpal and endodontic intervention (Table 23.1). One example of a more serious fracture involving the pulp is also presented with an explanation of techniques for handling this problem. Difficult fracture cases are usually emergencies. With our population living longer and retaining most of their teeth, the incidence of cracks in teeth also seems to be increasing. A tabulated review of cracked tooth syndrome, treatment options, and other considerations is included for easy reference (Table 23.2).

Some important factors have to be considered in management of tooth fractures, including the extent of fracture, which can involve biological width violation, endodontic involvement, or alveolar bone fracture. Another factor is the pattern of fracture and restorability of the fractured tooth, which can be complicated with root fracture. Also, secondary trauma injuries, such as soft tissue status and presence/absence of fractured tooth fragment, have to be considered for the best treatment outcome.[3]

Conservative restorative dentistry is always the goal in treating esthetic problems, and the fractured tooth is no exception.

Ronald E. Goldstein's Esthetics in Dentistry, Third Edition. Edited by Ronald E. Goldstein, Stephen J. Chu, Ernesto A. Lee, and Christian F.J. Stappert.

Table 23.1 Coronal Chips or Fractures

Diagnosis	Situation	Treatment Options	Considerations
No pulpal involvement	Small chip (enamel involvement only)	Recontour Composite repair	Occlusion
	Medium chip (dentin exposure)	Rebond fractured piece Composite repair	Shine-through effect; esthetics; occlusion
	Large chip (dentin exposure)	Rebond Repair Veneers (composite or porcelain)	Auxiliary retention; occlusion
Pulpal involvement	Direct pulp cap Endodontic treatment required: 1. conventional access with adequate tooth structure 2. extensive tooth loss; post and core required	Restore as for large chip Composite restoration Cast post and core Prefabricated post and core	Pulpotomy or partial pulpotomy Material choice: conventional glass ionomers, resin-modified glass ionomer, composite resin, and cast metal. Post materials: nickel-containing stainless steel, non-nickel-containing stainless steel, commercially pure titanium, titanium alloy, zirconia polycrystals, and carbon fibers

Table 23.2 Cracked Tooth Syndrome

Diagnosis	Situation	Treatment Options	Considerations
Intracoronal fractures	Affect enamel only Craze lines affecting enamel, dentin, and possibly the pulp	No treatment indicated	Long vertical craze line on anterior teeth
	Fractured cusp Supragingival	Remove the affected cusp; full crown/onlay coverage	Good prognosis
	Subgingival	Periosurgery, crown lengthening, orthodontic extrusion, full crown/onlay	Prognosis guarded
	Cracked tooth	Endodontics, full crown	Questionable prognosis
	Split tooth	Extraction; removal of mobile segment	Easily disclosed crack, movable segment; poor prognosis
	Vertical root fracture	Extraction or removal of fractured root	Difficult to diagnose; poor prognosis
Extracoronal fractures	Subgingival	Periosurgery, crown lengthening, orthodontic extrusion	Prognosis guarded
	Vertical root fracture	Extraction or removal of cracked root	Difficult to diagnose; poor prognosis

The most conservative treatment would obviously be cosmetic contouring, or the reshaping of the natural teeth, provided that it does not negatively alter the esthetics of the smile (Figure 23.1). Decades ago, the full crown restoration was the treatment of choice. Today, in addition to cosmetic contouring, the conservative solution is a choice between direct bonding with composite resin and laminating with porcelain.[4–6] Another option to consider when there is no or minimal violation of the biological width is the reattachment of the tooth fragment when it is available and has a good fit.[3,7] Tooth fragment reattachment offers a conservative, esthetic, and cost-effective restorative alternative.

The choice of restorative technique should be based on the following factors:

- **Amount of tooth destruction present.** Generally, small chips or fractures are easily restored with direct bonded composite resin (Figure 23.2). The esthetic result is excellent and provides the patient with an economic, one-appointment solution without any anesthesia.[8,9] However, if the patient continues to chip or fracture the bonding, then porcelain would be a better alternative (Figure 23.3). In the event that the enamel is severely compromised, requiring a more extensive restoration, the patient may ultimately be better off with a porcelain veneer. The fractured area is then replaced with the stronger and more durable porcelain. However, it may be a wise choice to select composite resin bonding as an interim restoration. This minimizes any further trauma to the tooth by additional preparation and allows observation time for any pulpal problem; moreover, the bonded solution can last for an indefinite period of time (Figure 23.4).[5] A more predictable long-term wear alternative to a composite resin restoration is reattachment of a tooth fragment with a dentin bonding agent or adhesive luting system.[7] Reattachment of a fragment to a fractured tooth is a great conservative solution to maintain the tooth's original form and

Figure 23.1 **(A)** This 21-year-old girl had chipped her anterior incisors when she was a teenager.

Figure 23.1 **(B)** Cosmetic contouring was the most conservative treatment available and was performed in a less than one-hour appointment.

Figure 23.2 **(A)** This man chipped his maxillary right central incisor.

Figure 23.2 **(B)** The right central incisor was bonded with composite resin.

Figure 23.3 **(A)** This young lady fractured her maxillary anterior incisors. Despite numerous bonding repairs, she continued to refracture the teeth. Because she also objected to the incisal translucency, she was treatment planned for three porcelain veneers.

Figure 23.3 **(B)** The initial preparations for the three porcelain veneers were done with a 0.5 mm depth cutter (Brasseler LVS System, Brasseler USA).

texture and offers minimal compromise to the remaining tooth structure. Reattachment was shown to be successful in more complicated fracture cases when endodontic therapy had to be performed on the fractured tooth.[7]

- **Longevity required.** If the patient does not mind the added cost, increased longevity can be achieved with the porcelain veneer. However, the patient needs to be informed about the limited life expectancy of each restorative option. Patients must also be made aware of the

Figure 23.3 **(C)** The two-grit diamond is used to reduce the enamel to the predetermined depth cut.

Figure 23.3 **(D)** The final preparations.

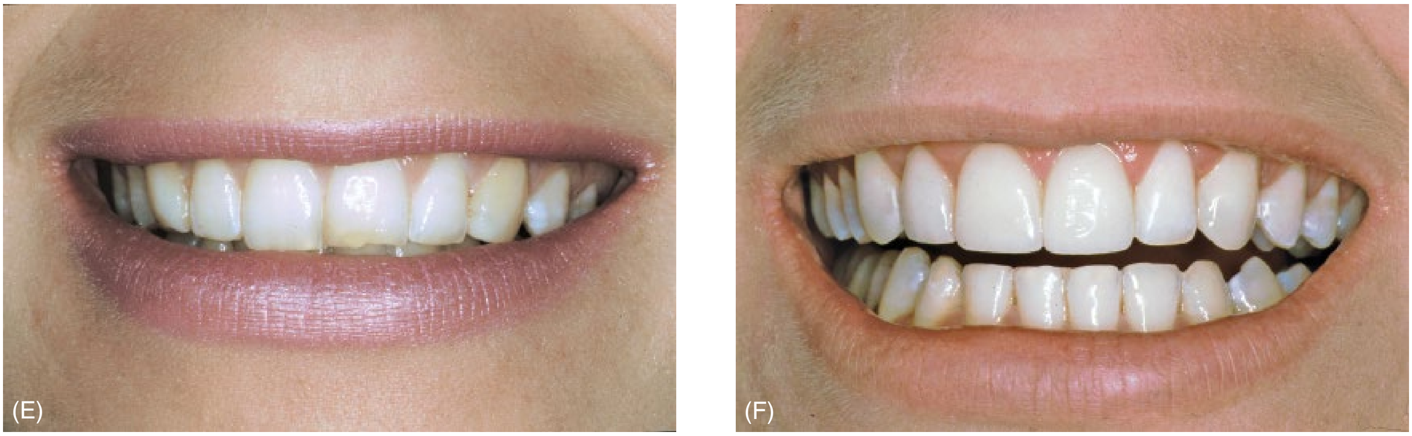

Figure 23.3 **(E, F)** Three porcelain veneers were placed on the central incisors and right lateral. The new veneers also achieved the objective to eliminate the incisal translucency.

periodic maintenance required, proper home care, and any dietary restrictions necessary to obtain the longest life possible.[6]

- **Economic considerations.** Although the cost savings of direct bonding might not be realized if numerous repairs are considered, it still may be easier for the patient to pay lesser amounts over the many years during which the direct bonded restoration can stay in place.
- **Occlusal factor.** If an end-to-end occlusal relationship or increased occlusal requirement exists, porcelain may again provide more durability, depending on the design of the veneer. It is essential to protect the incisal edge with sufficient porcelain to resist fracture. An example of this condition is seen in a patient who fractured his maxillary right central incisor (Figure 23.5A and B). During the clinical examination, this patient expressed his desire for a younger and brighter smile. The teeth were then prepared, and an impression was made for six porcelain veneers. To help protect the occlusion, porcelain was wrapped incisally to the lingual surface (Figure 23.5C). What began as an emergency visit to repair a fractured tooth resulted in enhancing this patient's entire smile (Figure 23.5D).

It is essential to use these opportunities to present each patient with alternatives that not only correct the immediate problem but also improve the entire smile.

In the final analysis, although direct bonding will generally be the method most often selected, there are definite situations for which porcelain veneers will be the technique of choice. The advantages and disadvantages of direct bonding, laminating, and crowns are outlined in Tables 23.3, 23.4, and 23.5 for comparison.[5]

Chips or fractures without pulpal involvement

Conservative bonding techniques for long-term results

Problem

A 27-year-old male presented with fractured maxillary central incisors involving the incisal edges (Figure 23.6A). Because the patient preferred not to reduce the tooth structure, a bonded composite resin was the material of choice to restore the fractured edges.

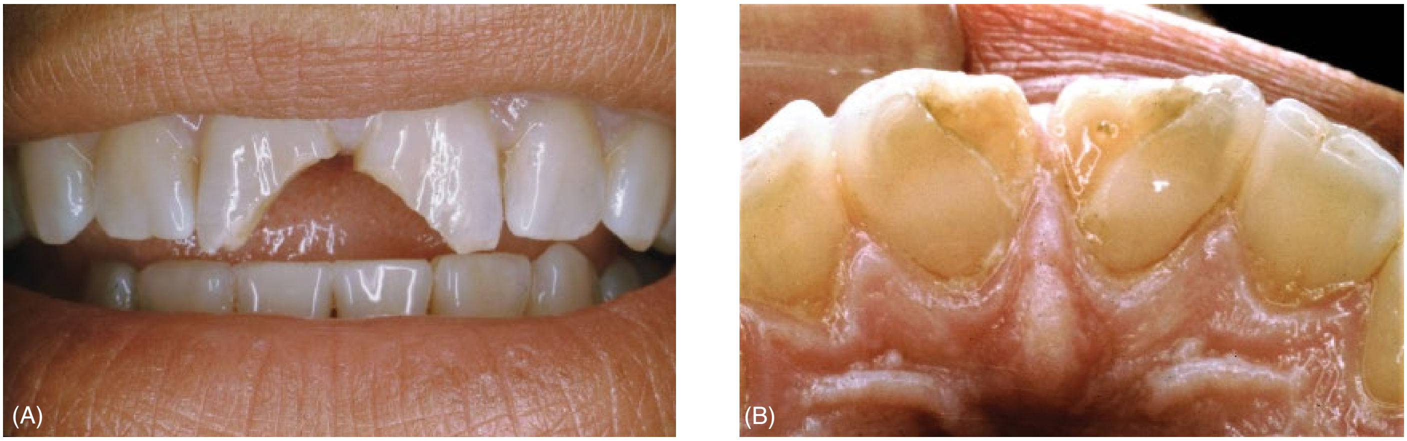

Figure 23.4 **(A, B)** This 17-year-old student fractured her central incisors on the edge of a swimming pool.

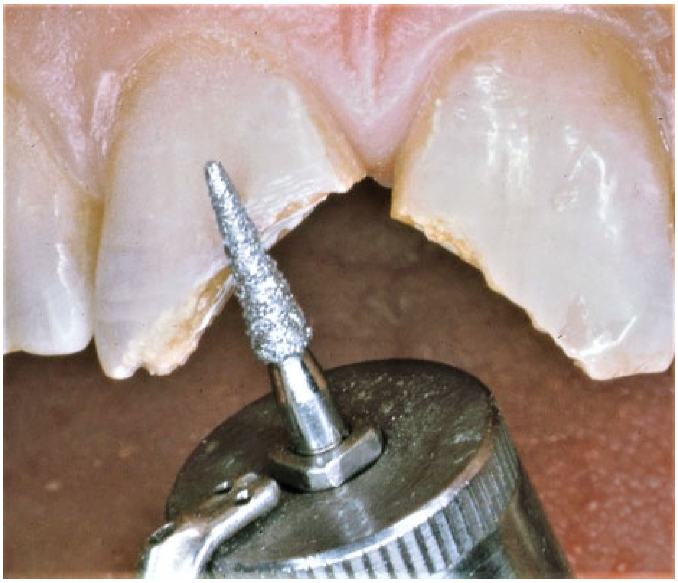

Figure 23.4 **(C)** A long bevel is placed using an extra-coarse diamond.

Treatment

Since the left central incisor overlapped the right one, the mesial surface of the left central was reshaped slightly to reduce the amount of overlapping in an attempt to create an illusion of straightness (Figure 23.6B). These fractures were old and not sensitive, so no protective base was required. In a new fracture or pulp exposure, the fracture site would have been protected first with glass ionomer or bioactive liner. A composite resin restoration was used for strength and to help blend in translucency. The restorations were finished with conventional composite resin finishing techniques (see Chapter 14).

Fourteen years later, the patient came in with a small fracture in the bonding material of the central incisor (Figure 23.6C). The teeth were reveneered with hybrid composite resin to improve his smile once more (Figure 23.6D). Although this patient may well be the exception to the rule of an average life expectancy of 5–8 years, his case does point out the fact that many patients would have preferred the restoration replaced long before the slight discoloration took place. However, careful maintenance, including good oral hygiene

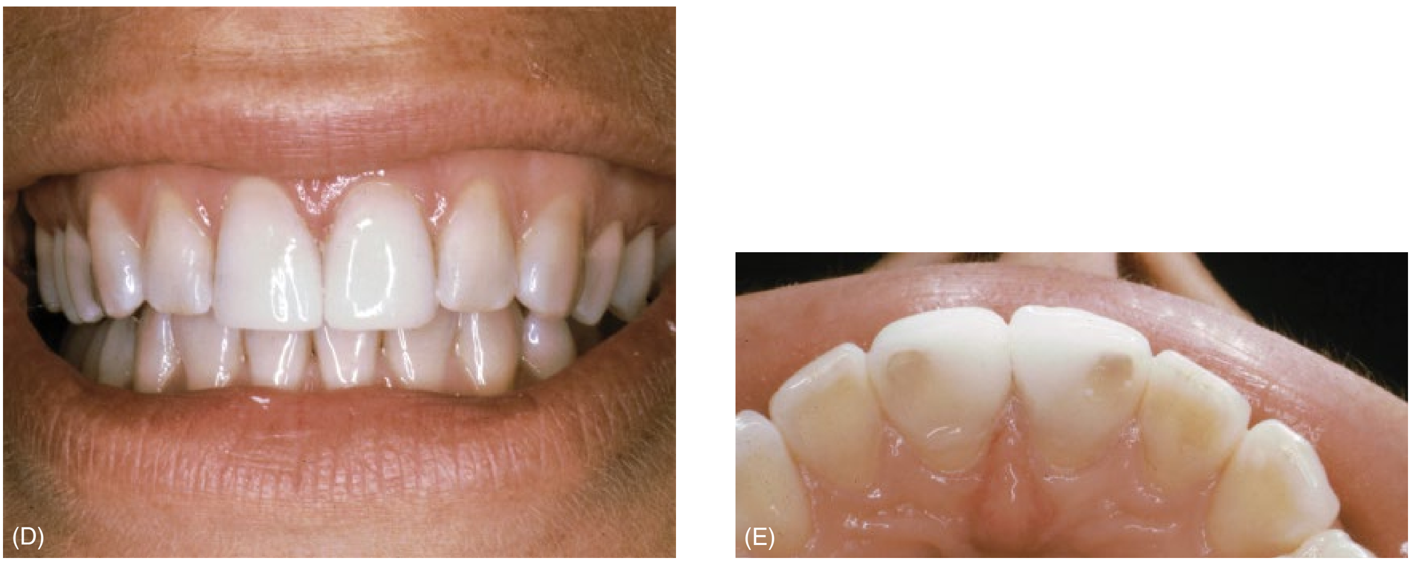

Figure 23.4 **(D, E)** The central incisors are bonded with composite resin.

Figure 23.4 **(F)** Five years later, the patient has continued to be maintained with composite resin restorations.

and prudent dietary habits, helped account for the extended life of these restorations. The tooth can always be veneered or crowned if bonding does not work, but once the enamel is reduced for a full crown, it can never be bonded or veneered. In the future, better bonding and laminating materials will, no doubt, become available.

Bonding original tooth fragment

Simonsen first suggested that fractured original tooth segments could be bonded back together.[10] If the patient has a "clean" break and brings in the fractured piece of enamel, it is entirely possible and many times advisable to attempt reattachment by acid etching both the tooth itself and the fragment. Light-polymerized tooth-colored resin cement is applied to both pieces and the fracture piece is carefully fit and polymerized 1 min labially and 1 min lingually.

Additional modifications have taken place, and there are newer techniques that are variations on the original philosophy.[11] For instance, Croll advocated attaching the two segments

Figure 23.5 **(A)** This 65-year-old man had fractured his right central incisor. Because he desired a younger and brighter looking smile, six porcelain veneers were treatment planned.

Figure 23.5 **(B)** This patient had an end-to-end bite, which required additional incisal edge reinforcement.

Figure 23.5 **(C)** To help protect the occlusion, porcelain was wrapped incisally to the lingual surface.

Figure 23.5 **(D)** Note the improvement in this man's smile with a lighter shade and teeth that are more proportionate to each other.

Table 23.3 Advantages and Disadvantages of Bonding

Advantages
Conserves tooth structure
Easier to match or blend in tooth shade
Less expensive than crowning
Immediate repair
Reduces possible trauma of a crown preparation for badly damaged teeth
No anesthesia required
Painless repair
Can improve shape and shade if necessary
Disadvantages
Can stain more easily than porcelain veneer or a crown
Needs periodic refinishing
Some maintenance required
Must have sufficient enamel left to be able to bond it
Must be repaired or replaced in approximately 5–8 years
Not appropriate for use in posterior teeth

Table 23.4 Advantages and Disadvantages of Porcelain Veneers

Advantages
Excellent esthetics
Improved edge strength
Better retention of surface finish
Fewer repairs required
Does not stain
Conserves tooth structure
Disadvantages
May require anesthesia
More costly than bonding
Usually requires two appointments
Some tooth preparation indicated
Cannot alter color once cemented

Table 23.5 Advantages and Disadvantages of Crowning

Advantages
Can ideally change color and shape of teeth
Longest lasting esthetic restoration
Lasts approximately 5–15 years
Less likely to require repairs
Disadvantages
Must reduce the enamel and dentin
Most expensive form of replacement
Possibility of pulp irritation
More chance for periodontal problems if margin is subgingival
Requires anesthesia
Difficult to repair

together, first with a glass ionomer light-polymerized liner (Vitrebond, 3M ESPE, St. Paul, MN) and then reinforcing labially and lingually with composite resin.[12] Many variations of such bonding are reported in the literature.[1,13–16]

Bonding the original tooth fragment is not limited to the anterior region. Posterior teeth fractures, especially in the case of premolars, can be successfully bonded together. The long-term survival of such repairs is reported to be in the region of 5 years.[1,17] However, in these cases, the bonded teeth are best viewed as a temporary restoration awaiting partial or full crown coverage. Liebenberg reported using resin-bonded partial-coverage ceramic restorations to treat incomplete fractures.[18,19]

Chips or fractures with pulpal involvement

In the event that the pulp is exposed, two choices exist:

- **Pulpotomy.** If the root apex is open, this is the preferred treatment according to several sources.[20,21] Ehrmann described the procedure beginning with coronal pulp removal, which will allow root maturation to proceed only with closure of the apex then taking place.[22] Following closure, a radicular pulpectomy is done and is usually followed by endodontic therapy plus construction of a post and core.
- **Partial pulpotomy.** Another view has been expressed by Cvek, who suggested a partial pulpotomy in permanent incisors with complex root fractures, regardless of whether the apex was open.[23] Basically, the technique consists of a 2 mm depth removal of the coronal pulp with sterile saline being used to control bleeding. Next, a calcium hydroxide pulp liner (Dycal Caulk, DENTSPLY/Caulk, Milford, DE) is used and is covered with a composite resin. Ehrmann concluded that this latter technique seems to be the method of choice, citing fewer traumas and preserving most of the pulp as two advantages.[22] He reported that 33 of 35 cases were successful and retained their vitality, with the longest follow-up being 8 years.

The consideration for a chipped or fractured tooth is whether the pulp is damaged. If it has been exposed, the tooth should be protected with a pulp-capping material (calcium hydroxide, glass ionomer, or bioactive liner) and covered with a tooth-colored restorative material for at least 6 weeks. A recommended technique after pulp capping is bonding with a composite resin. Kanca reported the success of a case with a 5-year follow-up.[24]

The responsibility of the dentist is to preserve the natural dentition. In some circumstances, this is impossible, but it is the ideal for which to aim. To achieve this goal, it may be necessary to call on colleagues for assistance. Who is credited with the result is unimportant. What is important is for the patient to receive the best possible treatment and advice. This point is well illustrated by the actual treatment of a patient with fractures of the maxillary central incisors that extended lingually beneath the crest of the bone and exposed the pulps. The patient's dentist consulted an

Figure 23.6 **(A)** This 27-year-old man fractured his maxillary central incisors.

Figure 23.6 **(B)** After light cosmetic contouring to the left central incisor, both central incisors were bonded with composite resin.

oral surgeon who recommended endodontic treatment. Before final restorative therapy was chosen, consultations were held with an oral surgeon, a pediatric dentist, and two general practitioners. The case that follows involved consultation with other dental specialists and shows an esthetic result that was worth the effort.[25]

Preservation of fractured maxillary central incisors through interdisciplinary therapy

Problem

A general practitioner saw a 12-year-old girl who had been in an accident. He referred her to an oral surgeon for removal of both maxillary permanent central incisors, which had been fractured horizontally and vertically, exposing the pulps. The oral surgeon thought that the teeth might be saved and referred the patient to an endodontist. After endodontic therapy on both teeth (Figure 23.7A and B), the patient returned to the general practitioner, who consulted the pediatric dentist. The two agreed that someone skilled in cosmetic restorative procedures should be called on for the reconstruction.

Treatment

Because saving teeth was a step-by-step procedure involving endodontic treatment, periodontal surgery, and reconstructive techniques, the treatment plan could be changed if one of the suggested treatments failed. Endodontic therapy had already been completed on both central incisors. These following surgical procedures were then performed: removal of the tooth fragments that were fractured vertically; labial and lingual gingivectomy and gingivoplasty; palatal ostectomy; and labial frenectomy (Figure 23.7C). Approximately 5 mm of palatal plate was removed to expose new margins on the fractured teeth (Figure 23.7D). After the tissue healed, gold posts were constructed and cemented on the two maxillary incisors (Figure 23.7E–H). Final preparations were made, and

Figure 23.6 **(C)** Fourteen years later, this patient fractured the bonding on the right central incisor.

Figure 23.6 **(D)** The central incisors were reveneered and the left lateral was also bonded to achieve an even more attractive smile.

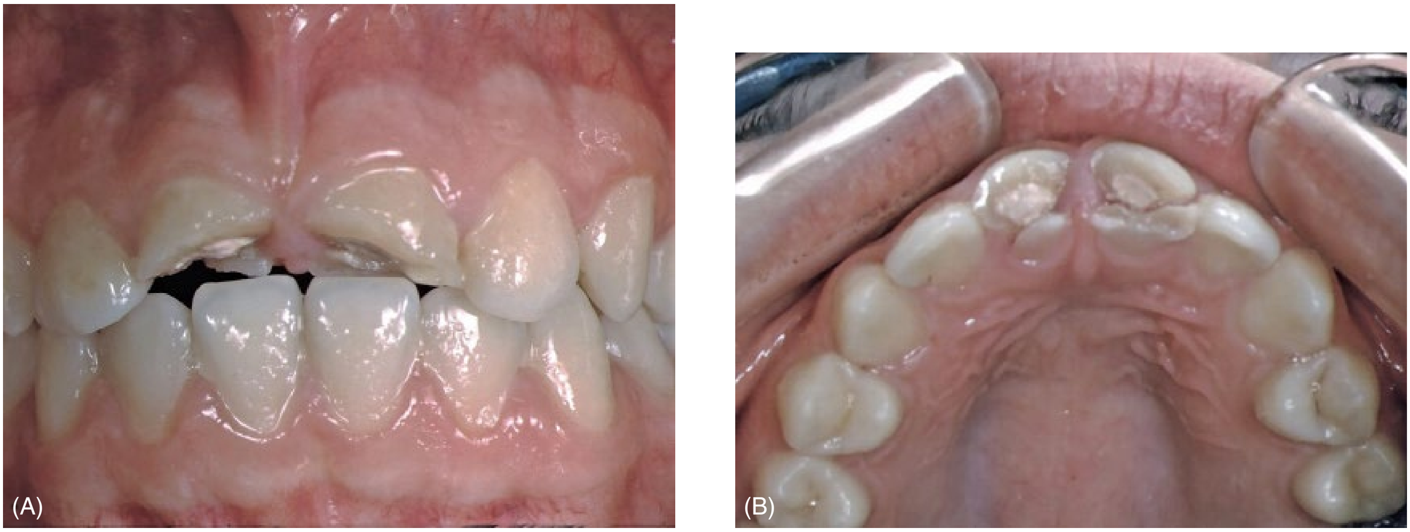

Figure 23.7 **(A, B)** Although this 12-year-old girl was referred to an oral surgeon for a postaccident extraction of both fractured central incisors, he wisely referred the patient to an endodontist in an attempt to save the teeth.

Figure 23.7 **(C, D)** Following endodontic therapy and removal of the fractured tooth fragments, periodontal surgery to lengthen the exposed crowns was performed.

impressions for all-ceramic crowns were made. The two crowns were seated (Figure 23.7I and J).

The parents were told that these crowns would probably have to be replaced when the patient is older because the margins may be exposed. However, they might last longer because of the higher marginal attachment. Because of the age of the child, the anticipated cost of the treatment, and the presumed lack of dental knowledge of the parents, the pediatric dentist and the general practitioner who were to do the treatment explained the reconstruction procedures at length. Although the endodontic therapy had been completed, the father informed the two dentists that he had decided to have "both teeth pulled and a plate put in." A subsequent conference convinced the parents that this would not be the wisest course to follow if restorative procedures could be performed. Their expression of thanks at the end of the treatment justified the time spent persuading the family to accept the outlined treatment plan (Figure 23.7 K and L).

Result

Dentists sometimes assume, incorrectly, that because a tooth is fractured beneath the periodontal ligament and into the bone, it cannot be saved. Proper surgical and reconstructive techniques can save these roots for many years, sometimes indefinitely.

Dentists may also assume, again incorrectly, that because of the expense or difficulty of treatment, a patient or their family would prefer to sacrifice a tooth. Not knowing what value the patient places on a tooth, the dentist should give the patient the opportunity to decide. It is almost always better to save a tooth. The patient can clean it more easily with floss, and the root support helps share occlusal load.

Figure 23.7 **(E–H)** Next, two posts and cores were constructed for the endodontically treated teeth.

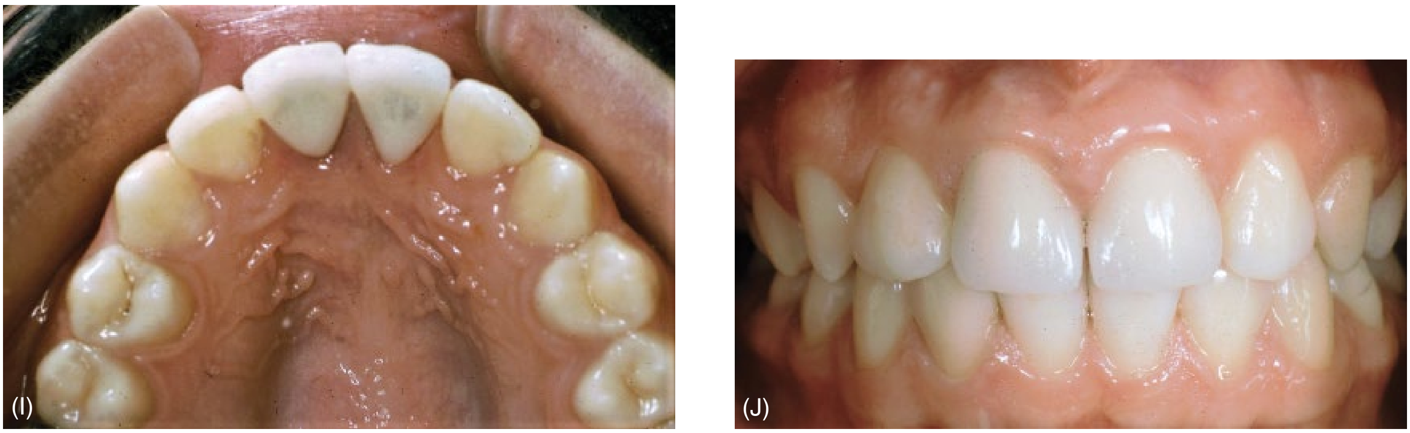

Figure 23.7 **(I, J)** Two aluminous porcelain crowns were constructed and inserted on the central incisors.

The purpose of this case is not to show the skill of the operator, but to call attention to the fact that, even though extraordinary measures are needed, it may be possible to preserve the natural dentition. To do so may involve multiple referrals and consultations, but the good result (Figure 23.7 J) and the knowledge that possibilities exist should be considered before a patient is allowed to lose a tooth. The function of dentistry is to maintain the integrity of the dental arch and to preserve the dentition. For this patient, at least, this goal was achieved.

Life expectancy with composite resins

Although the average life expectancy is 3–8 years, the fact is that some patients may experience a much longer and more useful restoration life (see Figure 23.8A–C).[6] These restorations are, for the most part, noninvasive, and the bonded restoration offers a good measure of protection to the tooth while odontoblastic activity is taking place at the damaged site. They can also continue to be reveneered rather than

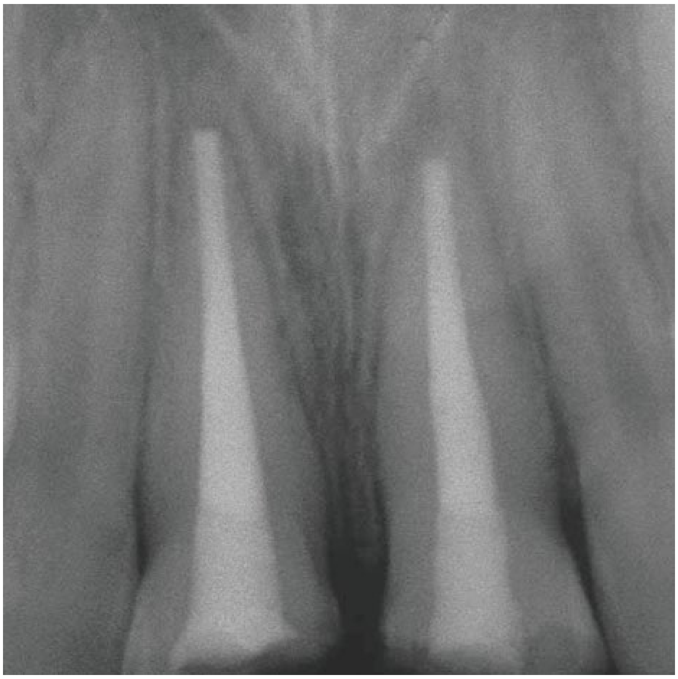

Figure 23.7 **(K)** Posttreatment radiograph of the two fractured and restored central incisors.

Figure 23.7 **(L)** A total team approach was necessary to save this young lady's maxillary incisors. Both she and her parents appreciated the benefits of interdisciplinary care.

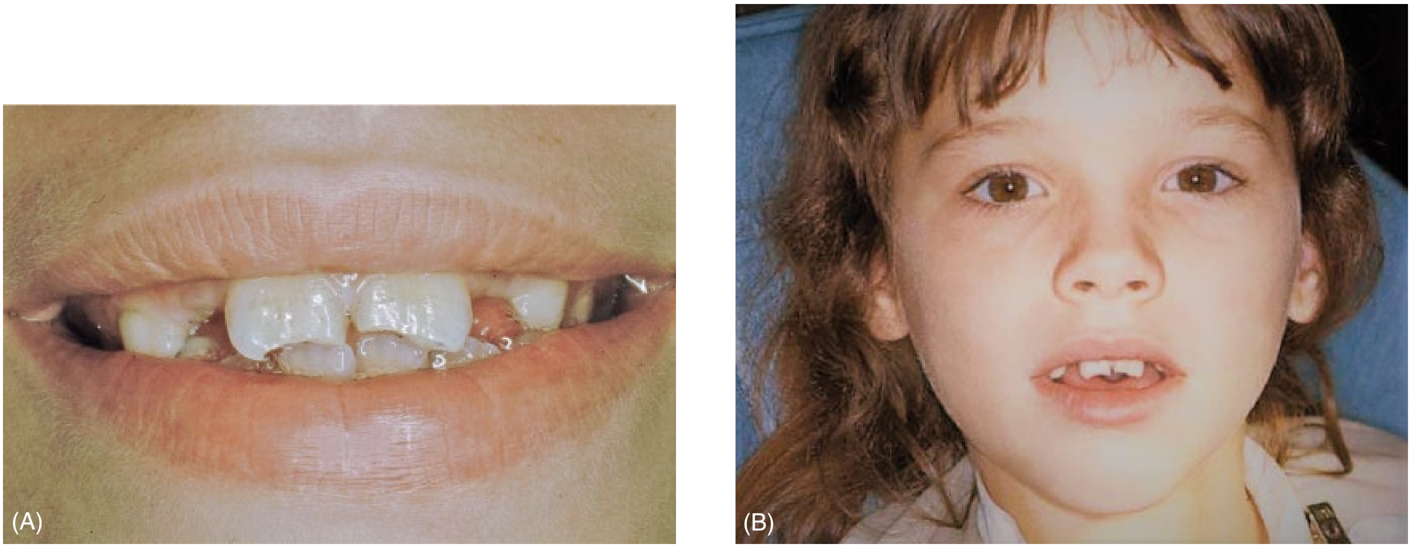

Figure 23.8 **(A, B)** This 6-year-old girl fractured her maxillary central incisors in an accident.

replaced for an indefinite period of time (Figure 23.8A–E). When replacement is necessary, if full crown coverage is the treatment of choice, it can be done with less chance of pulp involvement. The long-term success of this case is noteworthy because of the young age of the patient, high previous caries experience, deep cavities, and the saucer-shaped preparation technique predisposing to shorter longevity of resin-composite restorations. Literature reviews indicate that the annual failure rate of composite restorations is better than that of amalgam restorations. Principal reasons for composite restorations failure were secondary caries, fracture, marginal deficiencies, wear, and postoperative sensitivity.[26,27]

Posterior restorations

In these areas, it is even more important to place a protective base and use the etching technique on enamel walls and dentin. Marginal leaks can be minimized by this technique. In addition, patients must be advised of the possibility of replacing the restorations every 3–8 years.

Several methods of restoring the simple fracture have been shown in this chapter, although all seem to arrive at the same conclusion: the final measure of success is how these bonds respond to oral fluids. With further investigation, stronger materials and stronger bonds will be developed that may

Figure 23.8 **(C)** The two central incisors were beveled and bonded with composite resin.

warrant reinserting restorations as improved materials become available. Thus, in certain cases, it may be to the patient's advantage not to destroy tooth structure for full-coverage procedures at present. However, when small pieces break off of posterior teeth, bonding can be used either as an interim or the final restoration if it is not in an occluding area where it may be under too much stress. If it is, then porcelain may be the best choice.

In the final analysis, the full crown remains a viable option, especially if esthetic changes are to be made that may not be possible with a more conservative treatment. Also, some patients prefer the long-lasting benefit that the full crown provides.[28]

Restoration of endodontically treated fractured teeth

Principles

The philosophy for the restoration of endodontically treated teeth has changed significantly in recent years. Traditional concepts were that nonvital teeth were so weakened by root canal therapy that they required a post to reinforce the root in the same manner that concrete is reinforced with steel rods. Further, it was believed that these teeth also needed to be crowned to protect the tooth from fracture.

Clinical experience and research studies have, in some cases, produced a dramatic shift in the way endodontically treated teeth are restored.[1,29–32] Endodontically treated teeth have certain characteristics that are well known by clinical dentists. They include changes in elasticity of dentin, resistance to fatigue, and changes in morphology.[33] Also, the loss of vitality results in a change in color over time. This can result in an unacceptable esthetic result. These teeth are structurally compromised due to the access opening required to accomplish root canal therapy. Additionally, these teeth often have extensive restorations or caries, further compromising their strength and structural integrity. Clinical experience has shown that these teeth seem to have an increased risk of fracture.

There is no large body of in vivo scientific literature to determine how to best restore endodontically treated teeth. However, there are several good retrospective studies that provide some guidance. From these studies, it is clear that anterior teeth have different characteristics and require a different clinical approach than posterior teeth. Another conclusion that can be made is that endodontically treated anterior teeth do not automatically require restoration with a crown. In fact, most endodontically treated

(D)

(E)

Figure 23.8 **(D, E)** Ten years later, the patient still retains her original bonding, although reveneering has been done to maintain appearance.

anterior teeth will have the same longevity whether or not they have been crowned. So, the clinical options for restoration of an anterior tooth are dictated by the condition and the functional and esthetic requirements of the tooth. If the tooth is relatively intact, it should simply be restored with a composite resin restoration. If it has changed color, then bleaching of the tooth would also be indicated. If the existing restorations or caries are moderate in size or include the incisal edge, then a porcelain veneer could be the appropriate choice for treatment. In many instances, bleaching of the endodontically treated tooth prior to restoration with composite resin or a porcelain veneer will provide a better esthetic result.

Three major reasons for using crowns are (1) if the tooth is badly broken down, (2) a significant change in tooth contour is desired, or (3) if the tooth is to be used as an abutment for a fixed or removable partial denture. Most anterior teeth in this condition have little sound remaining tooth structure and will require a post-and-core restoration to support and retain the crown. This concept is supported by most studies. Such a patient can be seen in Figure 23.9A–C. Post restorations used in anterior teeth fall into two broad types: (1) the prefabricated post with a core material to replace the missing coronal tooth structure and (2) the cast metal post and core that is custom made for the tooth (Figure 23.10A–J).

As previously mentioned, posterior teeth require a different treatment approach than is indicated for anterior teeth. Posterior teeth usually have a greater bulk of remaining tooth structure than anterior teeth. Also, the occlusal forces on posterior teeth are significantly greater than anterior teeth. Retrospective studies of posterior teeth that have had root canal therapy indicate that these teeth may be more likely to fracture if they are not crowned. The basic principle for posterior teeth is that the restoration should provide for cuspal coverage or protection. This can be accomplished with a crown (either full or partial coverage) or even an onlay. The logical exception to this rule might be for a molar or premolar that has a minimal endodontic access and at least one intact marginal ridge. In this instance, if the occlusion is favorable (i.e., canine disclusion), a small two-surface bonded composite could be considered.

Unlike anterior teeth, which many times require a post to retain the core, posterior teeth seldom need a post. The retention

Figure 23.9 **(A)** This 60-year-old woman fractured the bucco-occlusal surface of her mandibular right second bicuspid. Because the fracture was in an occluding area and was previously repaired with composite resin bonding, plus aligned microcrack so the patient opted for the longer lasting protection of a full crown.

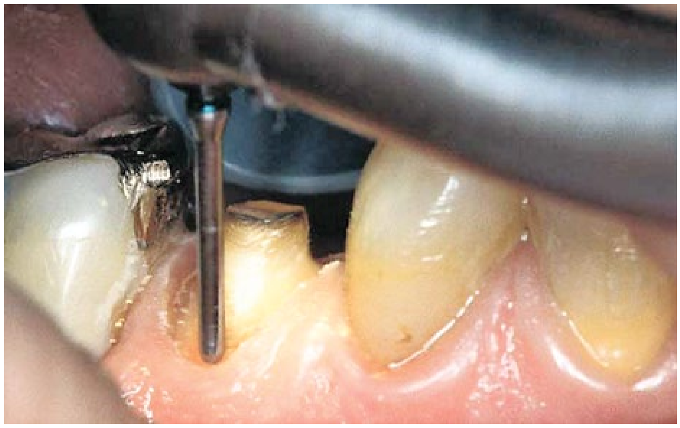

Figure 23.9 **(B)** Full shoulder margins are prepared with a TPE diamond (Shofu or AC11, Brasseler USA).

Figure 23.9 **(C)** The final crown shows how well ceramics can mimic the natural tooth and esthetically blend with the existing dentition.

Figure 23.10 **(A)** This young lady fractured her left central and lateral incisors in an accident. Because the original teeth had protruded before fracturing, the patient requested that the restoration be accomplished with an improved appearance in the most permanent treatment available.

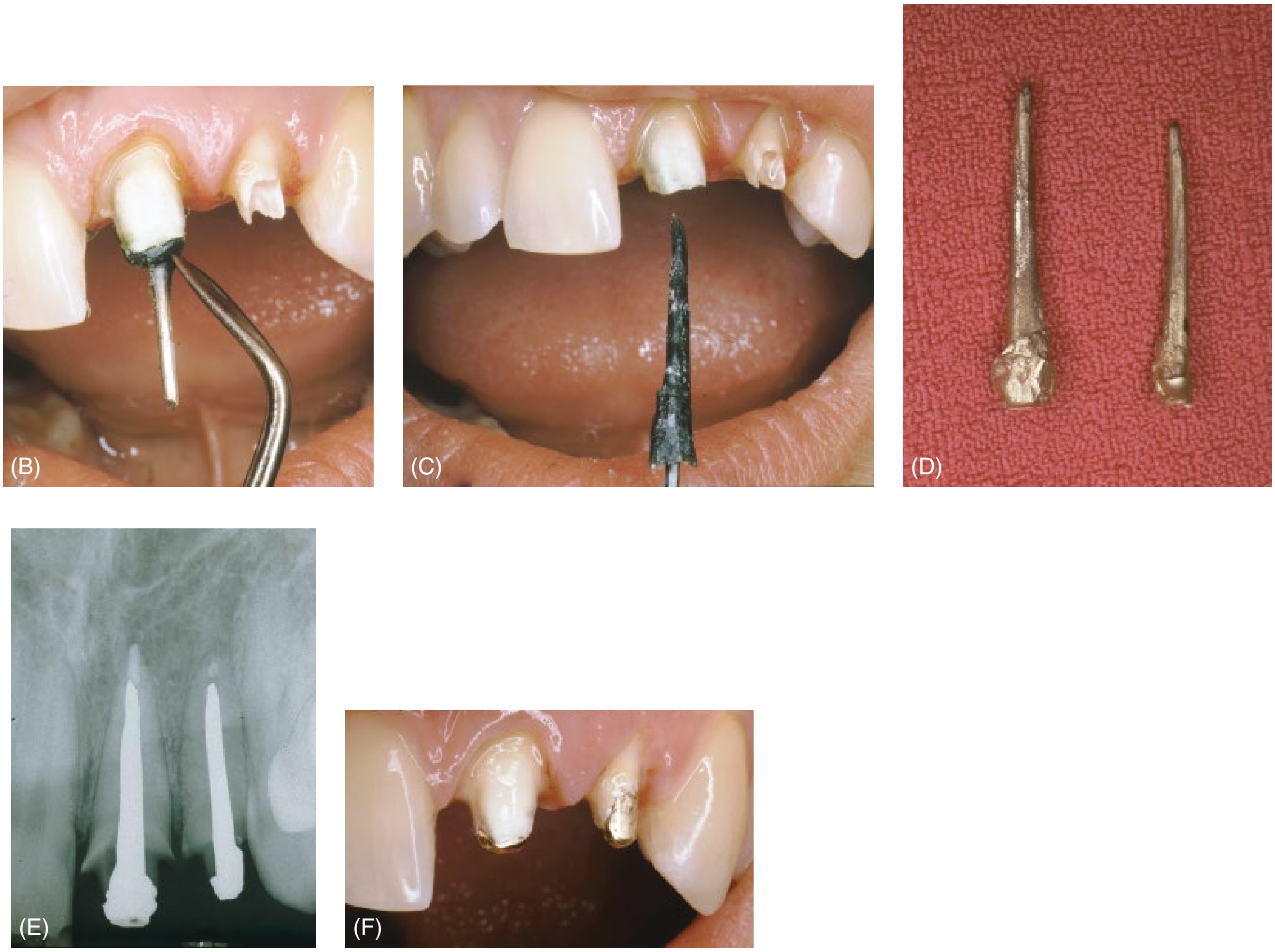

Figure 23.10 **(B–F)** Following endodontic therapy, two cast posts were constructed and cemented to place in the prepared incisors.

Figure 23.10 **(G)** The final all-ceramic crowns were bonded to place. Note how shade and texture help to blend in with the other teeth.

for the core or foundation can usually be obtained by taking advantage of the undercuts present in the pulp chamber, especially in molars. If a composite resin core material is used, it can be retained by both dentin bonding and the pulp chamber. If the tooth has hardly any coronal tooth structure (i.e., level with the gingival margin), a cemented, prefabricated post can be used to provide the required retention for the core restoration. Clinical research has supported the ability of posts to distribute stress in a favorable way that improves the fracture resistance of restored teeth.[34–36] Small premolars are more likely to need a post restoration because there may not be sufficient retention for the core.

In summary, endodontically treated anterior teeth do not always need to be crowned; when they are to be crowned, a post may or may not be required. Posterior teeth usually need a crown (i.e., cuspal coverage) but rarely require a post. The purpose of a post is to retain the core; it does not reinforce the root.[37,38]

Post design

Several principles must be considered in post selection and design. These principles apply for either prefabricated or cast posts. Design characteristics include length, diameter, shape, surface configuration or texture, method of attachment, and material. Many of these characteristics have been studied extensively by in vitro studies. In addition, several retrospective studies give guidance concerning optimum factors for post selection and design.

Retention of a post increases with increasing length. The post should at least be equal in length to the clinical crown or two-thirds of the root length, whichever is greater (Figure 23.10A and B). At least 4 mm of gutta-percha should be left in the apex of the root to maintain the apical seal. In contrast to post length, post diameter has little influence on retention. In fact, increasing post diameter requires removal of additional tooth structure and simply weakens the tooth, increasing the risk of a vertical root

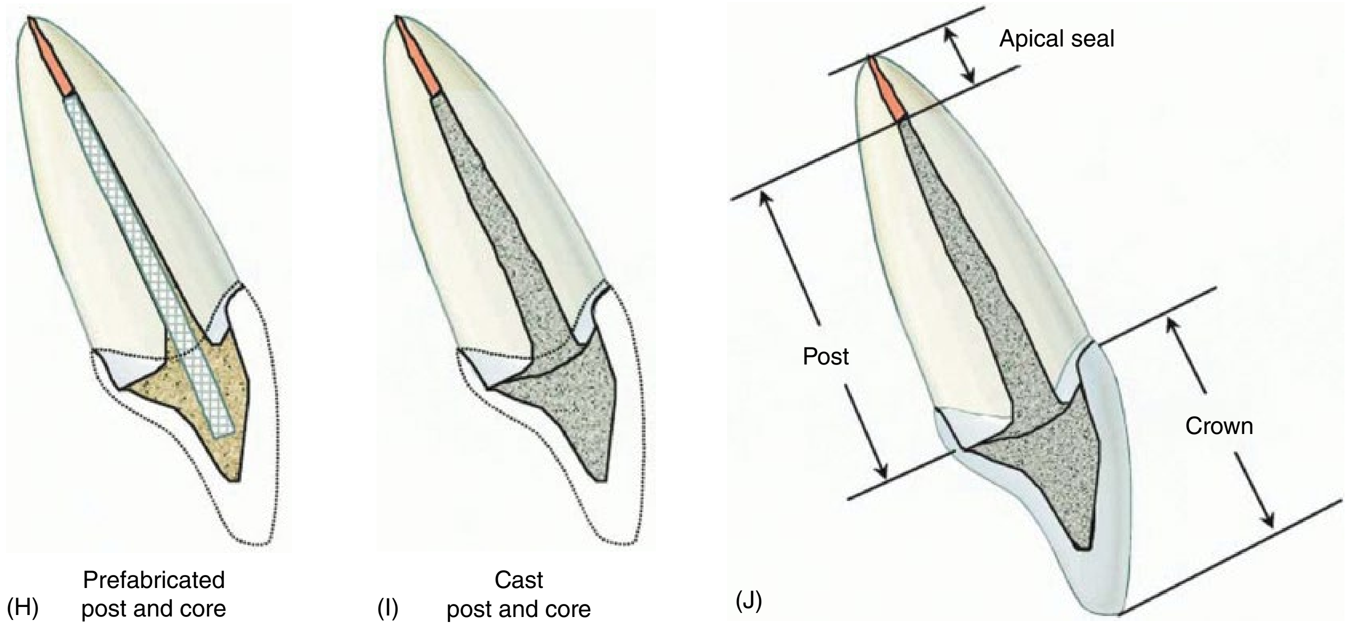

Figure 23.10 **(H)** The final all-ceramic crowns were bonded to place. Note the natural result of both the shade and texture of the crowned teeth. **(I)** Options for post-and-core restorations. **(J)** Optimum post length.

fracture. Therefore, the post should not be any larger in diameter than is absolutely necessary. The general guidelines are that the post should not be greater than one-third of the diameter of the root at the cement–enamel junction and that at least 1 mm of dentin thickness should be maintained at all levels of the root. Generally, it is best not to enlarge the post space any greater than the space created during root canal therapy. Too aggressive flaring of the canal during root canal therapy or enlargement of the canal space for a post will surely compromise the tooth. In the same vein, the shape of the post should be parallel rather than tapered. A tapered post design creates a wedging force within the root of the tooth. Conversely, parallel posts produce less stress and fewer vertical root fractures.

The surface configuration or texture has a significant influence on post retention. A smooth-surface or polished post is less retentive than a textured (e.g., sandblasted) post. Post designs that are serrated or crosshatched or have some other retentive design exhibit the best resistance to dislodgment.

One other design parameter is the mode of attachment. A post can have a passive fit in the tooth root and be retained by cement, or it can be actively retained (threaded like a screw) and retention gained by virtue of the threads (with or without the aid of cement). However, threaded posts create the potential for a significant wedging force within the tooth root and should be avoided. Parallel posts with proper length and a retentive surface design can obtain more than adequate retention. In situations when it is not possible to obtain the optimum length or shape, the required retention is much better and gained more safely by using a stronger cement (i.e., resin-modified glass ionomer or composite resin) than by using a threaded post.

There are several different materials that can be used for posts, including stainless steel, titanium, zirconium (tooth colored), ceramic, and polymers (Table 23.6). The material used for the post is much less important than the design and size of the post (i.e., preservation of tooth structure) unless esthetics becomes a consideration. If so, a tooth-colored post should be considered.

Sequence of treatment for posterior teeth (molars and large premolars)

The core buildup for a posterior tooth should be placed prior to crown preparation. A sufficient amount of time should have elapsed since completion of the root canal therapy to be confident that it has been successful. The tooth should be asymptomatic and not sensitive to percussion. Following root canal therapy, the typical molar will have a large existing restoration. All restorative materials and caries should be removed. The gutta-percha should be removed from the pulp chamber. The gutta-percha can be removed 1–2 mm into the canal orifices to increase retention (Figure 23.11). If there is at least one cusp remaining and the pulp chamber has walls of 2–3 mm in depth, a post is not required for retention of the core. The core should be composite resin (Table 23.7).

The advantage of composite resin is that it may be prepared immediately. Composite resin also offers the advantage of dentin bonding and a relatively simple technique for core placement. The main disadvantage of composite resin is that it is subject to water absorption and microleakage. It should only be used in posterior applications when it is possible to place the crown margins at least 2 mm beyond (i.e., apical to) the resin–tooth interface. A composite resin core material of contrasting color should be used to minimize the risk of inadvertently preparing the preparation margin on composite resin (Figure 23.12A–F).

For molars, if there is little remaining tooth structure or the pulp chamber is shallow, then a post should be used to provide retention for the core (Figure 23.13A). Usually, only one post is needed. A prefabricated post should be cemented into the largest

Table 23.6 Materials for Prefabricated Posts

	Material	Indications	Advantages	Disadvantages
Metallic stainless steel	Containing nickel (ASM 300)		Superior physical properties, radiopaque, excellent corrosion resistance	Nickel content (possible allergic response), metallic color
	No nickel (ASM 400)	General use; particularly suited for situations requiring high strength	Superior physical properties, radiopaque	Poor corrosion resistance, metallic color
Titanium	Commercially pure titanium (99%) Alloy Ti–Al–V		Moderate strength, biocompatibility Superior physical properties, biocompatibility	Metallic color, not as radiopaque as stainless steel, difficult to cut
Nonmetallic Ceramic	Zirconia polycrystals	Situations requiring high esthetic demand; all-ceramic crowns	Tooth color, light transmission, high strength, white	Lack of long-term clinical results
Fiber–polymer composite	Carbon fibers		High strength, modulus of elasticity equal to dentin	No long-term clinical results, or white, fiber–polymer matrix interface may degrade

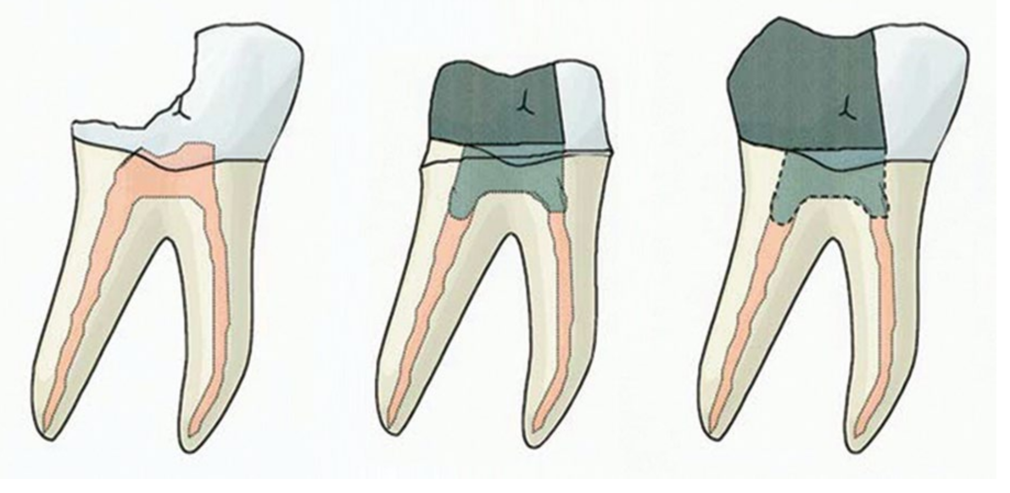

Figure 23.11 Composite resin core.

Table 23.7 Core Materials

	Indications	Advantages	Disadvantages
Conventional glass ionomers	Only for blockout of undercuts	Fluoride release	Low fracture toughness and strength, solubility
Resin-modified glass ionomer	Partial core buildup with adequate tooth structure present	Fluoride release, moderate strength, tooth color	
Composite resin	Core with prefabricated posts in anterior teeth	Tooth color, dentin bonding	Plastic deformation, absorbs moisture, dimensionally unstable
Cast metal	Cast post and core	Strength, core joined to post, biocompatibility	Cost, metallic color

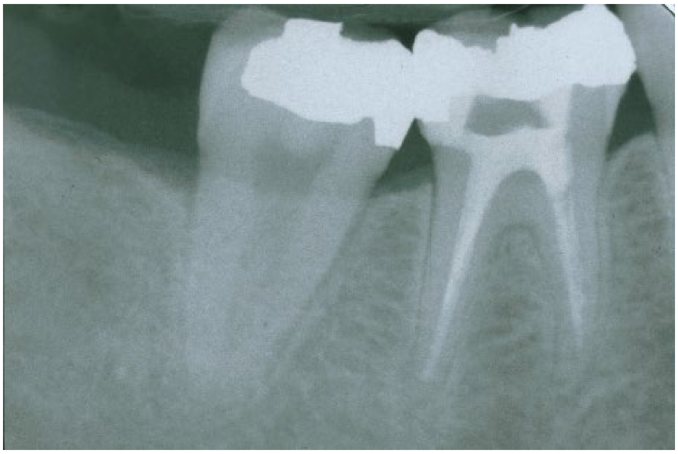

Figure 23.12 **(A)** Periapical radiograph showing tooth #30 after successful root canal treatment.

Figure 23.12 **(B)** Bitewing radiograph showing tooth #30 with amalgam core buildup completed. Note that the core material extends approximately 2 mm into the canal orifices for increased retention.

Figure 23.12 **(C)** Removal of temporary restorative material and remaining amalgam. Gutta-percha from the pulp chamber was removed for core retention.

Figure 23.12 **(D)** Tooth #14 after successful root canal treatment. Note the crack on mesial and a photo should be made and a notation in the patient's chart since cracks may propagate.

Figure 23.12 **(E)** Completed core buildup on tooth #14.

Figure 23.12 **(F)** Completed crown preparation on tooth #14.

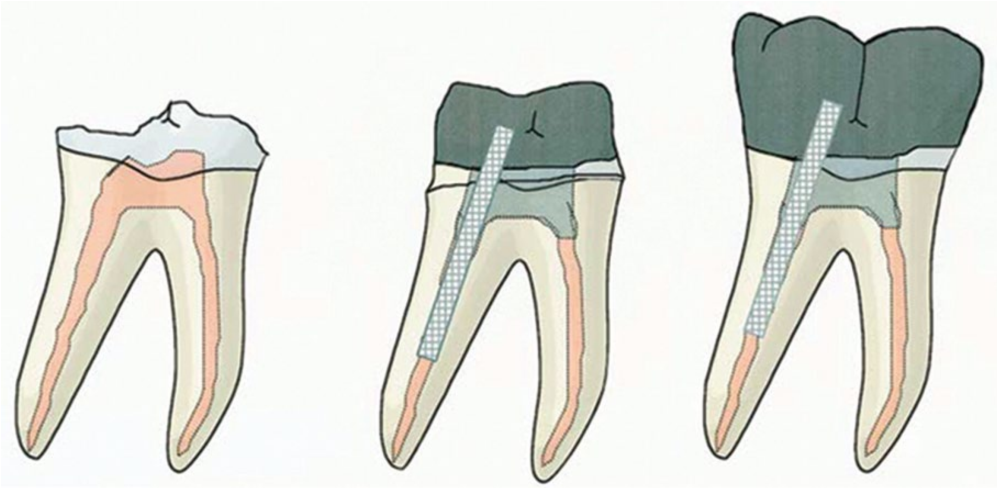

Figure 23.13 **(A)** Prefabricated post with core.

Figure 23.13 **(B)** Tooth #3 after successful root canal treatment.

Figure 23.13 **(C)** Inadequate pulp chamber wall height and lack of remaining tooth structure evident after removal of previous restorative materials. Additional retention with prefabricated post is indicated.

Figure 23.13 **(D)** Completed core buildup on tooth #3.

Figure 23.13 **(E)** Completed crown preparation on tooth #3. Note that the preparation margin extends apical to the core-tooth interface. (Although not esthetic, a metal 360 degree circumferential cord will improve long term retraction and fit of the final restoration.)

Figure 23.13 **(F)** Composite resin may also be used as core material, as is seen in another patient.

canal. In mandibular molars, this will typically be the distal canal. No attempt should be made to place a post in the mesial canal of a mandibular molar as the distal wall of the mesial root is thin and easily perforated. For maxillary molars, a single post in the lingual canal is adequate. Because the direction of the post is divergent from the pulp chamber, it creates excellent retention for the core (Figure 23.13B–F).

Sequence for anterior teeth

For anterior teeth, the decision to use a prefabricated post versus a cast post and core is best made after the crown preparation is completed (Table 23.8). The appropriate amount of incisal and axial reduction should be created. Then the amount of remaining sound tooth structure can be evaluated to make the decision about the post type. The prefabricated post and core is indicated when there is a moderate amount of remaining tooth structure or there are significant undercuts in the canal or pulp chamber that would require excessive removal of tooth structure. It should also allow the preparation of the crown margin to be at least 2 mm beyond the core to minimize the risk of water absorption. The advantage of this technique is that it conserves tooth structure, decreases the risk of root fracture, and is less expensive and time consuming. There are several disadvantages with the prefabricated post technique. The core of a prefabricated post and core is not as strong as a cast post and core. There is a risk of mechanical failure of the core since the composite resin core materials do not bond to cemented posts, unless a metal bonding agent is utilized, and, the resin core is susceptible to water absorption. It is also not indicated when the long axis of the root is significantly different from the long axis of the core.

The cast post and core is indicated when there is a minimal amount of remaining tooth structure or the core will be very close to the crown margin (less than 1 mm). It may also be needed when the core does not align with the root or there is a deep vertical overlap resulting in minimal occlusal clearance. The advantage of the cast post and core is that it is strong and will fit irregular or flared canals. The major disadvantages are that it is expensive, time consuming, and less conservative (requires more tooth reduction to eliminate undercuts or for canal enlargement).

Post preparation

After the decision has been made for either a cast post and core or a prefabricated post and core, the canal preparation should be initiated. The gutta-percha may be removed with either a hot instrument (plugger) or with a rotary instrument. The rotary instrument is more convenient, and there is no risk of burning the patient. A noncutting drill (Gates Glidden, Miltex, or Peeso reamer, Miltex) is the proper instrument for this step. The noncutting drill should be smaller in diameter than the existing canal space so that it only removes gutta-percha. A high-speed bur or an end-cutting drill from a prefabricated post kit should never be used to remove the gutta-percha because the risk of perforation is too great. The tooth is measured on a radiograph, a reference point is established on the tooth, and the gutta-percha is carefully removed to the desired depth, leaving a minimum of 4 mm for the apical seal. Ideally, a minimum of 10 mm of length should be obtained. The canal preparation should be the same at this point regardless of the type of post that is planned. No attempt should be made at this time to enlarge the canal; the goal of this step is to establish the proper post length.

Table 23.8 Post and Core Options for Anterior Teeth

	Indications	Advantages	Disadvantages
Prefabricated post and core	Moderate amount of remaining tooth structure Undercuts in canal or chamber Crown margin can be prepared ≥2 mm past core	Conserves tooth structure, decreased risk of root fracture, less expensive, simple technique, less time consuming	Not as strong as cast post and core, failure may occur at post–core interface
Cast post and core	Minimal amount of remaining tooth structure Core close to preparation margin Core does not align with root	Strong, fits irregular canals	Expensive, time consuming, less conservative

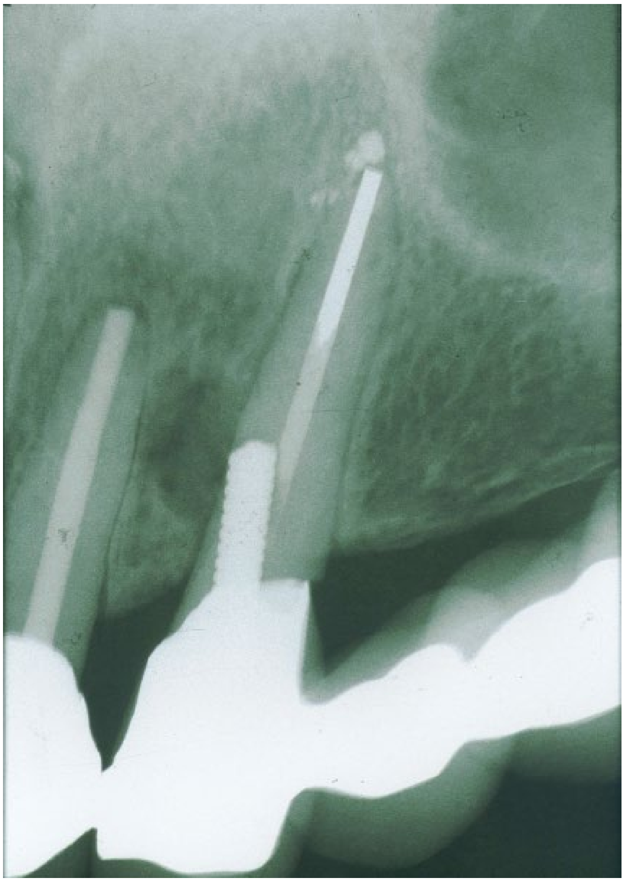

Figure 23.14 **(A)** Improper post and core technique leading to clinical failure.

Figure 23.14 **(B)** Even when the proper guidelines are followed, endodontic-treated teeth can still lead to catastrophic fracture and end in extraction. Proper patient consent must be obtained before post placement in order to avoid future problems.

Figure 23.14 **(C)**

Figure 23.15 **(A)** Periapical radiograph showing tooth #7 after post space preparation.

Figure 23.15 **(B)** Try-in of prefabricated posts. The post should be at least equal in length to the clinical crown or two-thirds of the root length.

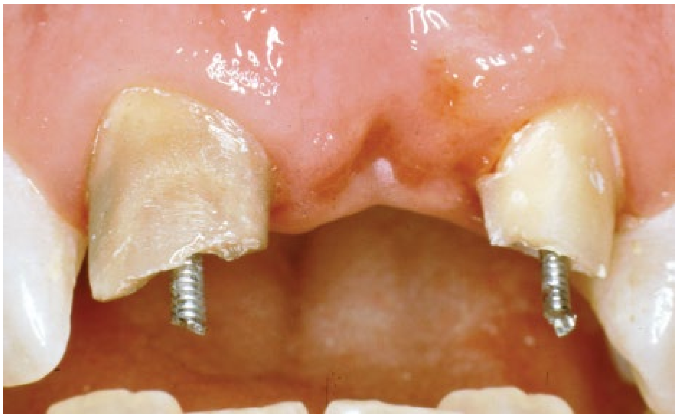

Figure 23.15 **(C)** Prefabricated post cut to length and cemented.

Figure 23.15 **(D)** Teeth #8 and #10 restored with composite core buildup material and prepared to receive porcelain-fused-to-metal crowns.

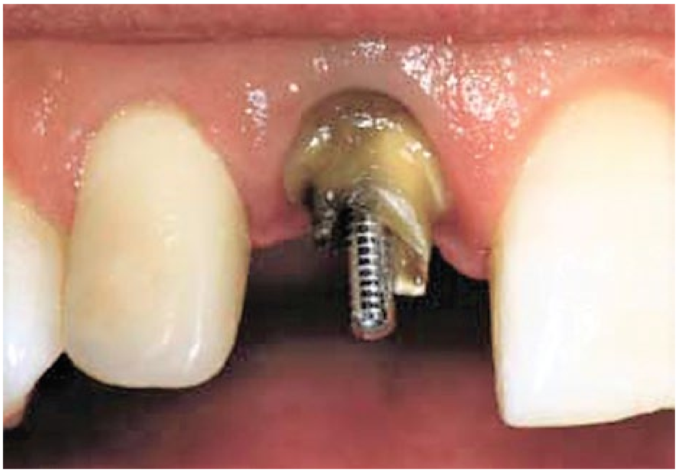

Figure 23.15 **(E)** In another patient, tooth #8 with a prefabricated post cut to length and cemented.

Figure 23.15 **(F)** Tooth #8 restored with composite core buildup material.

The post space length and preservation of gutta-percha in the apical portion of the root can be verified with a radiograph at this time. Digital radiographs are a distinct advantage as they save considerable time and require much less radiation, thus allowing the operator to take multiple views during the entire procedure. Combined with digital radiography, the use of an intraoral camera or surgical microscope can provide an excellent view of the canal and an inherent safety factor in preventing perforation. A tiny light source can also be a help in visualizing if you are still drilling in the center of the channel (Microlux, Addent). Next, the canal should be shaped with the drills provided with the post system. Enlargement of the canal should be kept to a minimum, remembering that the tooth becomes weaker as more tooth structure is removed. The canal should not be enlarged any greater than is necessary to accommodate the post (Figure 23.14A–C). The typical maxillary lateral incisor should not be enlarged to more than 0.040 inches (~1 mm) in diameter. Maxillary central incisors may be enlarged to a diameter of 0.050 inches (~1.3 mm). If the coronal portion of the canal is flared, the canal should not be enlarged to achieve

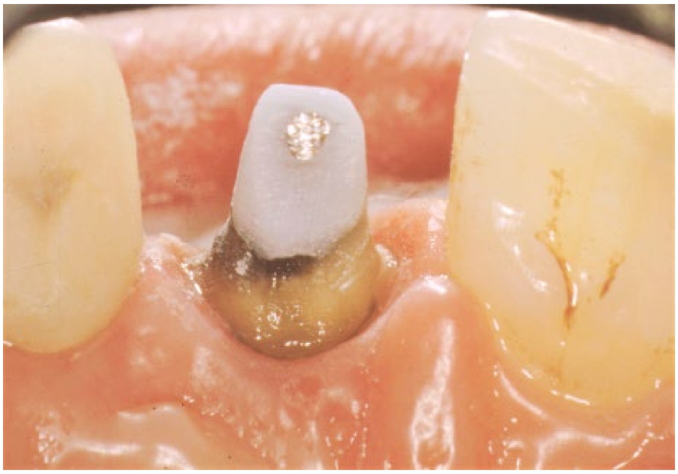

Figure 23.15 **(G)** Mirror view of the lingual surface of tooth #8. Note the ferrule design with 1–2 mm of vertical tooth structure beyond the restorative margin.

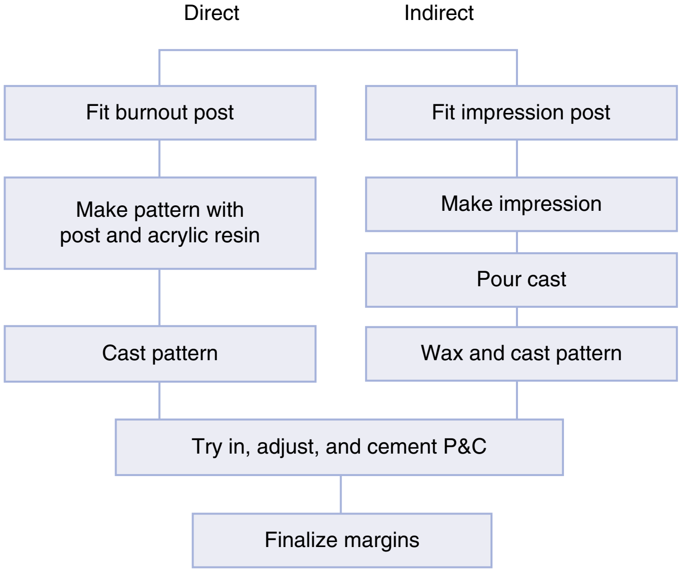

Figure 23.16 Direct and indirect techniques for cast post and core.

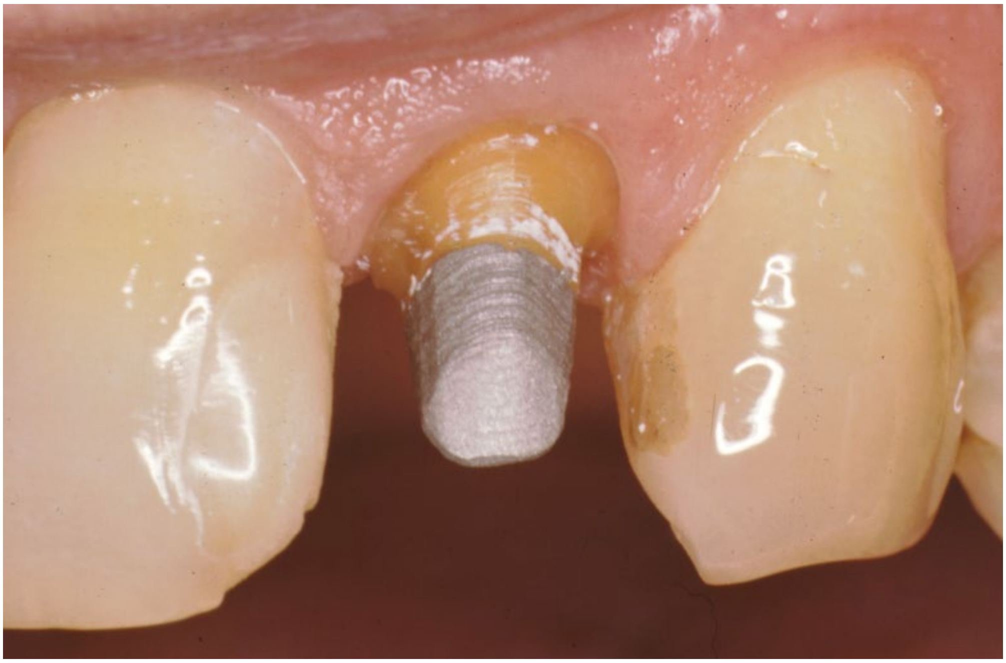

Figure 23.17 Similar case restored with post and core. The decision between restoring a tooth with a prefabricated post or cast post and core depends on how much intact tooth structure is remaining.

parallel walls as this will unnecessarily weaken the root. In this case, it may be better to use a tapered, prefabricated post design or a cast post and core in combination with a resin cement, but use a parallel drill below the tapered area.

The choice of material type is probably less significant than adhering to accepted design principles (i.e., adequate length, parallel shape). The most commonly used prefabricated post types are stainless steel, titanium, or titanium alloy. The prefabricated post can be cemented with any acceptable cement, including glass ionomer or resin cement. If the post is shorter than desired or the canal is tapered, a resin cement should be considered. For the core, composite resin has the necessary strength, provides dentin bonding, and is the material of choice to use with prefabricated posts in anterior teeth. Figure 23.15 shows two examples of the use of post and composite resin buildup.

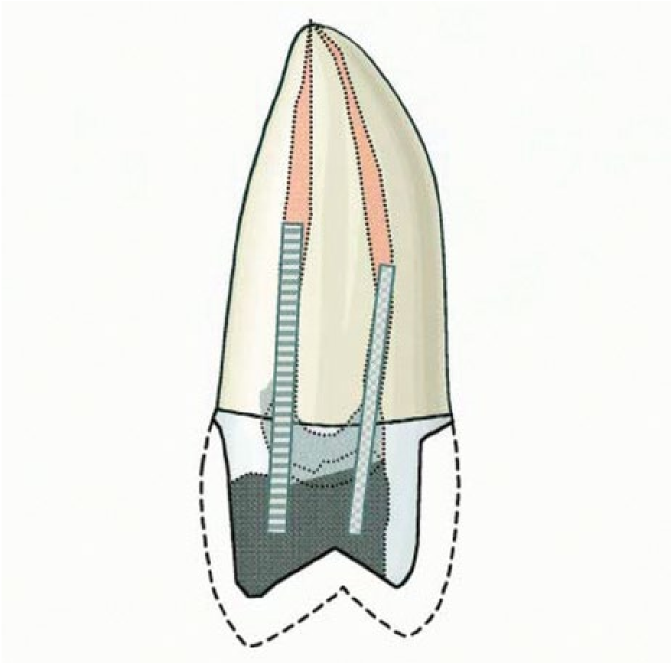

Figure 23.18 **(A)** Prefabricated post for additional core retention.

Figure 23.18 **(B)** Prefabricated posts in the two canals of a premolar prior to core placement. It is usually not possible to make these posts very long because of canal curvature. Because canals are usually not parallel to each other, the core is well retained by posts.

If a cast post and core is indicated, the pattern can be made by either a direct or an indirect technique (Figure 23.16). For the direct technique, undercuts in the canal or pulp chamber must be blocked out. Then a direct pattern can be made using the appropriate-size plastic post from the post system and making the core with autopolymerizing acrylic resin. With the indirect technique, an impression of the tooth is obtained using a plastic post to record the post space. The post can be cast in either a noble or non-noble metal (Figure 23.17). For smaller diameter posts, a type III gold alloy is inadvisable as it does not provide adequate strength. The use of a non-noble alloy (Ni–Cr–Be) provides the potential for resin bonding of the post to the dentin surface of the canal. This may be desirable for short posts or for tapered canals.

For cementation of the post, a groove or vent should be created along the length of the post to allow for excess cement to escape. If using resin or glass ionomer cements, a Lentulo spiral drill (DENTSPLY/Caulk) should be used to place the cement into the canal. This will result in the maximum retention for the post. After the cement has set, the excess is removed, and the core material is placed (prefabricated post) or the impression procedures are initiated (cast post and core).

For resin cement, the instructions for the bonding and cementation procedures for the cement should be followed. This may include placing cement on the post rather than into the canal to prevent overly rapid set of the cement. One advantage of using resin cement is that the core material can be placed immediately after the post is seated. Then the cement and core resin can set simultaneously and bond together. This technique works especially well when retrofitting a post to an existing crown (reverse post crown repair).

Sequence for premolars

The type of foundation restoration for a premolar is determined by the amount of available tooth structure. This requires making an estimation of the amount of tooth structure that will remain after the crown preparation. If there is a moderate amount of tooth structure, the tooth can be restored like a molar using composite resin as the core material. Similar to a molar, the retention for the core would be gained by either mechanical retention and/or dentin bonding. If there is minimal tooth structure, it is best to use the same treatment sequence as described for an anterior tooth. First, the tooth is prepared for the indicated crown. Then the amount of remaining tooth structure is evaluated. If the premolar has two roots, prefabricated posts can be cemented in the two canals (Figure 23.18A and B). It is usually not possible or even necessary to make these posts very long because of canal curvature. However, because the canals are usually not parallel, following placement of the core, the posts and core are virtually impossible to dislodge. For a small premolar, composite resin is an excellent material. If there is minimal or no coronal tooth structure, a cast post should be considered, especially for a single-rooted premolar.

Principles for crown preparation

The proper preparation of the tooth after completion of the post and core restoration is very important. Even with the ideal canal preparation and post restoration, the post has a tremendous potential to act as a wedge in the tooth root. This can result in initiation of a vertical root fracture and subsequent loss of the tooth. The best way to protect the tooth (i.e., the

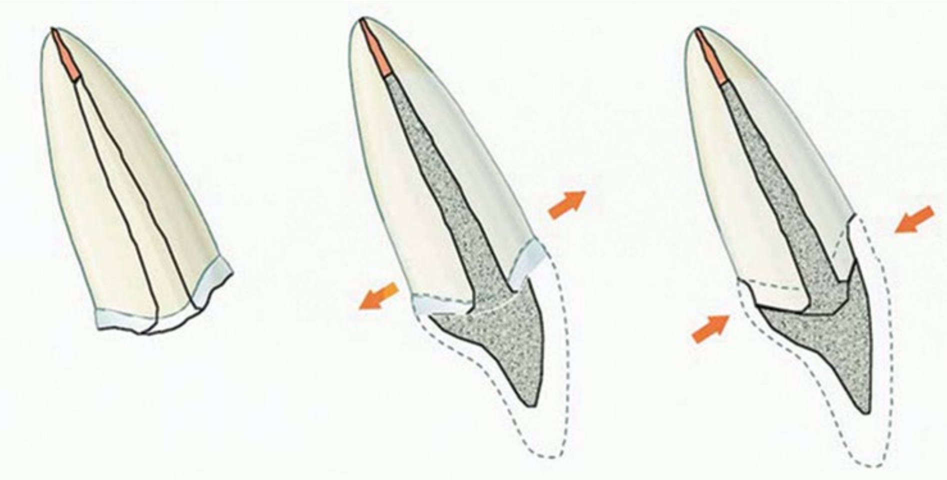

Figure 23.19 Ferrule design resists wedging force of post.

Figure 23.20 **(A)** Proper ferrule design on preparation for porcelain-fused-to-metal crown.

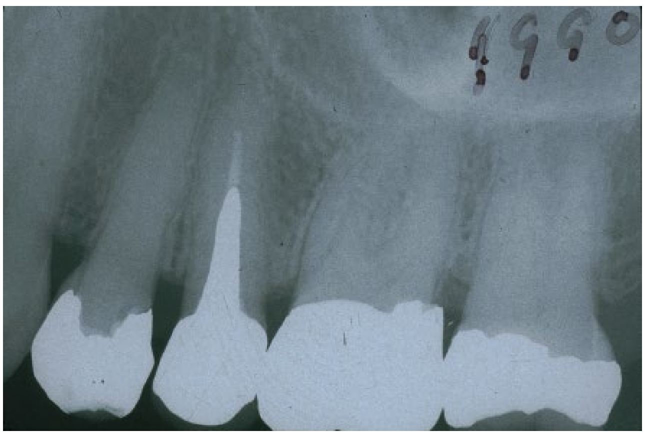

Figure 23.20 **(B)** Radiograph showing cast post and core after cementation. Note that the post is more than one-third of the diameter of the root at the cement–enamel junction and is tapered. Tooth preparation did not exhibit ferrule design.

Figure 23.20 **(C)** Same clinical case as in Figure 23.20B after 8 years. Note the oblique root fracture. Such a fracture could be prevented by a more conservative post in combination with proper ferrule design in the crown preparation.

root) against this wedging force is by the creation of a ferrule design in the crown preparation on the tooth.[13,31,39–41] The ferrule design is the encirclement of 1–2 mm of vertical tooth structure by the crown. This encirclement, like metal bands on a barrel, helps protect the tooth from fracture. It resists the wedging forces that would be transmitted to the post from the occlusion. To create an adequate ferrule, the margin usually must be prepared further apically. Often, this requires a crown-lengthening procedure to gain sufficient tooth length to prepare the ferrule (Figure 23.19). This principle of creating a ferrule around the tooth is probably the single most important principle in the restoration of endodontically treated teeth (Figure 23.20). If an adequate ferrule is obtained, the type, material, and design of the post and core become much less important. Conversely, if a ferrule is not obtained, then the tooth is at risk of fracturing no matter what type of post or core is used. This is especially true for teeth that are expected to carry a heavy load, such as a removable partial denture or fixed partial denture abutment or in patients who exhibit excessive wear or bruxism.

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Chapter 24 Endodontics and Esthetic Dentistry

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* Deceased

Ronald E. Goldstein's Esthetics in Dentistry, Third Edition. Edited by Ronald E. Goldstein, Stephen J. Chu, Ernesto A. Lee, and Christian F.J. Stappert.

This chapter is dedicated to the memory of our colleague Donald E Arens, co-editor of the previous version of this chapter, whose passion for teaching was exceeded only by his humor and ability to see the finest qualities in his large circle of friends. May his memory be a blessing to all who were touched by him. Don was alive when we began this endodontic and esthetic chapter update, and his hand has had a profound positive influence and was his final contribution to dentistry, education, and the advancement of our profession.

Within the last three decades, dentists have witnessed a change in the number of patients who have shifted their priorities from prevention and repair to alignment and esthetics. In response, dental manufacturers have focused their attention on developing restorative materials that are color-fast and strong enough to resist maximum biting forces. As those materials became easier to manage and more reliable, dentists have designed and developed operative techniques that require minimal tooth reduction without losing their retentive and esthetic value.

The goal of esthetic dentistry is to create a smile that improves a patient's appearance and restores their self-image while also meeting biologic and structural considerations. However, reaching that goal goes beyond just reshaping a tooth or teeth and replacing the tooth's surface with a resin or ceramic. A comprehensive esthetic treatment plan must be all encompassing and take into consideration occlusive malpositioned teeth within the natural curvature of the arch, the health and welfare of the periodontal tissues, including pocket depth, and the loss of crestal soft tissue and bone. Of greatest importance is the diagnosis of pulp health before restorative procedures are scheduled. As such, the practitioner performing the endodontic procedures must either believe in their diagnosis and continue with the treatment plan or, when the prognosis is difficult, aggressively eliminate the potential for a latent endodontic problem by intentionally removing the pulp. This decision, as difficult as it is, is preferable to responding to pulpal disease after the esthetic restorations are in place.

Endodontics: an essential part of treatment planning

Endodontics should be incorporated into the interdisciplinary treatment process when the ultimate esthetic design is being determined. Treatment sequencing can be established and painful episodes and disruption of the restorative schedule avoided if the pulpal health and any previous endodontically treated teeth are evaluated early in the planning stages. The patient should be informed that the overall treatment plan is dynamic and may change as conditions arise. It is equally important to evaluate the patient's radiographs and, if deep existing amalgam or other restorations will be replaced as part of the treatment plan, the patient should be advised of future problems due to the depth and extent of those restorations. If, at a later time, there are complications such as an inflamed pulp or pain following final cementation, the patient has at least been informed and forewarned. The key here is to "pave your way with words." Irreversible pulpal inflammation and subsequent pulpal necrosis is often cumulative and multifactorial and can occur when the dentist least expects it, such as with a seemingly innocent and small facial restoration. However, a minor operative procedure may be the last pulpal insult needed to damage the pulp. After all, the pulp cannot benefit from the usual healing potentials in the body. It is incased in unyielding walls of dentin; it is a terminal circulation; it is a relatively large volume of tissue for a relatively small foraminal blood supply. This problem is sometimes complicated by difficulty not seeing or appreciating the depth of certain tooth-colored restorations. Magnification helps to overcome this obstacle.

The removal of existing restorations, excavation of decay, and the paralleling of multiple abutments may require periodic reassessment and endodontic reconsideration. Sensitive teeth that do not respond to palliative measures within a reasonable period of time may require endodontics. There is nothing more disheartening to a patient who has completed perhaps 18 months of combined orthodontic, periodontal, and restorative treatment than to experience a "toothache" shortly after final cementation. Although pulpal problems cannot always be predicted, a great majority can be avoided with insight, careful evaluation, and good interdisciplinary collaboration, sequencing, and judgment.

Clinical evaluation

The success of any reconstructive treatment plan begins with the question: is it predictable? Predictability begins with biology. Biology begins with health of periodontium (see Chapter 37), pulp, and surrounding attachment apparatus. The health of the pulp, the periradicular area, and the quality of the existing root canal treatment of the teeth to be restored need to be in the forethought and not an afterthought of treatment planning. That is why an endodontic chapter is included in this text about esthetics. Discussed in the following are standardized and time-tested procedures which help determine pulp and periradicular condition. Proper evaluation should include many, if not most of these.

- Communication that includes listening and recording
- Visual examination
- Periodontal probing
- Thermal tests
- Electric tests
- Cavity tests
- Periradicular tests: percussion and palpation
- Bite tests
- Radiographic evaluation
- Anesthetic test.

Dental history and building rapport

Besides knowing the medical condition of the patient, the diagnostician should ask the patient about previous dental experiences. Their desires and objectives should be clearly defined.

If neglect is evident, the reasons for the neglect should be determined and discussed. If phobia and anxieties exist, the extent of the case should be explained and relaxation techniques should be offered to assure a comfortable and pain-free treatment experience.

In addition, when a professional air of confidence, concern, and care are exhibited by the doctor and staff, the patient's trust, faith, and interest are earned and developed.

Once this rapport is established, the patient becomes far more receptive to accepting and entering a treatment plan regardless of its difficulty, fee, time, and patient apprehensions. The quality of treatment is inversely proportional to the level of stress experienced by the patient and the doctor during the dentistry. Again, informing your patient about the potential for existing restorations contributing to future endodontic treatment is essential for continued patient trust.

Communication: listen, learn, and record

As dentists, we are the professionals who must perform the tests, interpret the results, and design a treatment based on the information gathered. When the diagnosis is not evident, we must turn to the patient for that one pinpointing clue. Sir William Osler, the famous Canadian diagnostician, once said, "Listen, listen, listen, – for the patient is giving you the diagnosis." This statement is profound. The diagnostician must not only ask sufficient and leading questions to obtain as much information as possible but also listen carefully to interpret the verbal response and its expressed meaning. Patients should be quoted verbatim in the chart and their answers must become a permanent record for review.

Visual examination

Direct examination of each tooth with some method of magnification, loupes or a microscope, is essential to locate fracture lines, decay, or defective restorations. Transillumination through a fiber-optic light may be of great assistance in detecting color shifts in a crown (Figure 24.1A and B). A tooth with a pink or reddish hue could indicate internal hemorrhage from a recent injury (Figure 24.2), a dental procedure (Figure 24.3), or gingival tissue hyperplasia that has invaded a coronal cavity produced by caries or resorption (Figure 24.4A–D).

A gray, blue, or black color might indicate blood infiltrate hemostasis within the dentinal tubules and chamber, long-term necrotic tissue (Figure 24.5), or silver precipitants from certain root canal sealers and filling materials (Figure 24.6A–C). A yellow or brown (Figure 24.7A) unrestored crown often represents a physiologically calcified nonpathologic obliteration of the root canal chamber or root canal system (Figure 24.7B). Pharmacologically affected (i.e., tetracycline-stained) teeth may vary in color from yellow to black (Figure 24.8A–C) and their drug florescence and etiology may be verified by using an ultraviolet light or Woods black light. This situation is an infrequent finding now since the diminished use of tetracycline antibiotics in children. Many of these discolorations can be reduced or eliminated by oxidizing techniques and agents without requiring endodontic intervention (see Chapter 12).

Teeth with vertical fractures have a diagnostic constant. The transilluminated light does not pass through the fracture line, but the crown beyond the fracture (Figure 24.9A and B) or the opposite cusp(s) (Figure 24.10) appear darker. Periodontal probing, cold testing, and a bite test will possibly assist in confirming the diagnosis of cracked tooth syndrome (CTS).

Periodontal probing

Periodontal probing and evaluating the depth of the sulcus and individual pockets are of great importance to the treating dentist and the treatment plan. There are two main reasons for this:

1. If there is a combined periodontal–endodontal disease associated with a tooth, the true cause of the problem is not only difficult to diagnose but could be more difficult to manage during treatment.

Figure 24.1 **(A)** Transillumination of a maxillary left central incisor with a necrotic pulp.

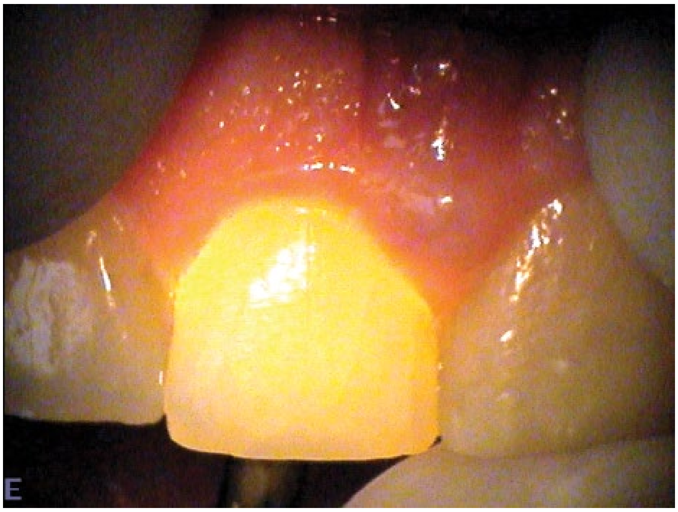

Figure 24.1 **(B)** Transillumination of the adjacent tooth with a vital pulp. Because there is an active blood flow through the live pulp tissue the tooth appears brighter to the fiber-optic light.

Figure 24.2 The maxillary central and lateral incisor teeth experienced a concussion injury and there was subsequent extravasation of blood causing the reddish hue.

Figure 24.3 One week following crown preparation the tooth structure was red, signifying extravasations of blood and the need for pulp extirpation.

2. If there is an isolated, narrow but deep periodontal pocket somewhere around the tooth, a vertical root fracture must be ruled out before any further restorative treatment.

The pocket could simply be a draining sinus tract from a necrotic or infected pulp, especially if the pocket probing is precipitous and not conical as it would be in an independent lesion of periodontal origin. Accurate periodontal probing is essential to make the diagnosis of endodontic sinus tract versus periodontal pocket. Like a waterfall, the endodontic sinus tract may be narrow or wide. The key question is the probing conical suggesting a lesion of periodontal origin or is it precipitous suggesting a lesion of endodontic origin? If the sulcular sinus tract is part of a lesion of endodontic origin, endodontic treatment would then be indicated. The pocket should heal without any periodontal treatment within days after the initial root canal system cleaning visit. It is important to note that periodontal scaling or curettage

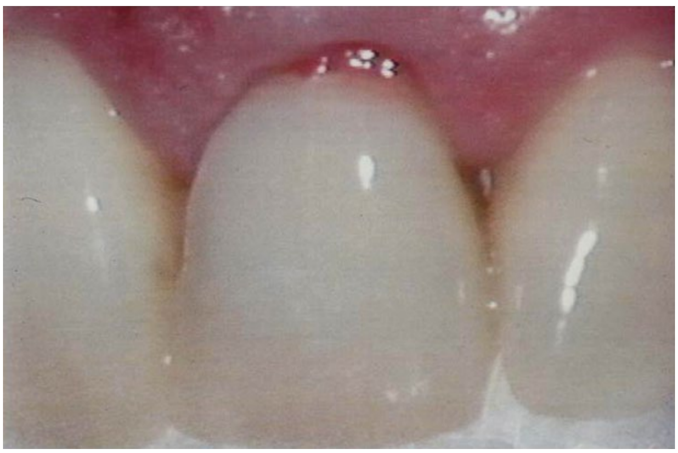

Figure 24.4 **(A)** Pink spot as a result of external resorption.

Figure 24.4 **(B)** Radiograph of the same tooth showing external resorption.

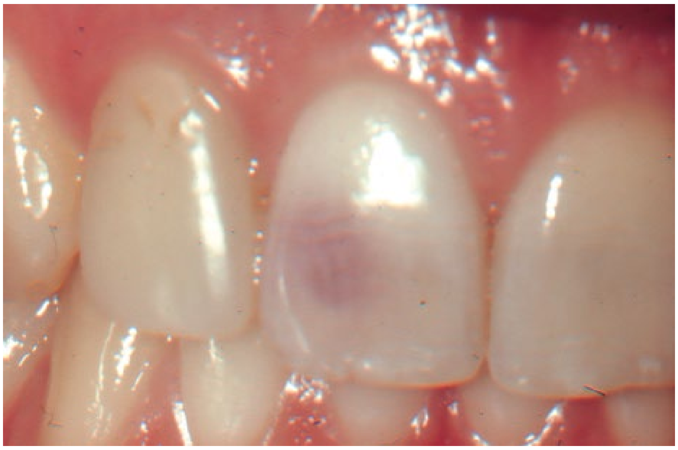

Figure 24.4 **(C)** Pink spot as a result of internal resorption.

Figure 24.4 **(D)** Radiograph of the same tooth showing internal resorption.

Figure 24.5 Maxillary central incisors with necrotic pulps.

Figure 24.6 **(A)** Discoloration from silver containing root canal cement.

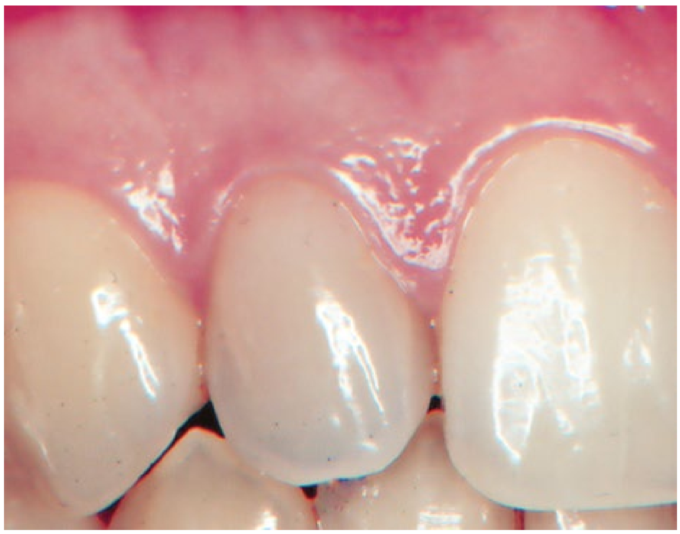

Figure 24.6 **(B)** Gray color of crown from a post.

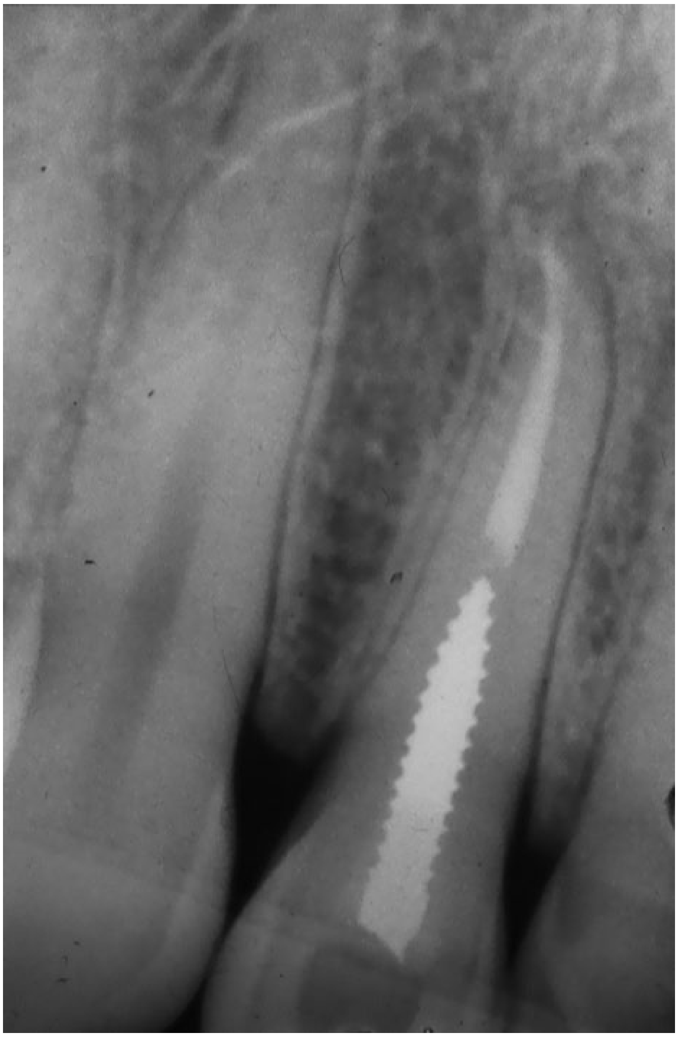

Figure 24.6 **(C)** An unnecessary post that caused the discoloration.

Figure 24.7 **(A)** The crown of this maxillary central incisor discolored gradually over a 3-year period following a concussion injury. The complete fill-in of the pulp chamber with dentin is the cause of the yellowish brown hue.

can be detrimental to healing of the pocket and, therefore, should postponed if the diagnosis is a lesion of endodontic origin. If the pocket has not healed after a few days of beginning endodontic treatment, the whole diagnosis needs to be reassessed and other possible diagnoses ruled out. The pocket could be associated with a vertical root fracture where the prognosis of the tooth is hopeless. Endodontic treatment would not resolve the pocket nor would periodontal treatment cure the condition. Removal and replacement of the tooth would be the only predictable treatment option.

Thermal pulp tests

Cold testing

In an effort to determine pulp vitality, cold testing is probably the most commonly advocated and the most accurate. In the past, an "ice pencil" (water frozen in sterilized anesthetic cartridge and removed) (Figure 24.11) or an ice cube was the only consistent way to chill a tooth. The problem with using frozen water is it may not be cold enough (≥0 °C) to penetrate a porcelain crown. However, in a tooth with an acute pulpitis an "ice pencil" could be an effective diagnostic tool. Recently, 1,1,1,2-tetrafluoroethane spray (Endo-Ice®, Hygenic, Akron, OH) has become the cold testing method of choice (Figure 24.12A). The spray is cold enough (−26 °C) to penetrate most crowns.

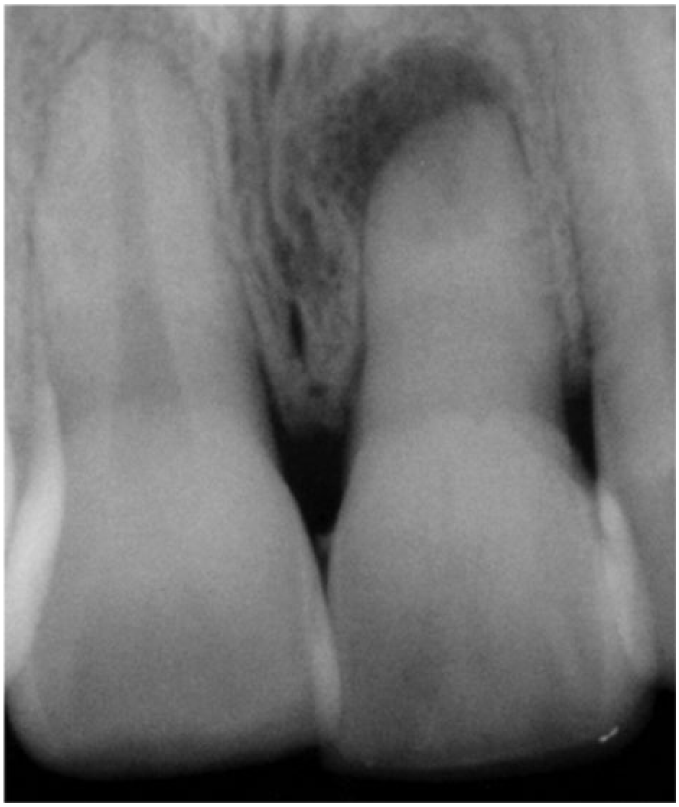

Figure 24.7 **(B)** Radiograph of a similar maxillary central incisor 10 years after a concussion injury. The pulp chamber is filled in with dentin producing the discoloration. In this case, there was pulp death after discoloration appeared. Because the pulp canal was obliterated, a surgical approach was used to seal the apex.

Figure 24.8 **(A)** Brown staining from Terramycin.

Figure 24.8 **(B)** Gray staining from Acromycin.

Figure 24.8 **(C)** Tan staining from Aureomycin.

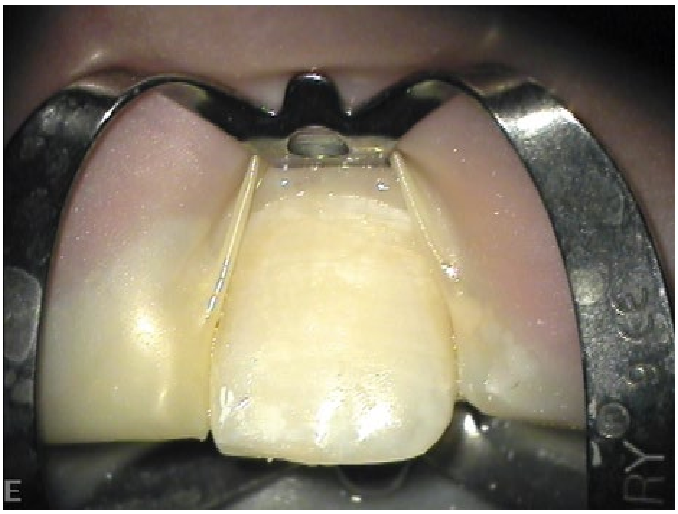

Figure 24.9 **(A)** View of a maxillary central incisor tooth with overhead lighting. No fracture is visible.

Figure 24.9 **(B)** Transilluminated view of the same tooth revealing the fracture line.

Figure 24.10 Transillumination of a mandibular second molar. The fracture lines at the mesial and lingual grooves do not allow the light to pass through.

Figure 24.11 An ice pencil being applied to a maxillary central incisor tooth.

The procedure is easy to use, and it is safe for the pulp. The gas is sprayed on a cotton pellet (Figure 24.12B), and then the chilled cotton is placed on the buccal/facial of the tooth that is to be tested (Figure 24.12C). A baseline control should be established on an adjacent for comparison before testing the suspected tooth.

The response of a normal, healthy, vital pulp is sharp and quickly dissipates once the stimulus is removed. If the response is more intense and lingers after the pellet is removed, it usually indicates an irreversible pulpitis. When calcified pulp chambers or constricted canals exist, the response from an otherwise healthy tooth may be delayed or nonexistent. The reduced conductivity can mislead the operator. Therefore, other tests must be used to confirm negative responses.

When faced with teeth that are heavily restored, the final tests can be delayed until the caries has been excavated and the patient is in a provisional restoration. By thermal testing prior to anesthetizing but with the temporary crown removed, the true status of the pulp may be validated before final cementation and any changes that may have arisen during the fabrication interval can be appraised.

Heat testing

To duplicate patient heat symptom, heat can easily be applied to the buccal/facial of teeth using any warm gutta-percha heat source (Calamus, Tulsa Dental Products, Elements, Sybron Endo, Touch 'n Heat, Kerr). Special heat tips are made for heat testing. It is important to remember that heat is delayed and lasts, while cold in instant and fleeting. Heat pain will typically last from 8 to 36 h and then the pulp becomes necrotic.

Heat can be an informative of the pulp test; however, it is the most difficult test to apply. Heated water applied to an individual tooth after it has been carefully isolated by a rubber dam is the most reliable method. It is time consuming, and extreme care has to be taken so there is no leakage under the rubber dam. It is recommended to isolate and stimulate a tooth that is posterior to the one that is suspected to be heat sensitive first. Then move the rubber dam anteriorly and test tooth by tooth. Heated temporary stopping applied to the lateral surface of a natural tooth or a metal surface of a veneer casting has been recommended, but it is difficult to control the heat and the stopping has the tendency to stick on the tooth and may cause prolonged stimuli and thereby an inaccurate test. A rubber polishing wheel in a low-speed handpiece is another heat test alternative. Since it is difficult to control the heat generated, this method is not recommended. The antiquated method of touching a tooth with a red hot burnisher should be avoided because of the risk of overheating the tooth and creating a pulpal problem.

Electric pulp testing

Over the last 35 years, the Analytical Technology Vitality Scanner, more recently renamed Vitality Scanner (Sybron Endo) (Figure 24.13), has become the standard within the endodontic community. This battery-operated device is simple to use, accurate, and virtually trouble free. A small amount of an electrolytic gel (toothpaste, fluoride gels, or EKG paste) is applied to the end of the testing tip prior to its contact with the tooth. When the low-voltage electrical stimulation is transmitted to the teeth (Figure 24.14), the responses can be recorded from the patient's verbal identification of heat, tingling, or slight discomfort or pain. Credence should not be placed on the specific numbers displayed, nor should the differential between tests of individual teeth be used to determine stages of pulpal degeneration. The single purpose of electric pulp testing (EPT) is to test vital or nonvital and does not measure health versus inflammation. As previously stated, pulp testing heavily restored teeth can be inaccurate, and therefore unreliable. The Vitality Scanner "mini-tip" (Figure 24.15) is useful for full-coverage teeth to determine pulp vitality if root structure can be exposed with a plastic instrument or by first packing periodontal cord. The "mini-tip," when used

Figure 24.12 **(A)** Endo Ice (Hygienic).

Figure 24.12 **(B)** Spraying Endo Ice on cotton pellet.

Figure 24.12 **(C)** Applying iced pellet to labial surface of tooth.

in conjunction with a prepared test cavity or a small opening in a cast crown (Figure 24.16A and B), on the other hand, is a very accurate pulp vitality test. The tip is then placed directly through the opening of the restoration or fabricated crown and onto the exposed dentin (see "Cavity test" section). Care should be taken to keep the electrolyte (tooth paste, fluoride gel, or EKG paste) from touching the metal of the casting.

If the dentist can determine that root canal treatment is indicated while the patient is still in the provisional restorations, the endodontic needs can be addressed without disturbing the crown margins. The patient should have been informed of such possibilities during the treatment plan discussion.

Ideally, no single test should be considered conclusive. Collaborative tests are, of course, more reliable and accurate. This is particularly true when dealing with apprehensive patients. Under stress, these patients will anticipate and respond even when no stimulus exists. The decision to treat these patients may be based on finesse, experience, intestinal fortitude of the dentist, and the intensity of the patient's pain. The option of when to treat what tooth should be communicated in detail. The records should indicate that the diagnosis and treatment plan is based on the patient symptoms, duplication of those symptoms and responses (or lack thereof), to vitality tests, as well as a thorough clinical, pulpal, periodontal, structural, functional, and esthetic evaluation. Your written informed consent document should be signed by you, the patient, and a witness, preferably the assistant who was in the treatment room during the discussion phase of the treatment. In the case of an emergency situation, the alternative should be offered to wait until the symptoms and signs localize. The patient decides whether to proceed or not.

Figure 24.13 Vitality Scanner 2006 (Kerr Endodontics).

Figure 24.14 Vitality Scanner being applied to a dried tooth.

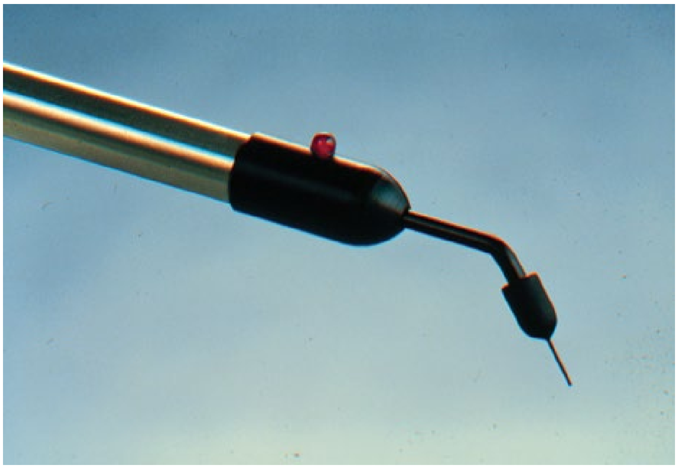

Figure 24.15 Mini-tip for the Vitality Scanner.

Cavity test

When tests are inconclusive with the less apprehensive patient, penetrating to the dentin with a new and small bur through the occlusal of a posterior crown or lingual of an anterior crown of an unanesthetized tooth is an excellent method of validating pulpal necrosis. This should only be done if the tooth has not responded to the electronic pulp testing and cold vitality tests. It should be carefully explained to the patient that, based on testing, it is likely that the pulp is already necrotic and therefore they should not feel any pain during the cavity test. If the patient reports pain/sensitivity when the cavity preparation has reached the dentin, this test indicates the EPT and ice tests were false positives and the cavity is restored and further diagnostic tests required. The cavity test to determine pulpal necrosis trumps the accuracy of both EPT and ice tests. If extensive caries is present, the patient should be anesthetized and the caries removed prior to restoring. This will allow visual evaluation of the cavity floor and the ability to estimate the strength of the abutment value of the tooth. If the patient does not report any pain or sensation, an endodontic access is

Figure 24.16 **(A)** Access through porcelain and metal to the dentin.

Figure 24.16 **(B)** Mini-tip placed on dentin through prepared cavity.

prepared and endodontic treatment is initiated after all decay excavation.

Electronic pulp testing with a "mini-tip" through a test cavity may be the key to making a diagnosis in a tooth with a radiolucency that cannot be differentiated as of either periodontal or endodontic origin. A necrotic pulp is diagnosed if the reading is negative. Endodontics would then be the treatment of choice (Figure 24.17A and B). If the reading is positive and there are no pulpal symptoms despite the radiographic appearance, periodontal therapy would be indicated if the tooth probed (Figure 24.17C–E). If the radiolucency is neither a lesion of endodontic nor periodontal origin, the patient should be referred to the oral surgeon for biopsy consideration. Finally, endodontic treatment may be required if the root apices are compromised during periodontal procedures (Figure 24.17 F and G).

Periradicular tests

Percussion

Gently tapping or pressing the forefinger on the incisal or occlusal surface of a tooth may elicit a painful response (Figure 24.18). In situations when the response generated is mild or absent, the test should be followed with gentle tap of a mirror handle (Figure 24.19). A painful response usually indicates inflammatory changes in the periodontal ligament caused by pulpal degeneration. When bacteria have entered the pulp, necrosis will follow. Endotoxins from the bacteria will eventually exit the canal and create an inflammatory reaction of the periodontal tissue surrounding the apex and/or lateral root portion of the tooth tested. The reaction is usually more intense when the inflammatory condition is endodontic rather than periodontal origin.

Occasionally, painful responses to percussion are elicited from teeth not undergoing pulpal degeneration. Acute sinusitis can cause the maxillary posterior teeth to be painful when percussed. Usually in this situation, more than one tooth responds painfully

Figure 24.17 **(A)** Maxillary central incisor tooth with a vital pulp. Endodontic therapy was not indicated.

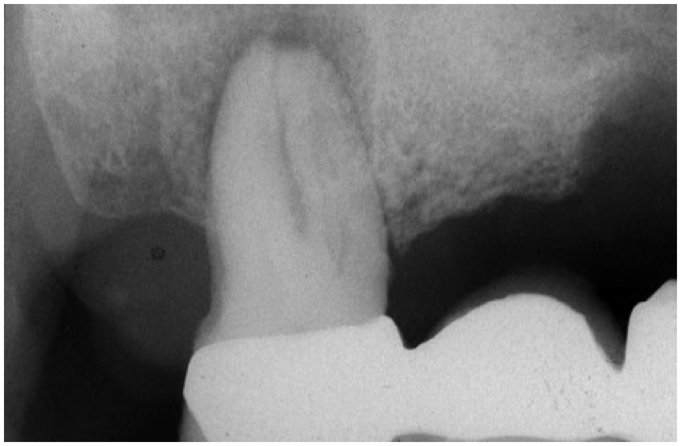

Figure 24.17 **(B)** A maxillary first molar with periapical radiolucency.

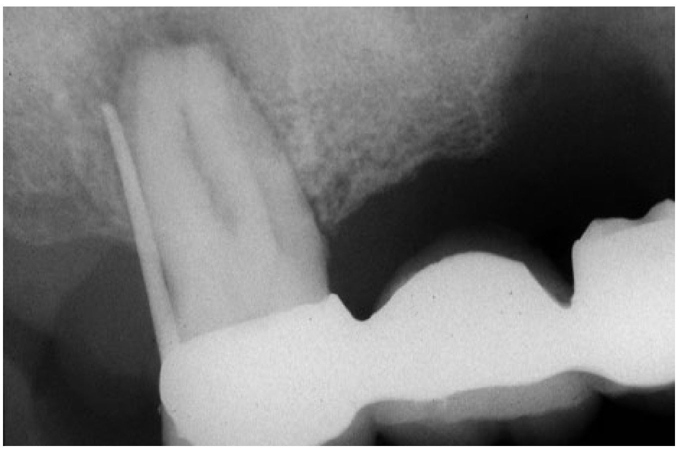

Figure 24.17 **(C)** A gutta-percha point placed in the distal periodontal pocket. Pulp testing through an occlusal opening revealed a vital pulp. The cause of the radiolucency was of periodontal origin, and therapy followed that course.

Figure 24.17 **(D)** Mandibular molar with a necrotic pulp. Root canal therapy was instituted.

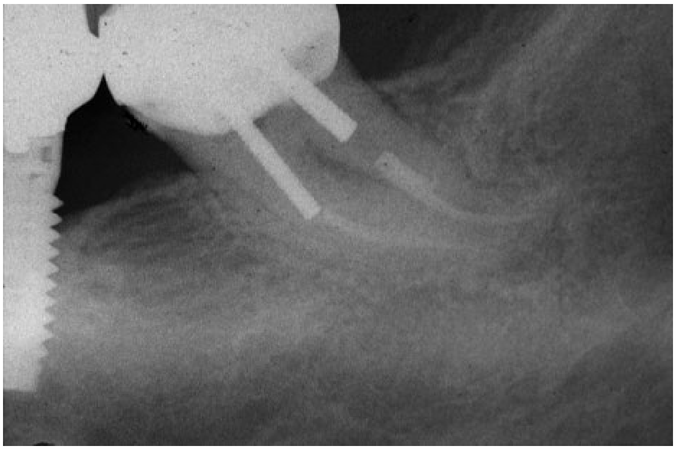

Figure 24.17 **(E)** Ten years after completion of root canal therapy, there is complete bone fill in. No periodontal treatments were performed on this tooth.

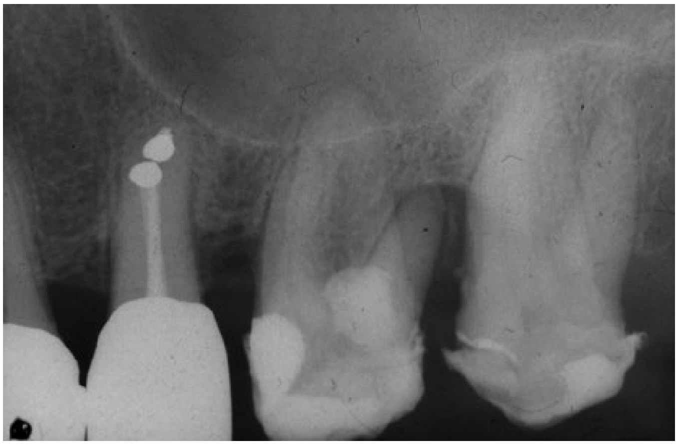

Figure 24.17 **(F)** Maxillary first molar with an uninflammed vital pulp. There was extensive bone loss surrounding the distobuccal root.

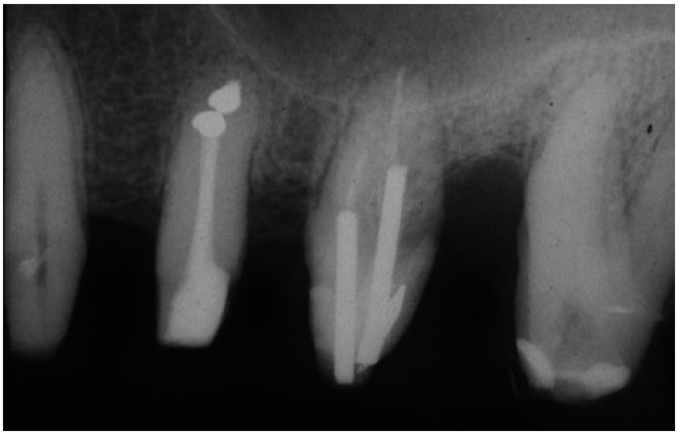

Figure 24.17 **(G)** Root canal therapy was performed to allow for the resection of the periodontally involved root.

Figure 24.18 The first percussion check is a gentle tap with a fingernail.

Figure 24.19 The second percussion check is a gentle tap with a mirror handle

to percussion. A careful history of the patient's respiratory experiences and allergies is essential in making the differential diagnosis, as well as history of pain in the affected area with sudden movements like bending over or running quickly up or down stairs. Teeth in traumatic occlusion are frequently sensitive to percussion but are also painful to cold. To exclude this possibility, a check for occlusal prematurity is indicated. A degenerative pulp does not usually respond to thermal pulp tests unless it is in the early stages of the process. If a tooth is painful to both percussion and sensitive or even hypersensitive to cold, the dentist should suspect a vertical fracture. Fractures are most frequently observed in mandibular second molars and maxillary bicuspids and occur irrespective of their restorative conditions. The use of the transilluminator or fiber-optic light is quite useful in diagnosing a fractured tooth (Figure 24.10).

Palpation

Pressure with a gloved forefinger over the root of a suspected tooth may reveal tissue distention and may also elicit a painful response (Figure 24.20). This indicates a radicular inflammatory response from the root canal system that must be validated with a negative pulp test (necrotic pulp) and a gingival crevice that probes within normal limits. A periapical radiograph may suggest the forming of a lesion of endodontic origin. The tender area may be so extensive that the teeth adjacent to the suspected tooth must also be tested. Once again a differential diagnosis of acute sinusitis should be considered when the maxillary posterior teeth are involved. The tissues painful to palpation with sinusitis usually spread away from the dentition and extend superiorly and facially. Although the area of pain is usually concentrated at the zygomatic process of the maxilla, the pain may extend around the orbit and incite headaches. Pulp testing and a careful history are essential in these situations.

Figure 24.20 Palpation with forefinger in mucobuccal fold over suspected tooth.

Bite test

Every time that the patient's symptom is sensitivity to biting and/or chewing, it is important to investigate further which tooth and which part of the tooth is sensitive to biting pressure to distinguish between vertical crown/root fractures and periapical pathosis. A very helpful device for this investigation is Tooth Slooth® (Professional Results, Inc.; Figure 24.21). By design, this instrument has a slight depression in the biting surface so the patient will only bite on individual cusps (Figure 24.22A and B) without adjacent cusp interference during testing. If there is a

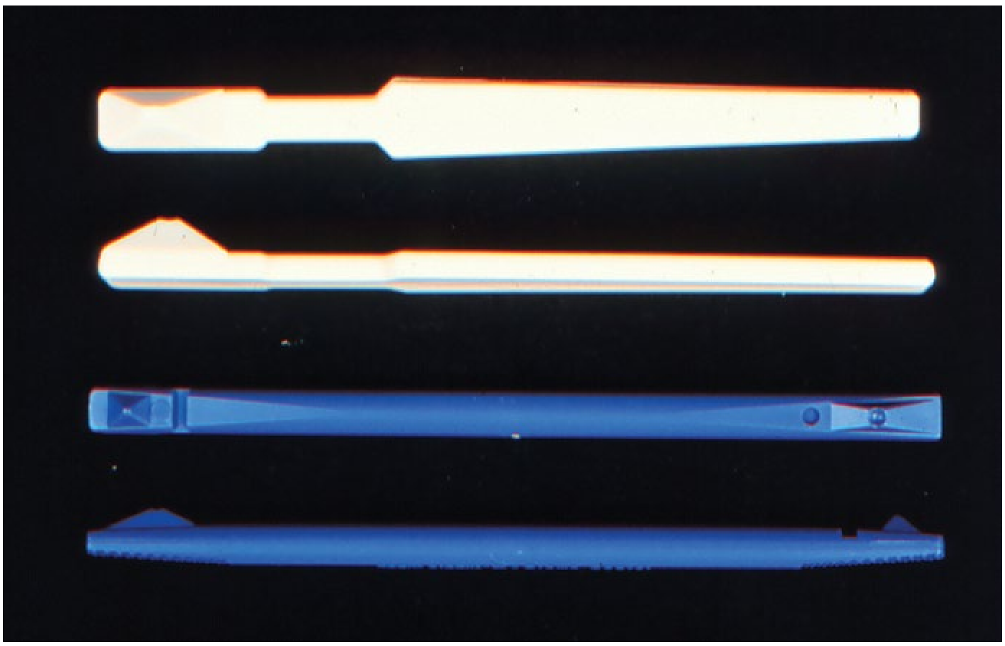

Figure 24.21 Tooth Slooth; two sizes.

Figure 24.22 **(A)** Bite test with Tooth Slooth checking distobuccal cusp of mandibular molar.

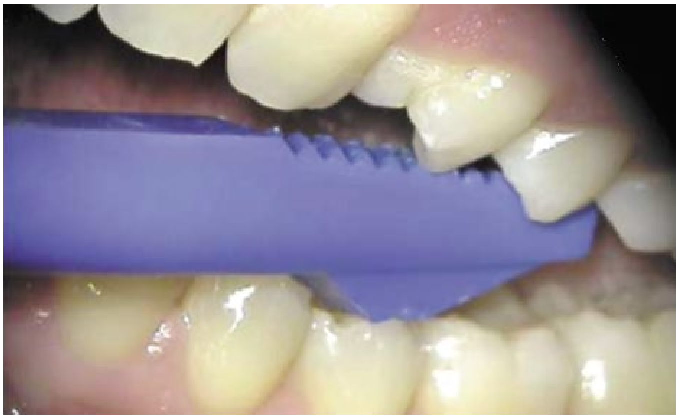

Figure 24.22 **(B)** Bite test with smaller-sized (blue) Tooth Slooth.

Figure 24.23 A plastic saliva ejector is useful in bite testing the entire tooth rather an individual cusp.

fracture in the crown, the patient is likely to report normal sensation to biting on all but the area/cusp that is fractured. It is advisable to start with having the patient bite on the Tooth Slooth on a tooth that is not suspected of being fractured to establish a normal baseline response. Then test from tooth to tooth around the mouth as the patient exerts pressure. The patient is asked to close slowly yet exert maximum pressure. Pain on bite release is indicative of an inflamed pulp/irreversible pulpitis requiring extirpation.

A plastic saliva ejector may be used as an alternative instrument for this test (Figure 24.23).

Pretreatment radiographs

Treatment planning requires a full set of well-angulated long cone exposed periapical films or digital images using film holders such as XCP (DENTSPLY RINN Corp.) or Kodak digital imaging that enables 90° angulation of the X-ray beam on the film or sensor. In addition to good angulations on the radiograph, these film holders will enable the operator to compare the images over time, which is essential when evaluating healing or failure. A bitewing and mesial, perpendicular, and distal periapicals images are diagnostically desirable.

When dealing with extensive situations, panoramic film is another diagnostic aid. If the patient requires endodontic treatment and is referred to the endodontist, then these films and a description of the goals and objectives of the referring dentist should be sent to the endodontist prior to the patient's first appointment. The endodontist may take additional films of the teeth to be treated to establish a complete record. In most cases, an endodontic procedure should not be initiated without evaluating at least two recent radiographs exposed at different horizontal angulations of the suspected tooth (Figure 24.24A and B). Examining varied views is essential in diagnosing the presence of additional roots, anatomical configurations, anomalies, and other unusual circumstances that may complicate the treatment.

Cone-beam computed tomography (CBCT), three-dimensional (3D) limited area scans, gives the clinician an additional instrument to help in diagnosis and treatment planning.[1] Endodontists often use the 3D scan as part of their regular preoperative regimen in teeth involved in periapical surgery, root resorption, retreatment (Figure 24.25A–F), dental alveolar trauma, periapical bone defects, unusual anatomy, root fractures, and so on. This noninvasive diagnostic radiographic procedure allows the clinicians to proceed with greater confidence and accuracy because of the additional information they have prior to treatment.

Precementation radiographs

Prior to cementation, Yamada (personal communication, June 2001) reradiographs the prepared teeth (Figure 24.26A and B). These images, unencumbered by the presence of the metal or ceramic castings, provide a chamber/canal road map record if the tooth requires endodontics in the future. Arens and Chivian[2] reported that over 40% of teeth requiring root canal therapy are crowned.

Prior knowledge of the size, location, and direction of the chamber and canal will reduce the possibility of the following:

- crown damage during access opening;
- lost time searching for the canal orifice;

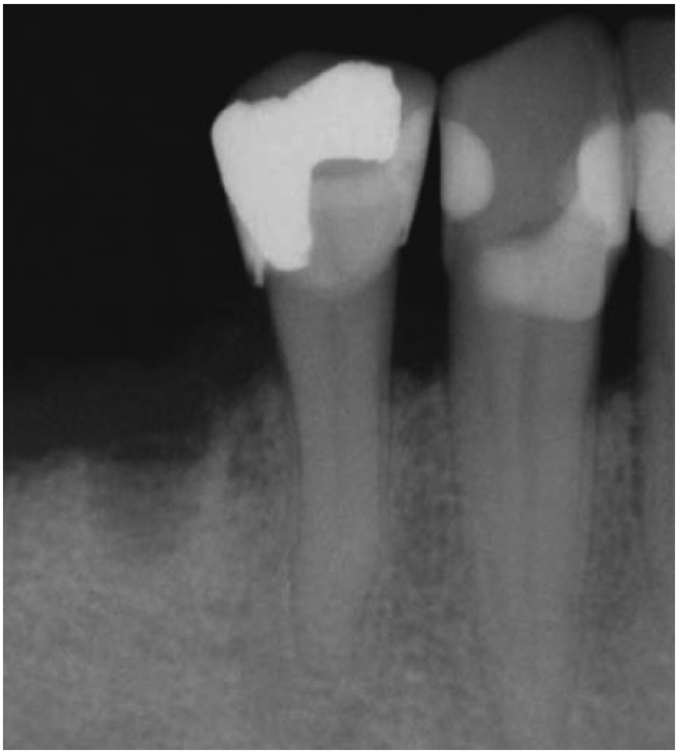

Figure 24.24 **(A)** Pretreatment radiograph of a mandibular premolar shows one canal.

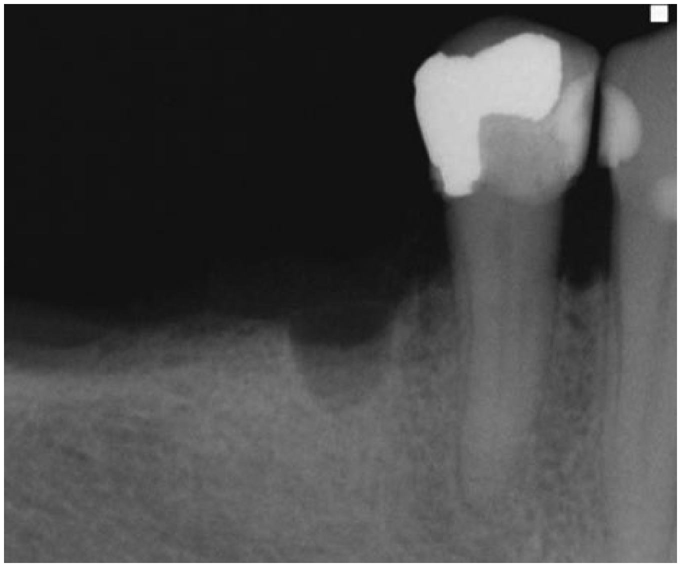

Figure 24.24 **(B)** A second radiograph taken from an angulation of 15° from the mesial discloses a second root.

- perforations of the chamber or the canal because of disorientation;
- crown dislodgement.

Each of these iatrogenic possibilities reduces the prognosis and jeopardizes the tooth's reliability as an abutment.

Anesthetic test

All the previously described tests are based on "duplicating" a patient's symptoms. Once the symptom is duplicated, the endodontic diagnosis can be made followed by appropriate treatment. Sometimes, however, a patient will present with "just pain" and the only test available to the dentist is the anesthetic test: administer anesthetic to the tooth or teeth where the patient "thinks" the pain is coming from and see if the pain vanishes. If the pain resolves, the anesthetic test indicates you have found the source but usually multiple teeth are anesthetized and a single source cannot be identified. The dentist should not guess which anesthetized tooth is the pain source. Instead, knowing that a pulpitis usually lasts from 8 to 36 h, administer a long-acting anesthetic such as Marcaine and have the patient return the next day or at end of the day if patient originally presents in the morning. If pain is still there when the patient returns, do anesthetic test again and see patient next day. Within a day or two, the pain will be gone (necrosis and gangrene) and the diagnosis is simple

Figure 24.25 **(A)** Patient experienced pain 3 months after nonsurgical root canal treatment. Reproduced with permission of Dr J. Chikvashvili.

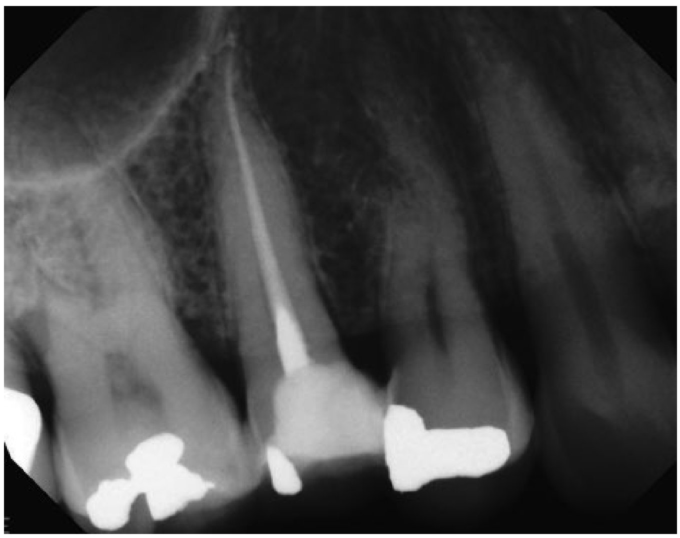

Figure 24.25 **(B)** Radiograph taken 15° from the mesial. Only one canal visible. Reproduced with permission of Dr J. Chikvashvili.

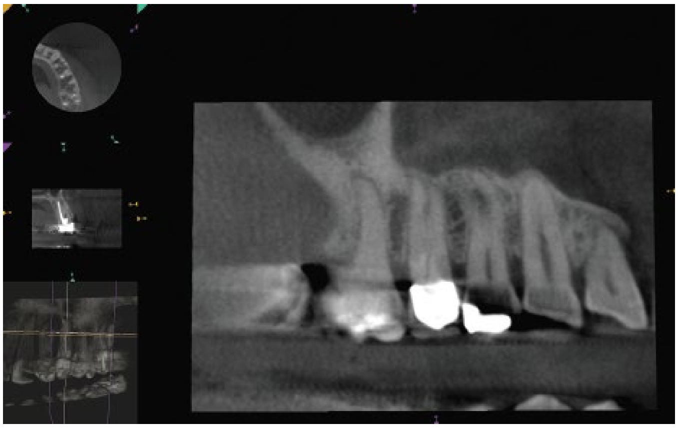

Figure 24.25 (C) CBCT sagittal plane image shows two untreated buccal canals. Reproduced with permission of Dr J. Chikvashvili.

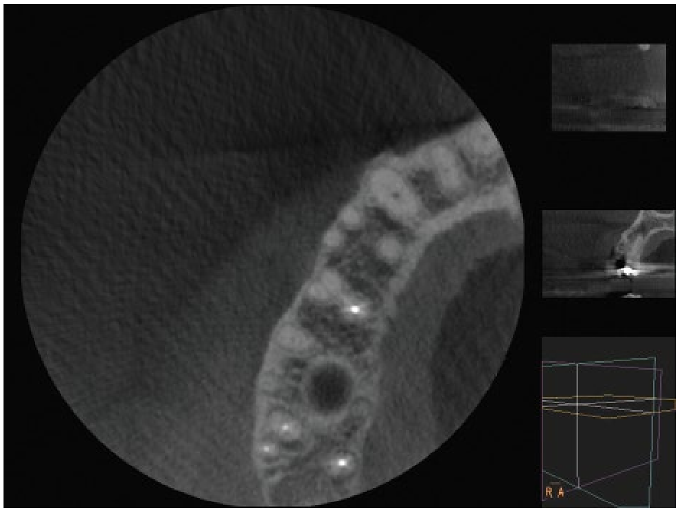

Figure 24.25 (D) CBCT axial plane image shows two untreated buccal canals. Reproduced with permission of Dr J. Chikvashvili.

Figure 24.25 (E) Canals located and negotiated. Pain abated after canal debridement. Reproduced with permission of Dr J. Chikvashvili.

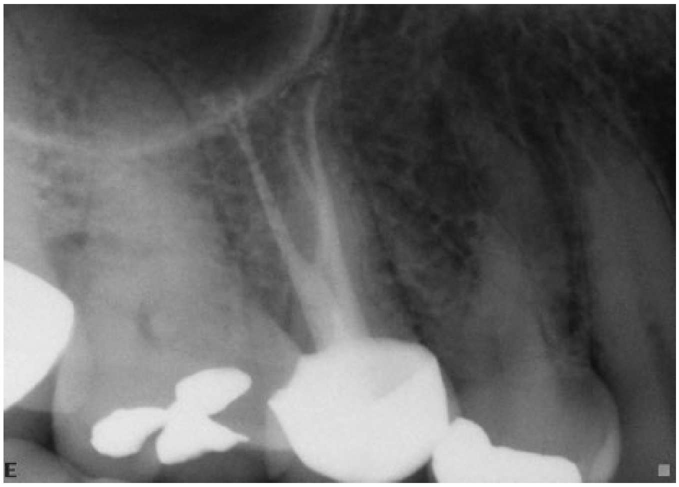

Figure 24.25 (F) Postoperative image showing three main and lateral canals obturated. Reproduced with permission of Dr J. Chikvashvili.

with pulp tests. Or in a day or two, the patient will be experience the beginning of an acute alveolar abscess. This tooth will be percussion sensitive and/or a periradicular radiolucency and/or cellulitis will be observable in its early stages. The pulp will test nonvital and the endodontic diagnosis is made. In summary, the anesthetic test buys time until patient symptoms can be duplicated or until nonodontogenic pain can be ruled out.

Diagnosis

By correlating all of the endodontic information, the dentist can, within reason, determine which tooth or teeth may or may not require root canal treatment prior to or during the reconstructive procedures. By far the most difficult pulpal tissue status to classify is found within the confines of a previously restored tooth. Therefore, it is important for the dentist and treatment team to understand endodontic biology and then to educate their patients how pulps react to dental procedures.

Pulpal response to operative procedures

Following caries, the single most influencing factor on pulp health (Figure 24.27) is the dentist correcting the ravages of caries and dental trauma. Simply modifying traumatic operative techniques could easily prevent adverse sequelae and reduce the eventual need for endodontics. A tooth with a healthy pulp, when operatively prepared, responds immediately to the dentinal injury. The dental tubules involved are vulnerable to the heat developed during the procedure, to the air during drying, and to any of the chemicals or materials used during the restorative procedures. Regardless of what the source, the odontoblasts will react. It is only a question of degree. With tooth reduction, the equation is simple: the higher the speed of the rotating instrument, the greater the heat generated and the greater the pulpal damage. Common sense would suggest that, in response to these predictable and undesirable insults, the surface of the

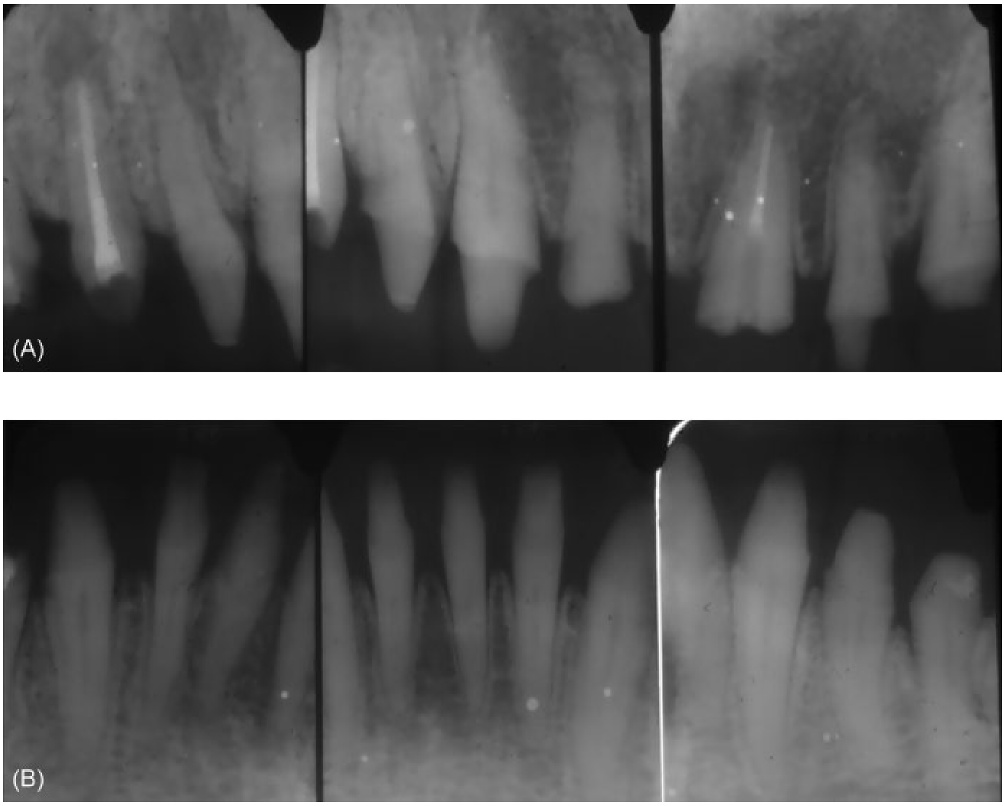

Figure 24.26 **(A, B)** Precementation radiographs provide a road map to the canals if endodontic therapy is necessary after cementation of the castings. *Source:* Courtesy of Dr Henry Yamada.

tooth should be reduced with well water-cooled high-speed dental handpieces and that the deepest excavation and final preparation should be achieved with low-speed handpieces. Adjunctively, a coolant spray should accompany all preparation cutting and every effort made to eliminate air blasts. Not only

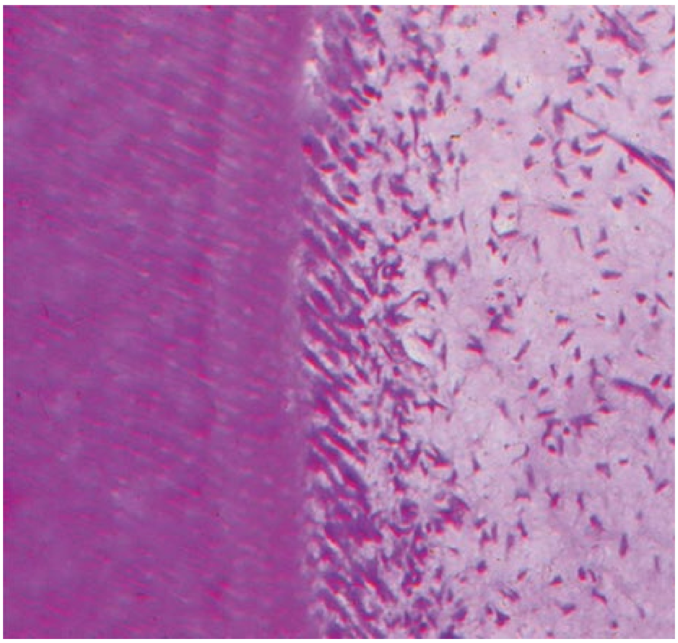

Figure 24.27 A vital healthy with its typical pattern of palisading odontoblasts. *Source:* Courtesy of Dr Harold R Stanley.

has Langeland[3] studies shown that l0 s of air is enough to displace odontoblastic nuclei (Figure 24.28) and present a definite hazard to the viability of the pulp, but Stanley's pulp studies[4] have also repeatedly demonstrated the pulp peril of cutting fast and dry.

In addition, unprotected dentinal tubules internal tooth bleaching, too rapid orthodontic tooth movement, impression taking, temporization, and cementation are other aggressive procedures within the normal dental regimen that demand attention and caution. The operator should also select materials and agents that have relatively neutral pH values, create little or no heat while curing, and control orthodontic forces within the physiologic tolerance of the periodontal ligament.

Despite using the utmost care during the course of restorative phase, there are situations that require the need for immediate root canal treatment:

- A tooth exhibiting exquisitely painful responses to cold liquids 10 weeks after deep decay excavation and pulp protection and sedation (Figure 24.29).
- The inability to exert full biting pressure on a crown 6–9 months after cementation even though the radiographs are negative (Figure 24.30).

Some postrestorative exacerbations are unavoidable, particularly when dealing with heavily restored teeth. Such episodes of acute or chronic pulpal inflammation more often stem from a preexisting pulpal condition that has been aroused before what appeared to be a simple operative procedure. Although the

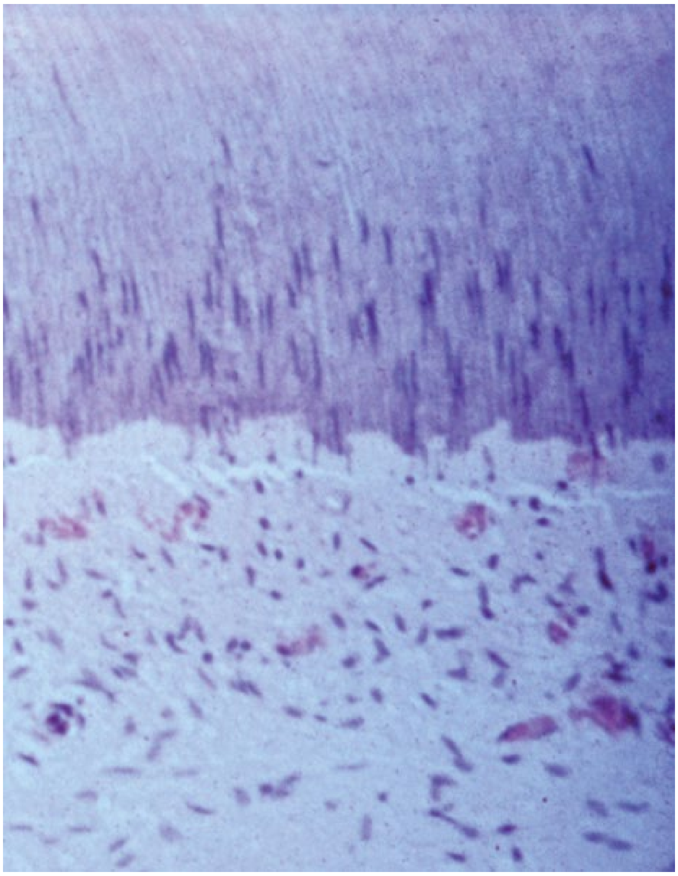

Figure 24.28 Displaced odontoblastic nuclei. *Source:* Courtesy of Dr Harold R Stanley.

Figure 24.29 Periodontally compromised maxillary central incisor that is painful to minor temperature changes 10 weeks after deep caries excavation and crown preparation.

healing potential of a healthy pulp following dental intervention has been well documented, the potential for complete repair has been known to decrease as the number of procedures is accumulated during a tooth's lifetime.

A healthy pulp's survival with resolution of acute inflammation will usually take place within 7–8 weeks after operative procedures provided there are no additional insults. Extending a patient's palliative treatment beyond that time frame is not only unjustified but also compromises the patient–doctor relationship. Rather, immediate endodontic treatment should be considered after this time, especially if diagnostic tests indicate pulpal distress.

Pulpal repair

Reparative dentin

Reparative or irregular dentin is deposited to form a protective barrier for the pulp tissue and is generally localized to the injury site. This abnormal dentin forms in response to intense and aggressive pulpal irritants that have reached the limit of pulp tolerance; for example, erosion, abrasion, caries, dentinal exposure by fracture, decay or mechanical tooth reduction, traumatic injury, caustic medicaments, and harmful restorative materials.

The histological appearance of reparative dentin (Figure 24.31) demonstrates dentinal tubules that are irregular, tortuous, or even absent. The increased thickness of the total dentin is likely

Figure 24.30 Mandibular molar with a normal radiographic appearance. However, the patient avoids using the tooth because of pain to chewing 9 months after cementation of the crown.

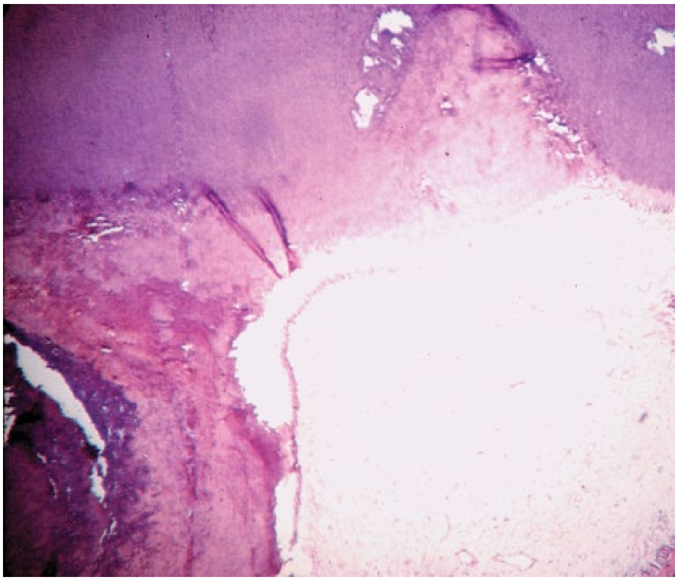

Figure 24.31 Reparative dentin. *Source:* Courtesy of Dr Harold R Stanley.

the reason patients have decreased responses to cold stimuli as time passes following a dental procedure. Quantitatively, it is noted the greater the degree of the "insult" caused by preparations and restorative materials, the greater the amount of reparative dentin that forms.

Although this calcified solid wall is considered beneficial and capable of resisting further episodes of irritation, the healing phenomenon decreases the ability of the tooth to respond to pulp testing at a later date.

Secondary dentin

Histologically and physiologically, there is a difference between reparative and secondary dentin. Secondary dentin begins forming soon after the tooth erupts into occlusion and continues to form throughout the pulp's life. This tooth structure is deposited over the primary dentin (Figure 24.32) throughout the entire chamber and the root canal system in response to stimuli within the limits of normal biological function, mastication, light thermal changes, chemical irritants, and slight trauma. The newly deposited dentinal tubules are smaller, exhibit more curves, and form a protective barrier for the pulp as the size of the pulp cavity is reduced. Reparative dentin, on the other hand, forms as a direct response to injury. Although secondary dentin deposition is not uniform in thickness, this dystrophic calcification may completely occlude the canal and complicate the eventual endodontic treatment. This diagnosis of calcific metamorphosis or calcific degeneration (CD) is a treatment decision-tree dilemma. Although historic dental literature has suggested nature has completed "her own root canal," many clinicians know differently. As the age of the human race rapidly increases, pulps will have to last longer and greater calcific metamorphosis or CD will occur, and as these pulps can eventually become necrotic, endodontic treatment will be increasingly technically difficult, sometimes resulting in access "accidents" such as loss of precious

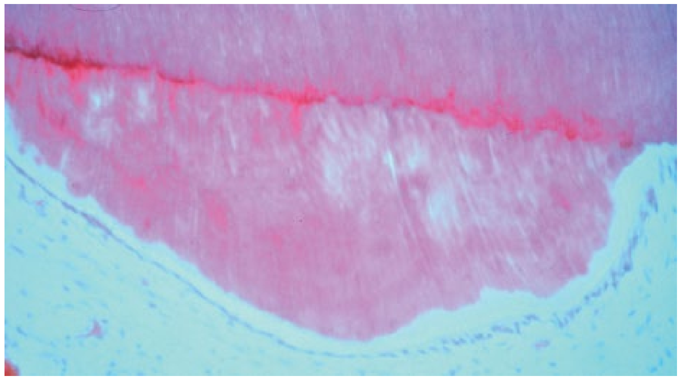

Figure 24.32 Secondary dentin. *Source:* Courtesy of Dr Harold R Stanley.

ferrule or even perforation. Calcific metamorphosis can be defined as a pulp calcifying that is out of sequence from other teeth or the tooth on the opposite side of the arch. Although this author (JDW) considers CD a pathology waiting to eventually become necrotic and symptomatic, most dentists would resist advising endodontics if the pulp were vital and patient asymptomatic. For those colleagues, you are obligated, however, to carefully monitor the CD condition for necrosis and eventual lesion of endodontic origin.

Elective endodontics for pulpal reasons

Depth of preparation/remaining dentin

According to Stanley, "The most important single factor in determining pulpal response to a given stimulus is the remaining dentin thickness between the floor of the cavity preparation or the surface of a crown preparation and the pulp chamber." Studies have shown that a 2 mm dentin thickness between the floor of the cavity preparation and the pulp (Figure 24.33) will provide an adequate insulation against the more traumatic thermogenic operative techniques in spite of intentional abuse and most restorative materials.[5]

Cavity or crown preparations cut with high-speed (200 000–300 000 rpm) air water spray and light touch produced minimal pathologic alteration to healthy pulps when the remaining dentin was 2 mm or more.

However Stanley[4] also states, "Although 2 mm of primary dentin between the floor of the cavity preparation and the pulp is usually a sufficient protective barrier against cutting techniques … the effluent of cements and self-curing resins can overcome this thickness of protection." To avoid such intrusions, calcium hydroxide lining materials capable of protecting the pulp tissue when appropriately used, should be placed in all deep-seated cavity preparations prior to building a secondary protective base of cement.

If the final restoration is a one-step procedure (i.e., amalgam or composite resin), then a dentin/pulpal floor protected with a calcium hydroxide dressing base can be permanently restored. The patient must be advised if there are pulpal risks involved. The records should reflect the risk condition and the discussion.

Figure 24.33 Cavity preparation with 2 mm of remaining dentin between its floor and the pulp tissue. *Source:* Courtesy of Dr Harold R Stanley.

The scenario differs with multiple-step restorations; that is, castings. If a tooth is compromised, the additional pulpal insults of preparation impression, try in, and cementation may exceed the pulp's ability to repair. If adverse symptoms persist, the pulp should be extirpated followed by endodontic treatment. Success rates justify this prophylactic approach.

If the requirements of the final restoration or the excavation of extensive caries results in less than 2 mm of remaining dentin, the expectation of a severe inflammatory reaction is greater. If a pink spot in the cavity or a blush on the tooth appears (Figure 24.34A and B) during or after preparation, it is possible that the 2 mm remaining dentin barrier has been violated. The probability of complete inflammatory reversibility and healing of a noticeably hemorrhagic pulp are minimal. Considering that additional procedures are required to finish the crown, endodontics should be performed before continuing. If at any time a patient elects to forego endodontic treatment following your recommendations, the records must indicate that the option to extirpate the pulp followed by endodontic treatment was strongly suggested and refused. However, an educated patient will always make the choice that is in their best interest. So the dentist's job is to pave your way with words and not only educate about esthetics, periodontics, structure, and function but also educate about endodontics. After a pulpitis occurs, it is often too late to inform your patient about pulpal risks that can occur during esthetic/restorative dentistry.

This presents a moral issue as to whether a patient should be allowed to dictate the final treatment when the risk of fracture is involved or other severe pulpal events are possible or likely. The dentist must realize they can always refuse to continue, provide palliative but temporary treatment to assure comfort, and suggest the patient see another dentist. If chosen, this decision, discussion, and referral must be recorded and witnessed. Irrespective of the remaining dentin thickness, the restoration has to be bacteria tight if the pulp is to have a chance to survive the insult. Care has to be taken to ensure the bacterial seal, because if there is leakage the bacteria will penetrate under the

Figure 24.34 **(A)** Pink crown preparation 1 week following instrumentation. *Source:* Courtesy of Dr Harold R Stanley.

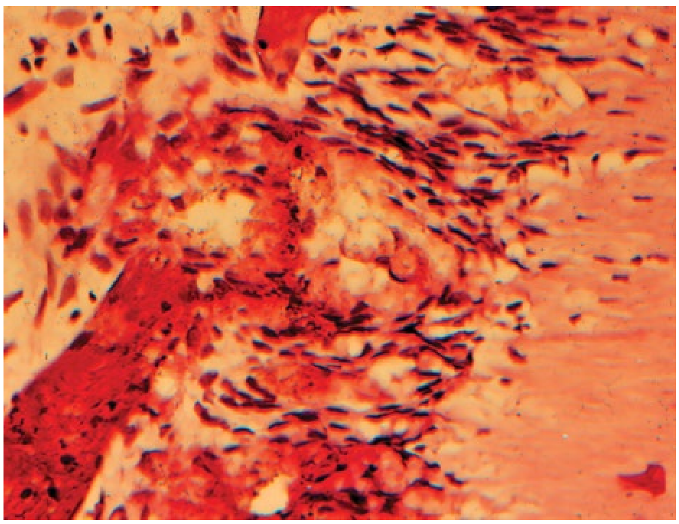

Figure 24.34 **(B)** Hemorrhagic pulp with extravasation of blood. *Source:* Courtesy of Dr Harold R Stanley.

Figure 24.35 Pulp exposure during crown preparation. Extirpation is indicated.

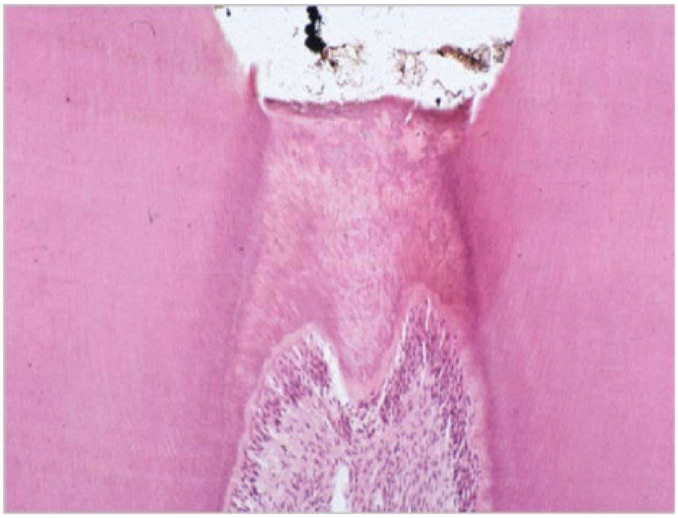

Figure 24.36 Dentin bridge following pulp capping with mineral trioxide aggregate (ProRoot MTA). Note thickness of bridge and absence of inflammation adjacent to the MTA. *Source:* Courtesy of Dr. Mahmoud Torabinejad.

restoration and through the dentinal tubules, initially cause pulpal irritation and eventually cause pulpal necrosis if the leakage is not stopped.

Pulp capping

Direct pulp capping in special situations has been shown to be safe, effective, and predictable. The ability of the pulp to repair when a mechanical exposure has been dressed with calcium hydroxide is well documented. The odontoblastic layer, once stimulated, forms a matrix that leads to the bridging of new dentin. This is because if the pulp were accidentally exposed by a dental bur (Figure 24.35) or by acute traumatic injury, then only the surface will show reversible inflammatory changes.[6] If the pulp exposure is under deep decay, there is good likelihood that the inflammation has affected a large portion of the pulpal tissue and even caused partial pulp necrosis. It is also important to remember that histologic pulpitis can be clinically asymptomatic, so the patient might not have any history of pain yet there can be a significant lesion in the pulpal chamber.[7]

Because of bacterial leakage risk into the pulp, direct pulp capping should only be considered with one-step restorations (i.e., amalgam or direct resin), and only when the patient is aware of the condition and the risk.

A thin calcium hydroxide mix of Dycal (acid resistant) is gently applied over the exposure. Care must be taken not to force the mix into the pulp because it could react adversely to an irritant like calcium hydroxide. However, healthy exposed tissue, unless insulted by pressure, contaminants, or leakage of the restoration, should respond favorably to the procedure. Successful pulp capping results have been reported by Torabinejad with mineral trioxide aggregate (Figure 24.36) (MTA pulp cap), ProRoot MTA (Tulsa/DENTSPLY).[8] Bogen et al. reported excellent results with MTA pulp capping in a two-visit procedure. The MTA was placed over an exposure, after caries removal, at the initial appointment.[9] At the following visit, the teeth were restored with a bonded composite. An analysis of the treated teeth after a 9-year observation period showed 97.76% favorable results based on radiographic appearance, cold testing, and subjective symptoms. However good the MTA may be for pulp capping, there is a downside to using it in a larger perforation as the material will probably need additional moisture in the form of moist cotton pellet placed on top of it to completely set. A larger perforation, therefore, will require an additional appointment to complete. More recently, Biodentine (Septodont), a calcium silicate-based capping material, has been suggested instead of MTA, because it completely sets in 15 min or less. It is important, though, to remember that most studies have not shown any significant difference in survival of the pulp when capped after accidental pulpal exposure with these three materials: calcium hydroxide, MTA, or Biodentine.

Pulp capping technique using direct acid etching and bonding has also been advocated. This concept is based on clinical observations but has little scientific data for support. Pameijer and Stanley studied the technique in a carefully controlled experiment on primates. Their results showed that pulp caps with acid etching and bonding agents produced 45% necrotic pulps and only 25% of the specimens developed dentin bridge formation,[10] whereas in the group pulp capped with calcium hydroxide only 7% of the pulps were necrotic and 82% of the teeth developed dentin bridge formation. Several more recent studies have all conclusively shown that, in human models, direct application of composite bonding or composite restorations on pulpal tissue is detrimental to its health.[11–13] Of note is that some animal studies have, at the same time, shown acceptable results. However, and because the animal evidence level is so low, these studies do not offer any treatment recommendation. It becomes obvious that if you elect to pulp cap, then calcium hydroxide, MTA,[14] or Biodentine are the materials of choice.

Even though there is a moderately good prognosis with pulp capping vital pulp exposures, the ease, predictability, and assurance of endodontic treatment certainly demands that the patient should be offered the option of root canal treatment when a definite exposure occurs; especially in teeth with fully formed apex. In teeth with pulp exposures and where multiple-step restorative procedures are contemplated (i.e., inlays, crowns, bridge abutments), nonsurgical root canal treatment is often the treatment modality of choice. Performing predictable endodontic outcomes prior to the prosthetic final cementation can obviate or avoid the aforementioned liabilities.

Stressed pulp

The dental literature is replete with methods and materials that demonstrate apparent success in preserving the integrity of the pulp, including the combination of sorghum molasses and English sparrow droppings.[15] But as time passes, subtle changes take place in the pulp, which create an unhealthy and unreliable tissue to depend upon as a sound foundation. This condition is often identified as stressed pulp. Abou-Rass considered the "stressed pulp" condition as an endodontic-restorative concept.[16] He believed it was of a clinical nature and not a histological entity. It should be considered a preexisting pulpal possibility in every restored tooth prior to subjecting the tooth to further restorative procedures. If the pulp is stressed, its ability to react favorably to the new insult will be diminished.

For example, a mandibular molar, although repeatedly restored, has remained without symptoms over a long period of time. A radiographic examination of the tooth demonstrates a deep occlusal amalgam and a large buccal composite restoration, recession of the pulp chamber, and narrowing of the root canals (Figure 24.37). Another example of stressed pulp is maxillary incisors that underwent concussion injuries and two previous crown preparations. Although there were no pulp exposures and there were minimal symptoms, intentional extirpations were performed because it was predicted the pulps would not survive another round of restorative procedures (Figure 24.38A–C). According to Abou-Rass's criteria, further insult to the affected (stressed) pulpal tissue would probably invite disaster. An intelligent decision would be elective endodontics, thereby intercepting potential problems.

Abou-Rass states that the pulp's ability to recover from "stressed" pulp is relative to:

- type of injury
- duration of injury
- physiologic age
- thickness of remaining dentin
- past trauma (impact injuries)
- repeated operative procedures.

When all of the aforementioned factors are examined and the patient's normal routine is changed because of vague symptoms, elective endodontic intervention should be considered. Another example of a stressed pulp is a patient with a maxillary anterior provisional restoration who required local anesthesia to remove the bridge 12 months after crown preparation and periodontal therapy because of pain from a maxillary central incisor tooth (Figure 24.39A). The combined dental procedure created additional stress and inflammation on the pulpal complex that was beyond its ability to repair. This scenario could have been avoided if elective endodontic intervention had been recommended to the patient.

Elective endodontics for prosthetic reasons

"No tooth or components of a tooth should be sacrificed if the prognosis of the remaining dentition can be improved by its retention."[17] Discussing elective endodontics vis-à-vis extensive restorations, Bohannan and Abrams felt that root canal therapy should he performed for[17]

- reorientation of occlusal planes;
- reduction of crown/root ratios;
- establishment of parallelism.

A clinician faces many such situations where the overall esthetic and restorative result could be enhanced if the pulp was extirpated and ideal root form was available. Unfortunately, the decision to perform the endodontics is often determined by issues other than what is beneficial to the patient; that is,

Figure 24.37 Mandibular molar with stressed pulp.

Figure 24.38 **(A)** Centrals incisor teeth after excavation of extensive caries. The pulps were not exposed.

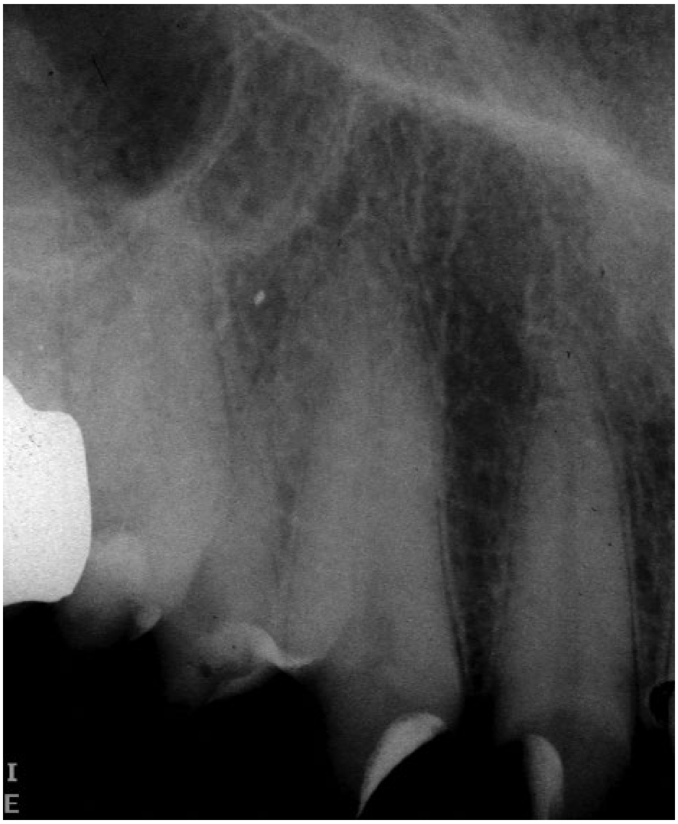

Figure 24.38 **(B)** Radiograph of same teeth. Note the minimal thickness of dentin adjacent to pulp chambers.

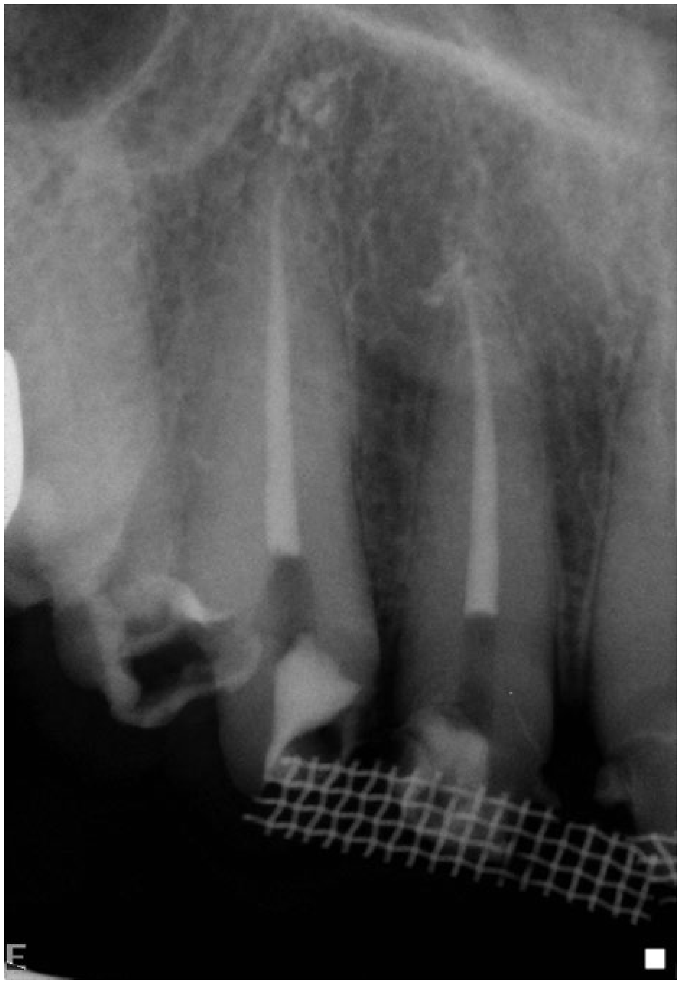

Figure 24.38 **(C)** Root canal treatment completed on the maxillary central incisors.

economics, time, lack of skill, or experience. Regardless, we must not lose sight that it is the duty of every dental diagnostician to evaluate and design each case with the goal of maximizing form, function, health, and esthetics. Therefore, when endodontic treatment enables the clinician to deliver the ideal restoration, why should the situation is compromised?

Endodontic treatment protocols

An understanding of basic endodontic principles and a clearly defined restorative plan are essential prior to beginning root canal treatment. The final esthetic result should not be compromised by an inadequate approach. Therefore, various phases of endodontic treatment will be examined to see how they may enhance or preserve esthetics rather than detract from it. Although this may seem repetitious, the risk of performing endodontic procedures for restored teeth must be explained and accepted by the patient, and all discussions should be documented and recorded before a procedure is attempted.

Rubber dam is essential

The use of the rubber dam in endodontics is mandatory for keeping risk of bacterial contamination to minimal and for patient safety.[18] Two studies have shown that 46% and 44% of general dentists do not routinely use a rubber dam when performing root canal treatment, although it is a deviation from standards of care.[19,20] It must be remembered that an untoward incident—that is, swallowing or aspirating a reamer or file when the rubber dam has not been used during therapy—leaves little doubt about legal liability. Other reports[20,21] showed that endodontists use a rubber dam 100% of the time. Crown lengthening may be required, prior to endodontic treatment, to expose sufficient tooth structure to accommodate the clamp. This is not a detriment since this procedure will be beneficial when establishing a finishing line for the restoration. "Even if the endodontically treated tooth is broken down and cannot be clamped, a rubber dam, regardless of the required modifications, should be used in all instances."[18]

The market offers over 100 different clamps, including wing, wingless, stainless, matte finish, and color coded, to cover a wide variety of clinical situations. One of the authors (NC) uses just three clamps in over 97% of his cases:

- #9 wing clamp—maxillary and mandibular anterior teeth and most crown preparations;
- #2 wing clamp—natural and restored premolar teeth;
- #4 wing clamp—natural and restored molar teeth.

Figure 24.39 **(A)** Maxillary central incisor teeth with a chronic inflamed (stressed) pulp.

Rubber dam clamps, when placed on ceramic restorations, have the potential to create problems.[22] In the study, porcelain-fused-to-metal (PFM) crowns, the clamps were placed on the crowns and left undisturbed for 1 h in the laboratory. They found

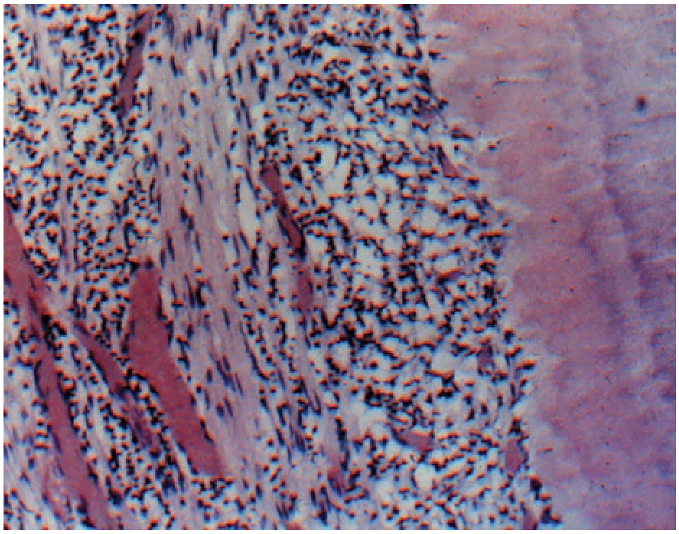

Figure 24.39 **(B)** A histological section of chronic inflammation, irreversible pulpitis, with round cell infiltration.

that, regardless of the crown margin design, all of the test samples displayed crazing of the porcelain in the area of the beaks of the clamp. Additional forces on the porcelain in clinical situations as the clamp is inadvertently moved during treatment would most certainly increase the probability of crazing. This problem could be eliminated when the teeth with questionable pulpal health are endodontically treated prior to cementation of the crown.

Since over 40% of root canal treatment is performed through existing restorations, the following alternative methods of rubber dam application are suggested for ceramic crowns to minimize potential problem.[2]

Alternative methods of rubber dam for ceramic crowns

- *Floss or Wedjets cord ligation.* Dental floss or rubber cord, Wedjets (Hygienic) (Figure 24.40A), can be used to retain a rubber dam when isolating a single tooth. Wedjets is a

Figure 24.40 **(A)** Wedjets; three sizes (Hygienic).

Figure 24.40 **(B)** Wedjets stabilizing the rubber dam and aiding in the isolation of a maxillary central incisor.

stretchable cord that is made from natural latex. The cord, available in three sizes, is placed like dental floss to hold the dam in place. Wedges can be used in conjunction with dental floss or Wedjets once the dam is in place. For convenience, it is recommended at least one tooth on either side of the treated tooth be included in the isolation (Figure 24.40B).

- *Cushee rubber dam clamp cushions (Practicon)* Cushees are soft silicone cushions that fit over the jaws of the standard steel clamps. The jaws of the clamp do not come in contact with the gingiva, tooth structure, or restoration. Patient comfort is increased and potential damage to ceramic restorations is decreased. They are available in two forms: yellow for anterior and bicuspid clamps (Figure 24.41A and B) and blue for molar clamps (Figure 24.41C).
- *Ingenuity/multiple teeth isolation* When dealing with splinted units, ingenuity is an important part of the problem-solving equation. This approach recommends the clamps be placed on unrestored adjacent teeth. Three or more contiguous holes are punched in the dam; the rubber is stretched over all the teeth to be isolated; and the most posterior tooth is clamped first. Then, the anterior tooth is addressed with the clamp placed in reverse with its bow facing anteriorly. The tooth to be treated remains unclamped and access is unrestricted (Figure 24.42). Once the dam is in place, Oraseal Putty (Ultradent) may be compacted around the gingival margin of the crown to block off any fluid leakage. When the entire arch is restored with ceramic restorations, you are faced with a difficult situation and must improvise to control esthetic damage. If there are individual crowns, avoid placing rubber dam clamps on any of the anterior or first premolar teeth. Surface damage to the porcelain when risked should be confined to the second premolar and molar teeth, which are less visible. Cushees or Wedjets should be used to protect the restorations.

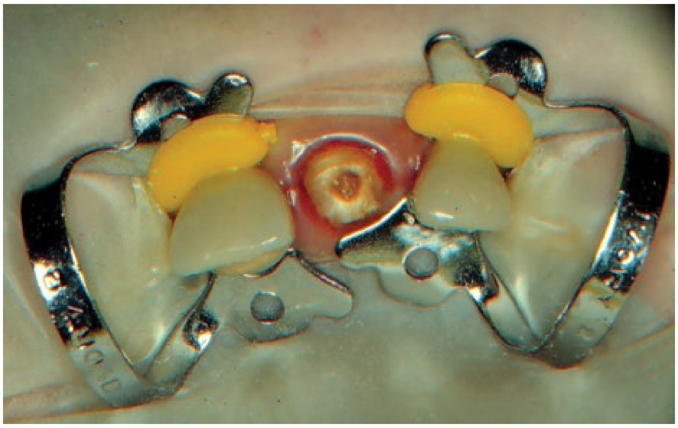

Figure 24.41 **(A)** Cushee rubber dam clamp cushions (Practicon) isolating multiple anterior teeth.

Figure 24.41 **(B)** Cushee rubber dam clamp cushions (Practicon) isolating maxillary premolar.

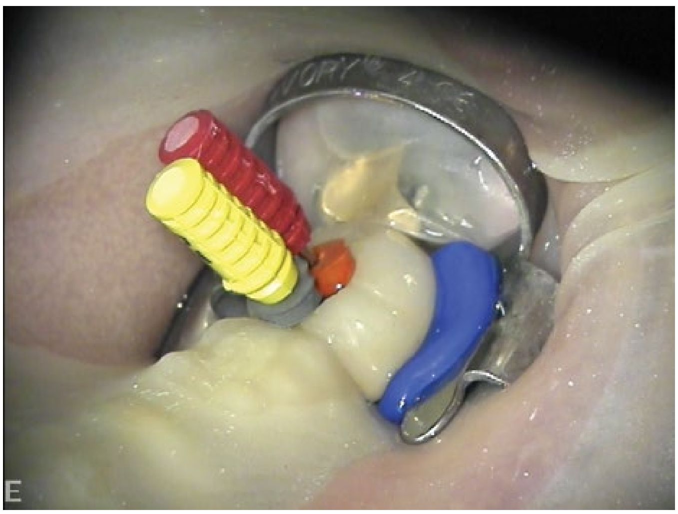

Figure 24.41 **(C)** Cushee rubber dam clamp cushions (Practicon) isolating mandibular molar.

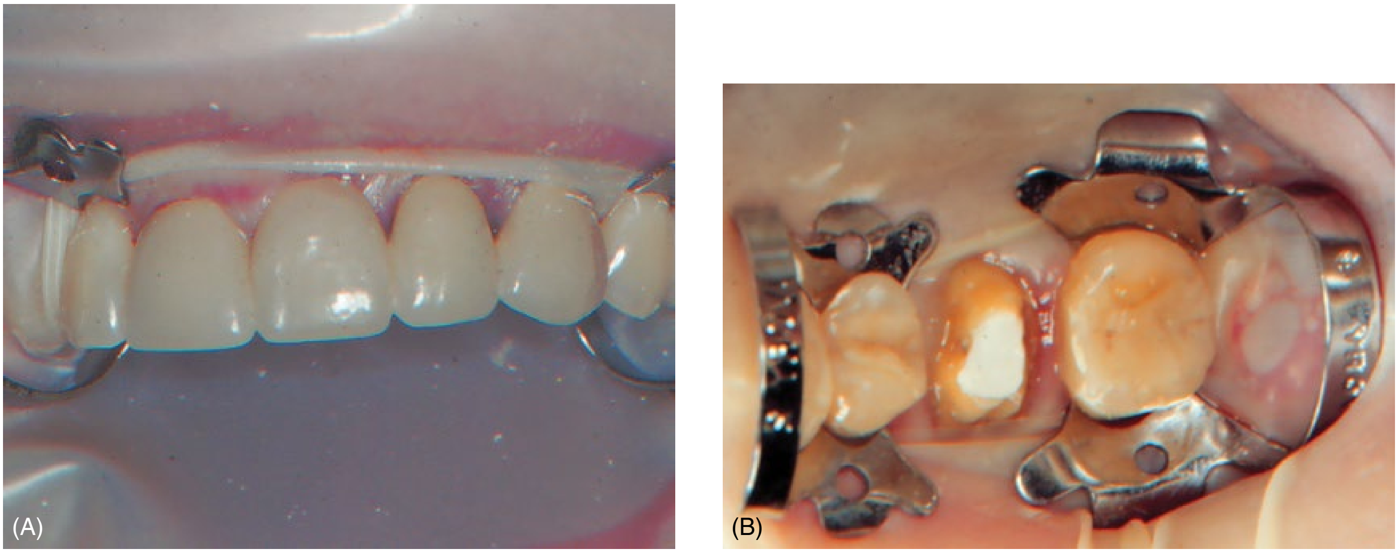

Figure 24.42 **(A, B)** Rubber dam isolation of multiple teeth.

Again for contamination and patient protection, as well as medicolegal reasons, endodontic treatment should never be attempted without rubber dam isolation. Nonlatex dam is available for those patients with known latex allergies. Apprehensive patients may be accommodated with use of Optra Dam Plus (Figure 24.43) (Ivoclar-Vivadent) or Insta-Dam Relaxed Fit (Zirc). It has a built-in frame and is smaller than the standard size of 5″ × 5″ rubber dam. It still affords similar protection and isolation.

Access cavity preparation

A carefully planned and well-executed access cavity preparation should maximize retained tooth structure, minimize weakening the tooth, provide for unobstructed visibility, and allow for straight-line entry into all of the root canal systems (Figure 24.44).

Entering the pulp chamber requires definitive knowledge of tooth morphology, the specific intricacies of the tooth to be treated, and proper instrumentation. As previously discussed, recent radiographs, taken with a paralleling device, ensuring minimal distortion, should be studied prior to picking up the handpiece. Two preoperative films exposed from different horizontal angles to give better information should be part of the pretreatment routine. Bitewing images are recommended for posterior teeth. The radiographs depict location of the chamber, presence or absence of calcification, number of roots and canals, and the relationship of the incisal or occlusal surfaces to the axial line of the root.

Figure 24.43 Optradam (Ivoclar).

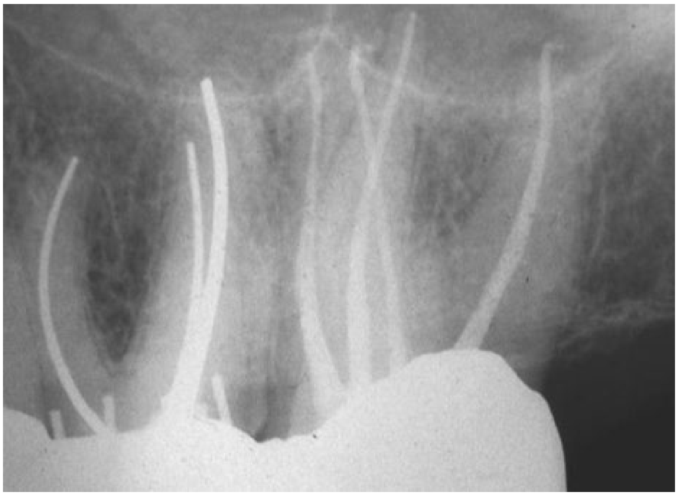

Figure 24.44 Straight-line access allowed for visualization of all four canals in the maxillary molar teeth. (First molar courtesy of Dr Hyman R Baer; second molar courtesy of Dr Stanley M Baer.)

Morphologically, the access cavity takes the shape of the underlying pulp chamber (Figure 24.45A–C). Variations in size and shape of the pulp chamber take place as the result of calcification resulting from caries, operative procedures, restorations, occlusal wear, abrasion, and so on. Therefore, by nature, the access cavity in a youngster's nonrestored tooth (Figure 24.46) would be larger than that of a similar tooth with multiple restorations in an older person (Figure 24.47).

Magnification is essential in searching for canals when calcification has obliterated the chamber. Magnification in conjunction with an auxiliary light source reduces the frustration of finding the canal orifices.

The access opening must be large enough to allow:

- visualization of the entire chamber;
- location of the root canal orifice(s);
- removal of all existing decay.

Preparation and equipment

The dentist should be aware that a tooth with a crown may be very different from the natural tooth it covers, both in regard to size and shape and to occlusal plane (Figure 24.48). A thorough examination of the preoperative radiograph(s) as well as careful periodontal probing of the tooth will provide important morphological information and should be part of the pretreatment process. It is customary to reduce the occlusal table if the final restoration will involve full coverage. This will provide flat surface for canal length measurement during the root canal treatment. It will also decrease the probably of postoperative discomfort since the tooth will not be in occlusion.

Natural tooth structure should be protected from heat during the access cavity preparation. Studies have shown deleterious crazing and cracking occurs in the enamel and dentin when access cavities are prepared dry. Regardless of the fact that the pulp will be extirpated, water should be used to cool both the bur and the tooth during this procedure.

Removal of existing occlusal and proximal restorations plus the decay should be completed prior to entering the pulp chamber. This will be the first step in establishing a bacteria-free environment. To facilitate canal orientation, some practitioners prepare the access and locate the orifices of the canals prior to placing the rubber dam. It is important, as always, to place the rubber dam before introducing an endodontic file into the tooth to eliminate the possibility of the aspiration or ingestion of the file.

Some manufacturers market endodontic access kits that include the instrumentation needed for this portion of the treatment:

- Endo Access Kit (Dentsply Tulsa Dental Specialties);
- CK Diamond Endodontic Access Kit (SS White);
- LAAXESS (SybronEndo).

Penetration and funneling are the two phases of an endodontic access cavity preparation, whether in natural tooth structure or teeth with full-coverage restorations. Penetration can be accomplished with high speed from various manufacturers: round burs #2 or #4 or round-ended fissure burs #1558.

Figure 24.45 **(A)** Access cavity outlines reflect the shape of the pulp chamber: maxillary canine. **(B)** Access cavity outlines reflect the shape of the pulp chamber: maxillary premolar. **(C)** Access cavity outlines reflect the shape of the pulp chamber: mandibular premolar.

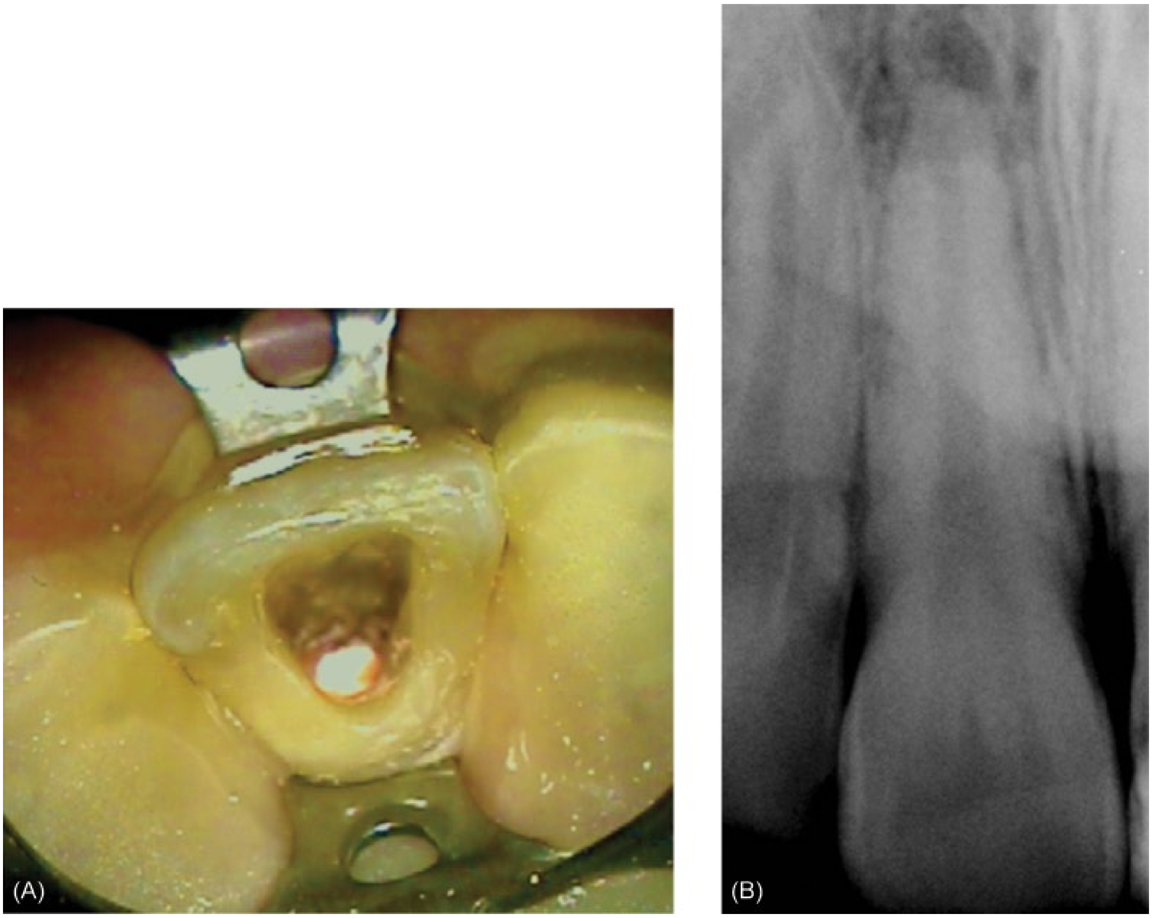

Figure 24.46 **(A, B)** Access cavity in a traumatized unrestored maxillary central incisor, 16-year-old person.

Round diamond burs are used for penetration in ceramic restoration. If decay is present in the chamber it can be removed with #2, #4, or #6 long-shank burs at low speed. A long-shank endodontic excavator #33 L is also very useful in the process.

Funneling is accomplished with tapered fissure diamonds or carbide fissure burs. A number of the diamonds have been specifically designed with noncutting tips to reduce the possibility of perforating the floor of the chamber while flaring the axial walls of the chamber:

- Endo-Z® bur (DENTSPLY Maillefer);
- LAAXXESS Diamond Bur (SybronEndo);
- Endo Safe End ESE018, ESE014 carbide, and CK Endo Access bur (SS White).

Tapered diamonds should be used for finishing access walls.

Various types of restored teeth

Teeth with partial or full-coverage restorations present additional obstacles in gaining entry into the pulp chamber. Gold, nonprecious metal, ceramo-metal, aluminum oxide cores with porcelain buildups, lithium disilicate and zirconium cores, and or all-zirconium crowns restorations require different types of instrumentation, burs, than natural tooth structure does.

Gold crowns

New transmetal burs, Transmetal Bur 19 mm (DENTSPLY Endodontics), are recommended for penetrating through gold. The sharpness of a new bur will maximize penetration and minimize the tendency to skip or skid. The bur is of similar shape to the #1558 used for access cavity preparation in natural tooth structure, but they are designed for efficient metal cutting. Electric-driven handpieces also facilitate minimal vibration during access preparations.

Ceramic restorations

Christensen found shallow microcracks in all samples tested after endodontic access cavities preparation. "… research results showed both a trend in glass ceramics (IPS Empress) and veneered ceramics (zirconia based) being more prone to cracks extending into body of restoration from endo access than monolithic ceramic materials (BruxZir, Lava Frame, Lava Ultimate, and IPS e.max CAD)."[23] One of his conclusions was, "Making access through a restoration thickness of less than 1 mm carries a greater risk of producing micro cracks

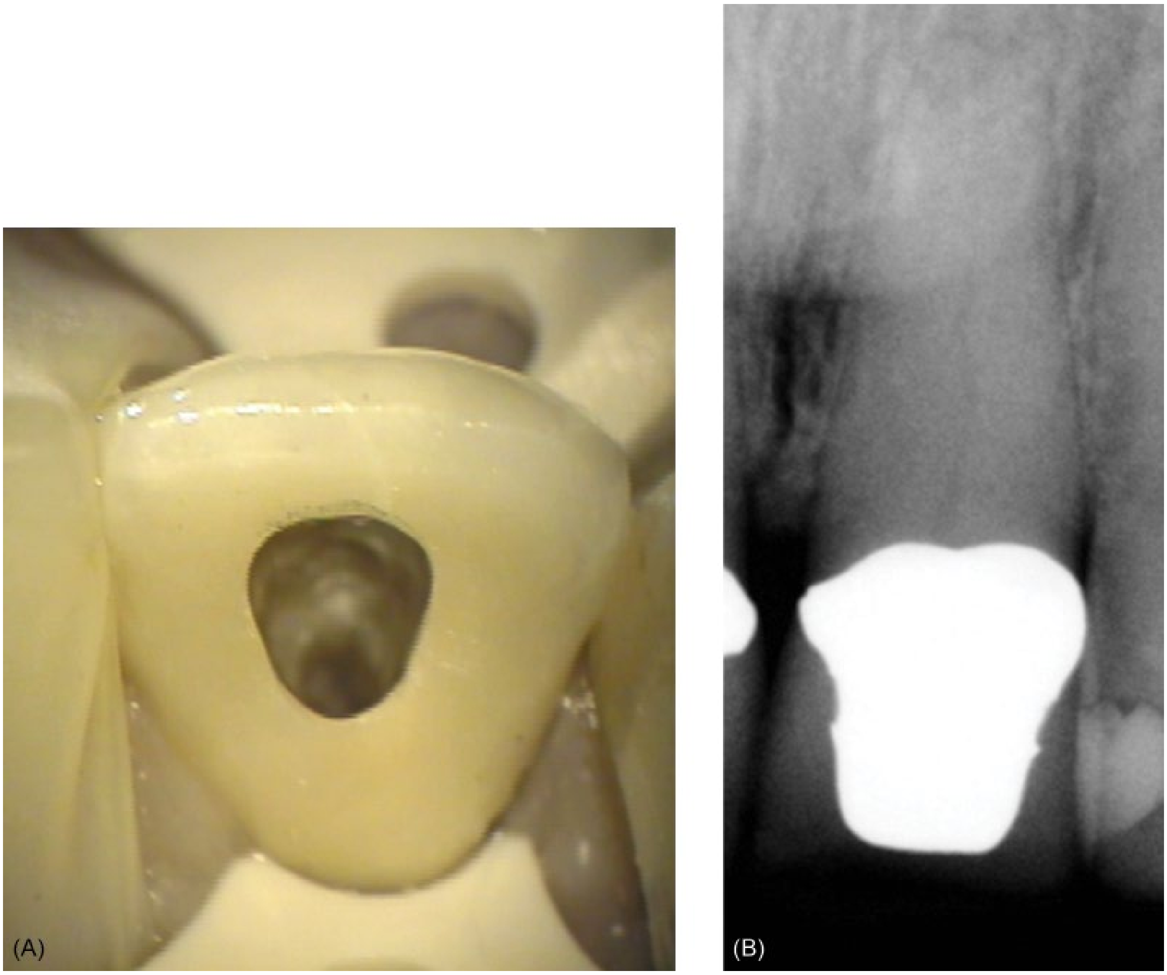

Figure 24.47 **(A, B)** Access cavities through PFM crowns in a middle-aged male.

which could propagate during service." To reduce this possibility, he suggested completing endodontic treatment before crown cementation. Since the need for treatment is not always predictable, Christensen recommends 1.5 mm or more of occlusal reduction when preparing the teeth for ceramic restorations. When endodontic treatment is needed after cementation, one-time-use diamonds, copious water spray, light pressure, and an electric handpiece are recommended to minimize cracking.[23]

Figure 24.48 Mesially inclined mandibular second molar. Because of the tilt toward the mesial, the direction of the bur should be angled toward the distal to avoid perforation during access cavity preparation.

Aluminous porcelain

Medium- or fine-cut diamonds accompanied by a water spray should be used to cut through porcelain. Carbide burs will generate incredible heat and the cutting action of the bur will significantly increase the possibility of porcelain failure.[24]

The dentist has the choice of the following round diamond stones:

- Brassier 801-016
- Premier 120 F
- Gnathos 801-016
- Premier 1116.8 round-end fissure diamond.

Disposable diamonds are efficient when cutting ceramic restorations. Being new, they tend to reduce crazing or cracking in the restoration and generate less heat.

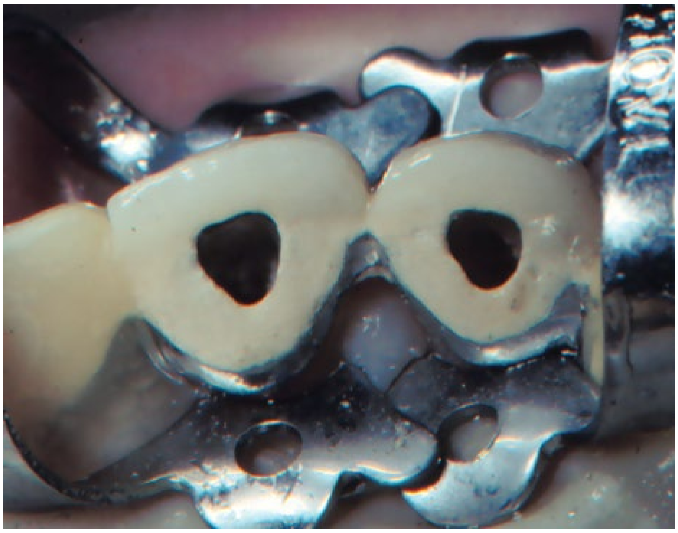

Figure 24.49 **(A)** Outline of access cavity traced through porcelain with a diamond stone.

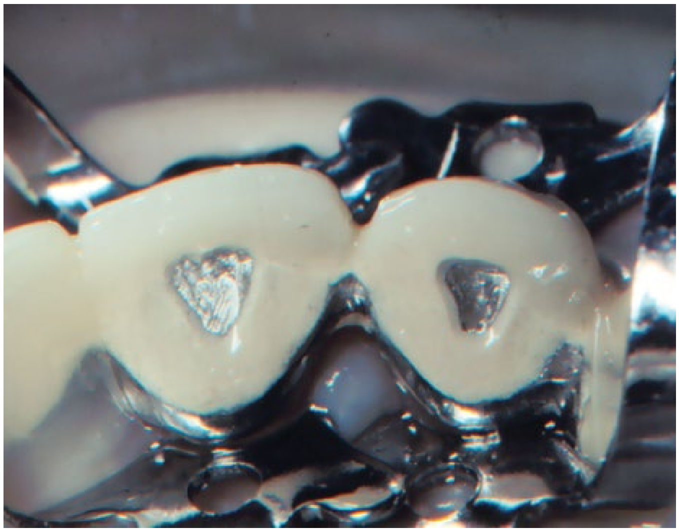

Figure 24.49 **(B)** Penetration and funneling of the access cavities.

Porcelain-fused-to-metal crown

A round diamond stone (Brasseler 801-016, Premier 120 F or Gnathos #801-016) accompanied by a copious water spray is best for the porcelain entry. Once the metal casting is met (Figure 24.49A), a classic access cavity is traced in the porcelain with the diamond stone. Penetration through the metal and dentin into the pulp chamber (Figure 24.49B) is accomplished with a new Transmetal Bur (DENTSPLY Maillefer). Carbide burs, cutting through metal, rapidly dull and should be discarded when they lose their efficiency. The funneling can be accomplished, as previously described, with flared fissure nonend cutting diamonds.

Ceramic crowns: cast glass–all-ceramic crowns (aluminum oxide)–pressed ceramics (lithium disilicate)

A laboratory study has shown that high-speed diamond instrumentation with water spray is efficient when cutting through Cerastore crowns.[25] The same study also indicated carbide burs used under similar conditions were inefficient. Years later, the ceramic technology has produced many new choices for use in patient care. However, the round diamond is still the choice for initiating the access cavity procedure.

Zirconia crowns

All-zirconia crowns or zirconia-core crowns have an unusual hardness and are difficult to cut through for removal or access cavity preparation. In preparing other ceramic crowns for endodontic access, the progress of cutting through the material can be observed in a matter of seconds. With zirconia, one questions the sharpness of the diamond stone or the rotation frequency of the handpiece when there is no progress in a reasonable period of time. It is not the diamond stones and handpieces that are the problem; it is the hardness of the zirconia that makes it difficult to cut. Research has shown zirconia is up to 10 times harder than other ceramic materials that we usually encounter. Therefore, a new classification of diamonds was developed by the dental manufacturing industry. The same preparation sequence is used for access with zirconia restorations: penetration, round diamond burs and funneling, and tapered fissure diamonds stones.

Zirconia cutting diamonds penetration funneling:

- Premier Dental round 125Z, tapered fissure 703.8 krz;
- Axis Dental round Z2801-18, tapered fissure Z856-18;
- Komet pear ZR 379 m, tapered fissure ZR379m.

If you inserted the zirconia crown and will be doing the endodontic treatment, you are ahead of the game and will be able to select the zirconia-appropriate diamond. If you are going to refer the patient to an endodontist, please let them know the crown is zirconia, so they will have the proper diamonds available. If you are doing the endodontic treatment for the patient and do not know what the type of ceramic material, try your usual and customary disposable diamond on the tooth. If there is no progress, in a reasonable period of time, assume the ceramic is zirconia and select a zirconia cutting diamond for the access cavity preparation.

Ceramic inlays and onlays

A twofold problem presents with these restorations vis-à-vis access preparation: fragility of the material and design of the restoration. Fracture and dislodgement are potential sequelae when cutting into these restorations. To avoid the problem, one must be certain of the pulpal health prior to selecting these restorations. If, however, faced with endodontic therapy through these restorations, the patient must be advised of the possible necessity of replacement. Once the risk is accepted, high-speed diamond instrumentation with copious water and minimal pressure will minimize the potential of rendering the restoration useless.

Etched cast restoration

Any tooth with a questionable pulp should be endodontically treated prior to placing an etched cast restoration. Frequently, this restoration is used to replace an anterior tooth that has been lost as a result of trauma. It is reasonable to assume the adjacent teeth may have sustained injury as well. Therefore, it is imperative that the pulp and periapical ligament status be ascertained before bonding the restoration in place. However, if faced with root canal therapy, the access cavity must be kept as small as possible. The likelihood of weakening the bond is great. In most cases, a new #2 or #1558 carbide bur and a copious water spray will minimize heat and reduce the vibration, which is the cause of debonding. Occasionally, it is more practical to prepare the access cavity through the labial surface, particularly when dealing with lower incisor teeth (Figure 24.50A–C). The distinct advantage of direct access without disturbing the casting is immeasurable. The opening can then be repaired with a light-cured composite resin (Figure 24.50D). Cosmetically, the lip and smile line should be considered before using this approach. Communicating the benefits of this approach and having the patient accept the technique before proceeding is essential.

Crown retention after endodontic treatment

In addition to esthetic compromises that occur as a result of access preparation, crown retention also becomes questionable. An in vitro study by McMullen et al. showed that the retentive value of a PFM crown was decreased 60.17% following access cavity preparation.[26] In a follow-up study, McMullen et al. showed that the retentive value of the crown could be increased 237% over its original value if the crown was recemented with poly carboxylate cement and the access cavity filled with amalgam.[27] However, it is rare that a crown or a bridge is removed after final cementation to allow for endodontic therapy.

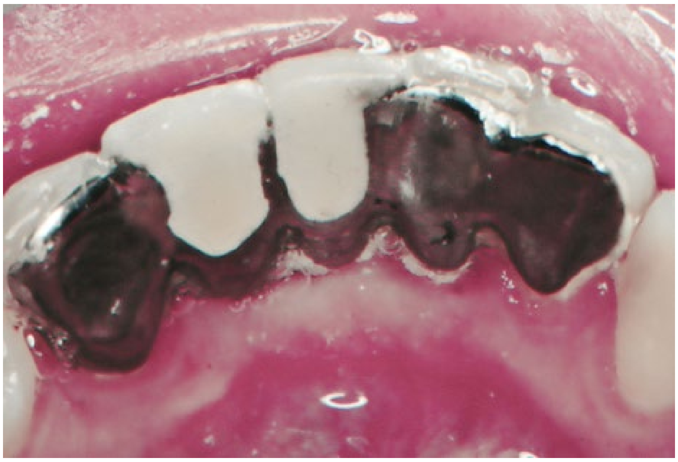

Figure 24.50 **(A)** Access alternative for an etched five unit cast bridge.

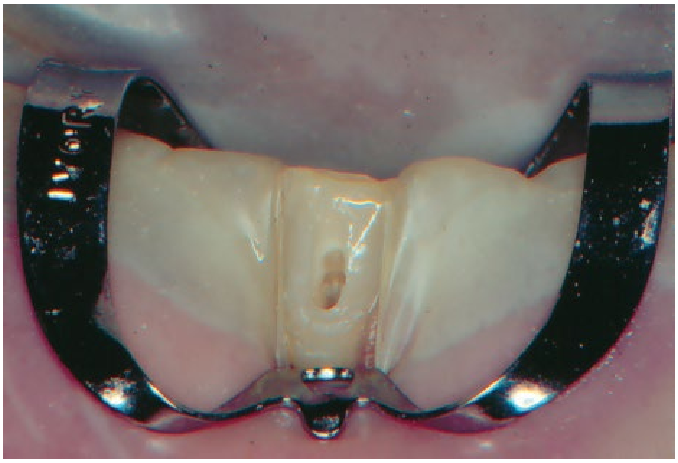

Figure 24.50 **(B)** Access cavity prepared on the labial surface.

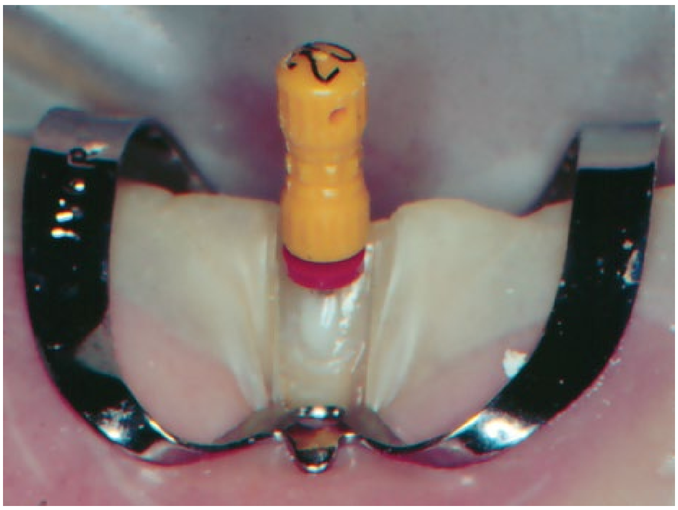

Figure 24.50 **(C)** Measurement file in place.

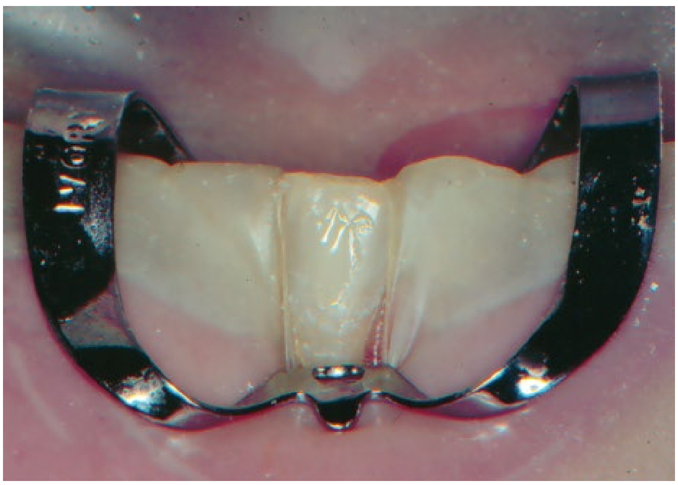

Figure 24.50 **(D)** Access opening repaired with composite resin.

Figure 24.51 Endodontic therapy completed prior to fabrication of final castings on four mandibular anterior teeth with questionable pulpal health.

Unfortunately, retentive value following the restoration of the access cavities with amalgam alone has not been studied. With this in mind, repairing an access cavity with amalgam after endodontics may not restore it to an acceptable strength or esthetic level. This affirms the need to perform elective endodontics whenever a risk exists prior to the fabrication and cementation of a crown(s) (Figure 24.51).

Removable partial denture abutments

When faced with unusual situations—for example, occlusal rests and attachment receptacles in removable partial denture abutments—innovation enters the picture. To preserve their usefulness, attempts should be made to keep away from the attachment area. The final access preparation outline should be finished near the attachment but not encroach on it. The shape of the preparation may be decidedly atypical, but the preservation of the mechanical lock integrity will be retained.

Instrumentation/debridement

The goal of this phase of endodontic treatment is to eliminate all microorganisms from the canal system by completely removing organic, inorganic debris, biofilm, and smear layer. The objective is to accomplish cleaning and shaping the root canal system yet maintain the constriction of the canal apex and the funnel shape of the coronal aspect. This canal design will accommodate condensing instruments during the gutta-percha compaction yet confine the filling materials within the canal. Thorough debridement and hemorrhage control will not only insure endodontic success but also prevent discoloration of the crown. This is an extremely important esthetic consideration. Crown discoloration can stem from blood entering the dentinal tubules followed by latent red blood cell degeneration. Severe pulpal bleeding usually occurs when an acutely inflamed pulp is not entirely removed during extirpation. Once an accurate measurement is ascertained, further debridement of the canal and subsequent shaping coupled with copious irrigation with 2.5% sodium hypochlorite (NaOCl) will normally control hemorrhage. If, on occasion, the flow continues full strength, 6.25% NaOCl should be used as the irrigant. The solution should remain in the chamber for periods of 5–10 min.

Today's suggested medication in teeth with vital as well as necrotic pulps is calcium hydroxide, which does not cause tooth discoloration. However, clinicians still encounter discolored endodontically treated teeth when beechwood creosote, silver nitrate, azochloramid, or paraformaldehyde paste has been used as a treatment agent. Their removal as well as bleaching procedures may return the crown to its optimum color, but the duration of its esthetic improvement may be short. The patients should be advised of this fact.

Nickel titanium has enabled mechanical radicular shaping after a successful glide path is manually prepared. Mechanical rotary shaping has allowed dentists to consistently design endodontic preparations that can be predictably sealed using a variety of 3D obturation techniques.

Sealing the canal system

The final phase of treatment and the key to successful endodontics is the sealing of all portals of exit from the root canal system, including the access cavity. Here again, esthetic consideration revolves around discoloration of filling materials. A nonstaining root canal cement—that is, Roth #801 (Roth International, Inc., Chicago, IL), U/P Root Canal Sealer (Sultan Chemists Inc., Englewood, NJ), Thermaseal Plus (Tulsa/DENTSPLY), or RealSeal Sealer (SybronEndo, Anaheim, CA)—provides the necessary sealing capabilities when used in conjunction with gutta-percha. If silver precipitate is used in the cement, the chamber must be thoroughly cleaned before the esthetic access restoration is placed. The canal walls are coated with the cement and then gutta-percha or Resilon (RealSeal SybronEndo, Anaheim, CA) that is deformed by heat, pressure, or chemicals acts as a piston to drive the cement to the outer recesses of the prepared dentin walls. This results in the formation of a cement–dentin interface, which is necessary to produce successful results.

The canals should be filled completely and confirmed by radiographs. The excess gutta-percha and or Resilon and root canal cement should be removed 1–2 mm apical to the cervical line to prevent discoloration (Figure 24.52) in periodontally involved teeth where longer crowns are planned; the root filling materials should be removed to the bone level. Remnants of the cement may be removed with alcohol. A tooth-colored restorative material—that is, composite resin or glass ionomer cement—may be used to fill the rest of the canal and chamber when a post and core are not indicated.

Figure 24.52 Gutta-percha root filling cut back 3 mm apical to the cervical line to prevent discoloration. This space will be restored with composite resin. The adjacent tooth will be restored with a crown.

Figure 24.53 **(A)** Thirty-five years post root canal therapy. Teeth asymptomatic and no radiographic changes.

The coronal restoration should be placed as soon as possible after completion of the root canal treatment if it is not placed at the time when the canal(s) are filled. There is now building evidence that the coronal restoration is as important, if not more important, in microbiologically sealing the root canal system as the root canal obturation material (Figure 24.53A and B). Ray and Trope evaluated the radiologic quality of both coronal and canal obturations. They demonstrated that a tooth with good coronal and root seals had the best rate of absence of periapical lesions (91.4%).[28] Good restoration resulted in significantly less incidence of periapical lesions than good endodontic filling (80% versus 75.7%). Poor restoration resulted in significantly more periapical lesions than poor endodontic fillings (48.6% versus 30.2%). A few years later, a study by Tronstad et al. further confirmed that good endodontic filling with quality access restoration gave the highest success rate.[29]

A proper finish of both the temporary and the final filling material is essential so as not to irritate the patient's tongue or soft tissue. Thirty-bladed finishing instruments (ETUF, OS 1, and Brasseler) are perfectly suited to provide the smoothest margins for both the material and especially the marginal remnants of the existing restoration. Gold restorations are particularly susceptible to rough edges that need finishing with the 30-bladed instruments.

Coronal seal background

Three-dimensional obturation of the root canal system has long been the essential goal of successful endodontics. Obturation is, in fact, the third point of the time-tested endodontic triangle: (1) disinfection, (2) instrumentation, and (3) obturation.

Three-dimensional obturation refers to obturation of all foramina, which includes the endodontic access cavity, which is by far the largest bacterial entrance for root canal system recontamination. And yet a proper access endodontic seal is often neglected and is ultimately time sensitive and quality sensitive when measuring predictability (Figure 24.54). For

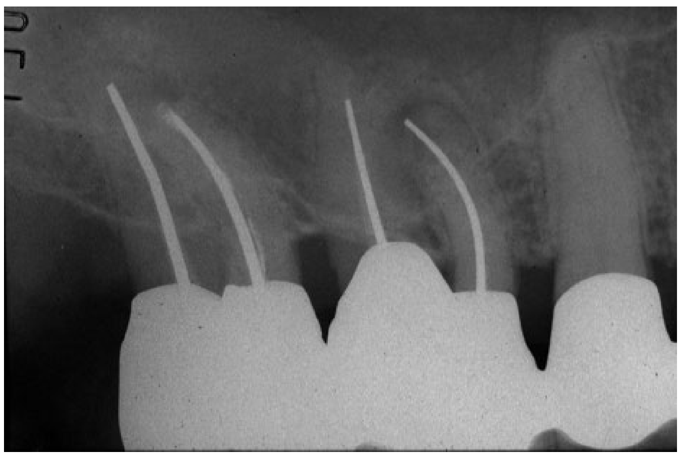

Figure 24.53 **(B)** Three years after distobuccal root resections and new castings. Periapical lesions developed around the mesiobuccal roots. During the extended treatment phase, the coronal ends of the silver points were periodically exposed to saliva.

Figure 24.54 **(A)** Coronal access is the largest portal of exit needed to seal for predicable endodontic success. Lingual view of mandibular anterior tooth demonstrating microleakage at periphery of access cavity repair.

Figure 24.54 **(B)** Coronal access is the largest portal of exit needed to seal for predicable endodontic success. Periapical image of gutta-percha cone tracing sinus tract emanating from radiographic lesion of endodontic origin.

example, it is not appropriate to finish the endodontic treatment with cotton in the access and Cavit (3 M ESPE) or some other temporary access coverage. If the Cavit breaks down or salivary microleakage occurs prior to restorative, the endodontic seal is recontaminated, which prevents healing or creates a new lesion of endodontic origin.

West (clinical study, unpublished data, 2004) found approximately one-third (37%) of the consecutive 100 full-coverage molars with irreversible pulpitis or necrotic pulps with or without lesions of endodontic origin demonstrated marginal microleakage using caries indicator paste (Figure 24.55).[30] About two-thirds (67%) of consecutive 100 full-coverage molars with endodontic "failures" demonstrated marginal microleakage using caries indicator paste. The conclusion was "as much attention should be given to a quality access seal and repair as the 3D obturation of the entire root canal system which includes both radicular and coronal portals of exit." In addition to the quality of the coronal seal, focus should be made to make access cavity repair as "invisible" as possible by blocking out metal and choosing composites that mimic the surrounding porcelain.

Restoration or removal of the endodontically diseased tooth

The management of the endodontically diseased tooth in the esthetic zone has changed dramatically over the past two decades. Twenty years ago, most dentists had fewer endodontic technologies available to them and endodontists compared with what is available today.[30] In addition, implant technology was not yet a proven esthetic choice for replacing the diseased endodontic tooth. Endodontists would argue many teeth are experiencing wholesale, unnecessary, and inappropriate removal, particularly

Figure 24.55 **(A)** Example of caries indicator paste, which is helpful in identifying mircroleakage and/or caries.

Figure 24.55 **(B)** Caries indicator paste observed in access cavity wall staining microleakage sites along junction of crown and crown preparation.

if the endodontically diseased tooth is not healing. Implant decisions are often based on the assumption that the tooth already has “two strikes” against it and that removal and implant placement is a biologic and cost-effective better choice. Which side of the argument is correct? What guidelines should be followed to present the patient with accurate options to make the decision that is in their best interest?

When making the decision to restore or remove a tooth, three important areas must be considered: biology, structure, and esthetics.

Two important questions must always be asked:

1. Is the tooth restorable?
2. Can the dentist create the endodontic seal?

Restorability guidelines

- 1.5–2.0 mm facial and lingual ferrule
- 1 mm ferrule wall thickness
- 2–2.5 mm biologic width
- crown/root ratio at least 1 : 1
- third, third, third

where the latter refers to desired diameter of radicular endodontic preparation. The mesial–distal width of the preparation should not exceed a third of the width of the root at the level of the cementoenamel junction (CEJ).

Endodontic seal guideline

The guideline for the endodontic seal is best summarized by the rationale for endodontics: Any endodontically diseased tooth can be predictably saved if the root canal system can be nonsurgically or surgically sealed and the periodontal condition is healthy or can be made healthy. In the case where a lesion of endodontic origin persists after treatment, the dentist must determine which approach, nonsurgical or surgical retreatment option, is best for the patient. Although many treatment plans are obvious, the dentist needs guidelines for teeth that may be in the gray area of a nonsurgical versus surgical endodontic seal.

The following five determinants will facilitate the thought process for dentist and patient (Figure 24.56A):

1. *Obturation.* If obturation is poor, nonsurgical retreatment offers the most predicable endodontic seal (Figure 24.56B).
2. *Lesion of endodontic (LEO) location.* If LEO is concentrated periapically, then a surgical seal may be the patient’s best choice (Figure 24.56C).
3. *Structure.* If disassembly or previous endodontics, then surgical seal may be less invasive to the existing dentistry (Figure 24.56D).
4. *Coronal leakage.* Evidence of coronal leakage requires nonsurgical endodontic repair of undersealed root canal system and structural repair (Figure 24.56E).
5. *Esthetics.* If surgical seal is considered, dentist must take precautions to avoid a resulting gingival “black triangle” or scarring, particularly in a patient with a high smile line (Figure 24.56 F).

Bleaching

Bleaching endodontically treated teeth has been a successful part of the endodontic treatment armamentarium. When indicated, the procedure should be instituted at the completion of the root fillings. The results are satisfying and the patient can readily see the change in tooth appearance.

Unfortunately, a liability associated with bleaching, external root resorption, has been noted by us, has appeared in the literature, and has been demonstrated in research studies.[31] External resorption is the result of an injury to and a subsequent reaction in the periodontal ligament. The use of 30% hydrogen peroxide (Superoxol) or heat has been demonstrated to increase the probability of resorption.[32] Microscopic opening in the dentinal wall in the cervical region, which is not covered by enamel or cementum, may allow for the penetration of the bleaching solution to the periodontal ligament. This morphologic abnormality

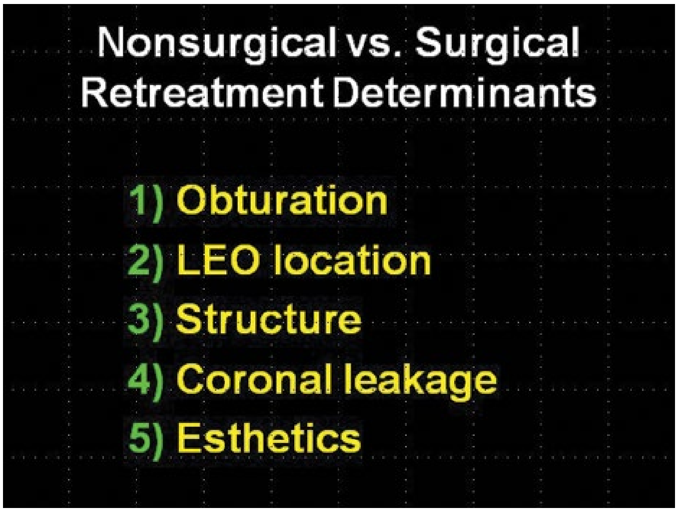

Figure 24.56 **(A)** Decision thought process for the five endodontic determinants that guide endodontic nonsurgical versus surgical retreatment.

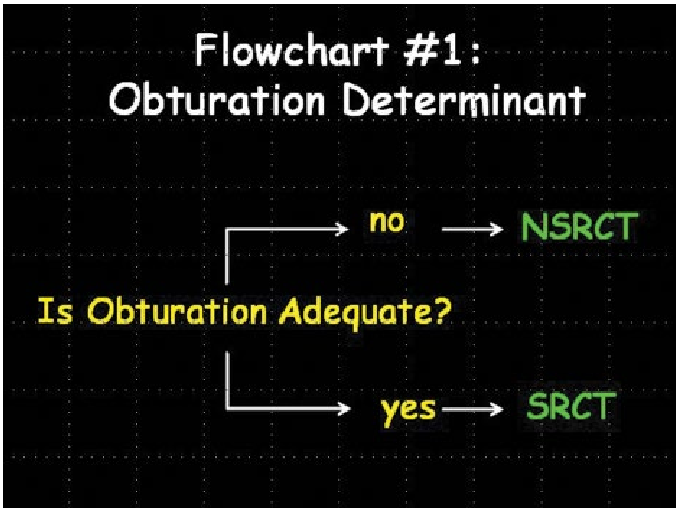

Figure 24.56 **(B)** *Obturation.* If obturation is poor, nonsurgical retreatment offers the most predictable endodontic seal. NSRCT: nonsurgical root canal treatment; SRCT: surgical root canal treatment.

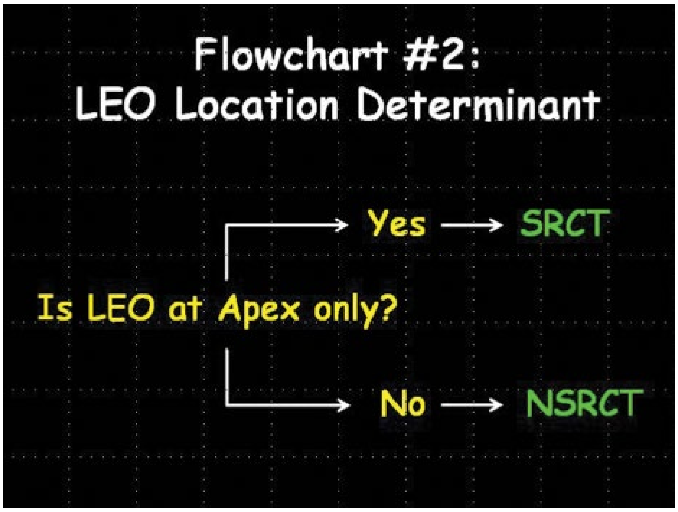

Figure 24.56 **(C)** *LEO location.* If LEO is concentrated periapically, then a surgical seal may be the patient's best and most efficient choice.

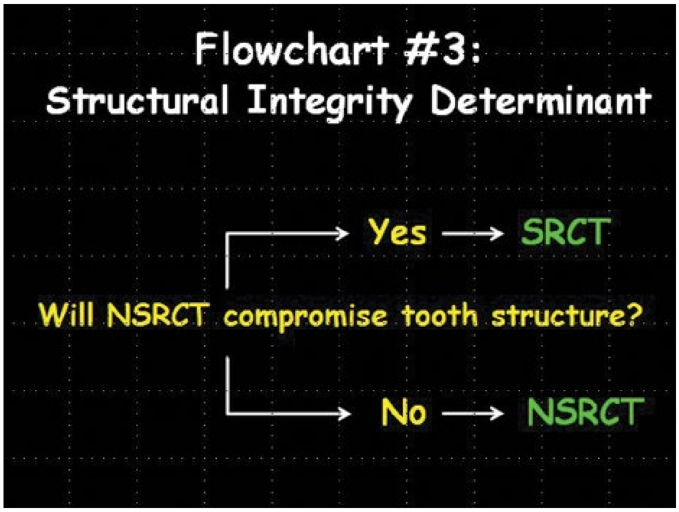

Figure 24.56 **(D)** *Structure.* If disassembly of previous endodontics presents a structural risk, then surgical endodontic seal may be less invasive to the existing dentistry.

occurred in 5–10% of the teeth examined.[33] Acid etching of the chamber has been advocated prior to bleaching to allow for deeper penetration of the Superoxol. Heat, Superoxol, and acid etching of the chamber increase the probability of resorption (Figure 24.57A and B) and should be avoided and a kinder, gentler technique should be used. However, the literature has never produced a report of a patient with cervical root resorption subsequent to internal nonvital bleaching, where "safe bleach" (described later) had been properly placed to protect the periodontal ligament.

Walking bleach technique

A solid, well-condensed gutta-percha root filling is a prerequisite to bleaching discolored endodontically treated teeth. This should be confirmed with a radiograph. If the root filling is inadequate, it should be redone. The bleach barrier must be placed 1 mm incisal to the undulating attachment apparatus to prevent possible migration of bleaching agents through unprotected dentinal tubules that exist in up to 6–8% of teeth. The "Bermuda Triangle" outline of endodontic resorption is identified by arrows (Figure 24.58). The incisally directed dentinal tubules serve as a direct bleach conduit that can ultimately initiate destructive resorption. Once it has been established that the gutta-percha obturation is adequate, it should be removed 2 mm apical to the cervical line and the reservoir that is created filled with zinc oxide eugenol temporary filling material, like IRM™ (DENTSPLY Caulk). All remnants of root and crown filling should be removed from the chamber. The chamber is washed with 70% alcohol. Sodium perborate powder mixed with water or 3% hydrogen peroxide to a resin-like consistency is packed into the chamber with a plastic instrument. Excess moisture is absorbed with a

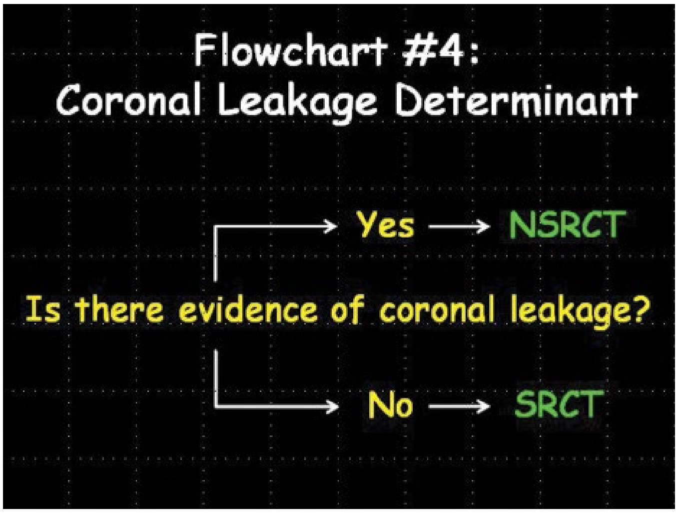

Figure 24.56 **(E)** *Coronal leakage.* Evidence of coronal leakage requires nonsurgical repair of undersealed root canal system.

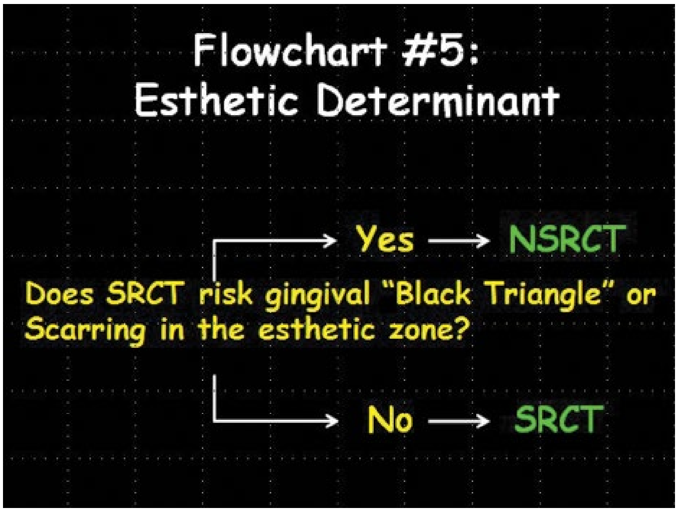

Figure 24.56 **(F)** *Esthetics.* If surgical seal is considered, dentist must take precautions to avoid a resulting gingival "black triangle" or surgical scarring, particularly in a patient with a high smile line.

cotton pellet. The access cavity is closed with good temporary filling material. An effort is made to ensure a total seal by removing the bleaching agent from the access walls. The maximum bleaching effect takes place within 48 h (Figure 24.59A and B). The tooth is evaluated for improvement after that time. Application of the paste is repeated until an acceptable result is achieved (usually two to three applications). A case of severe discoloration could even take more applications.

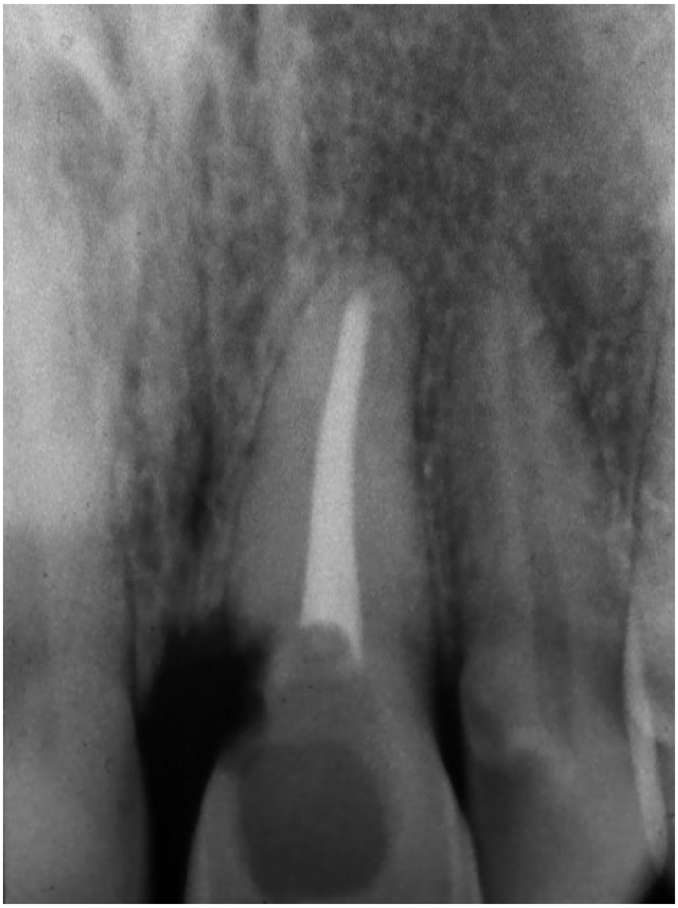

Figure 24.57 **(A)** External cervical resorption four years following bleaching with 30% Superoxol and heat.

Figure 24.57 **(B)** Two years after orthodontic extrusion and a surgical approach to repair the resorptive defect.

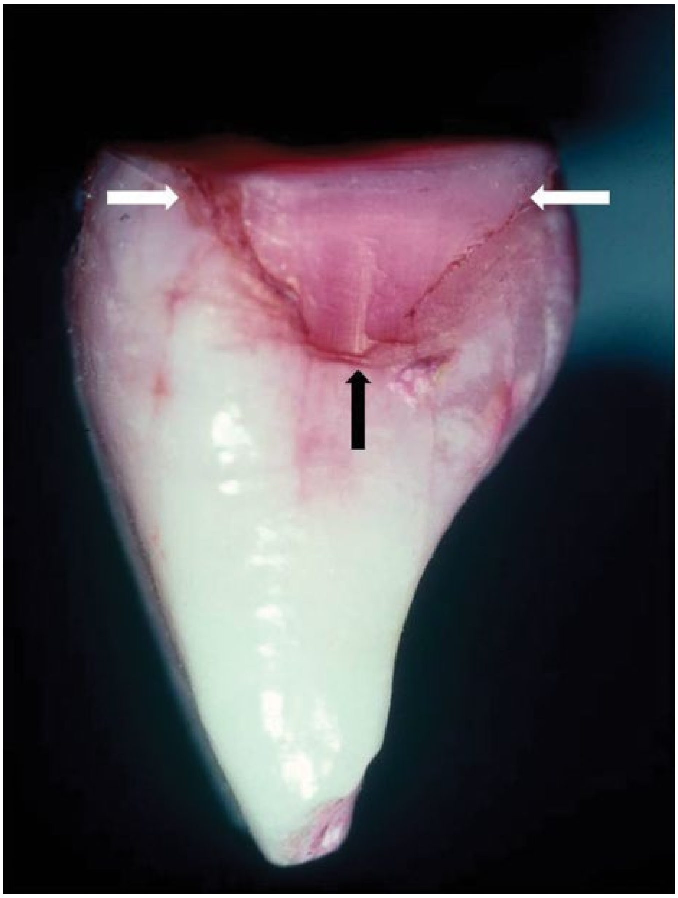

Figure 24.58 Three arrows identify the outer borders of the endodontic "Bermuda Triangle." The "safe" bleach barrier must be placed 1 mm incisal to the undulating attachment apparatus to prevent possible migration of bleaching agents through unprotected dentinal tubules that exist in up to 6–8% of teeth.

This "walking bleach" procedure was introduced by Spasser over 50 years ago.[34] The combination of sodium perborate and water apparently produces a sufficient oxygenating effect to bleach internal stains and is believed to be much gentler to the periodontal ligament.[3,35] In vivo and in vitro research studies have confirmed its efficacy. Its obvious advantage lies in its ability to produce the desired result without the liability of root resorption, which is associated with the use of Superoxol and heat.

Bleaching and endodontics

Bleaching pulpless teeth presents both a challenge and an opportunity. The challenge is to bleach the intact but discolored tooth while preventing cervical resorption. The esthetic treatment can be successful, safe, noninvasive, and cost effective.

Why discoloration?

Pulpal degeneration and subsequent endodontic access microleakage are the two main reasons for clinical crown discoloration, especially in the esthetic zone. Discoloration from an insufficient access seal is especially prominent where necrotic debris and endodontic sealer containing silver remains in the access cavity or its pulp horns. The initial discoloration after pulpal necrosis is due to extravasated red blood cells that undergo hemolysis and release of hemoglobin. Iron in the hemoglobin combines with hydrogen sulfide produced by bacteria to form dark-pigmented iron sulfide (Figure 24.60A). A pretreatment of maxillary left central incisor presents discolored and bleached. A clinical image after 6 weeks of walking bleach shows some improvement, but this is esthetically insufficient (Figure 24.60B). After 6 weeks the bleach was refreshed, and another 6 weeks later the color begins to match adjacent teeth (Figure 24.60C). Sometimes, color correction occurs in less the 24 h as well.

Preventing resorption

The literature suggests there are three key guidelines common to the "safe bleach."[36,37] In 10% of all teeth, a CEJ defect can be found between the cementum and enamel, where the dentin is nude of a cemented protective cover. In this region, dentinal tubules provide a direct conduit for internal bleaching agents to escape from the root canal system into the periodontal membrane. These tubules are particularly wide in younger patients and remain that

Figure 24.59 **(A)** Discolored maxillary canine with a necrotic pulp.

Figure 24.59 **(B)** Forty-eight hours after the completion of root canal therapy and walking bleach.

Figure 24.60 **(A)** Multiple walking bleaches are often necessary to achieve an appropriate esthetic result. Pretreatment of maxillary left central incisor.

Figure 24.60 **(B)** Clinical image after 6 weeks of walking bleach.

Figure 24.60 **(C)** After first 6 weeks, bleach was refreshed and another 6 weeks later the color begins to match adjacent teeth. Sometimes color correction occurs in less than 24 h as well.

way if pulpal necrosis occurs. Without sclerotic dentin closure, the periodontal ligament is vulnerable to being affected by bleaching agents. The combination of patent tubules, bare dentin, and bleaching agents running through the tubules represents a perfect storm for an inflammatory reaction that is the source of external root resorption at the cervical level.

Proximal dentinal

The CEJ runs up and down like a roll a coaster around the tooth where it curves incisally in the mesial and distal proximal areas. The potentially unprotected and also incisally directed trabecular must be protected by the location and protection of a bleach barrier. Figure 24.61A shows a discolored maxillary left lateral incisor. Figure 24.61B periapical reveals diagnosis of endodontically undersealed root canal system. In Figure 24.61C, endodontic retreatment was finished and safe bleach barrier appears similar to a "bobsled" cross-section protecting the incisal undulation of the epithelial attachment. Improved color occurs after a single day of walking bleach. (Figure 24.61D). Posttreatment image of access repair and endodontic finish was successful enododontically and free of symptoms (Figure 24.61E). The patient was scheduled for 6-month follow-up to confirm nonsurgical retreatment healing and color preservation. Color relapse should not occur when proper and careful access cavities are restored.

Barrier transfer

This step is essential in preventing resorption. Three periodontal probings are made and recorded: mesial, facial, and distal. The probings measure the distance from the epithelial attachment to the incisal edge of the tooth. The internal level of the barrier is placed 1 mm incisal to the corresponding external probing of the epithelial attachment in order to block potential patent tubules from the root canal system to the epithelial attachment. The internal protective template shape and position are now identified and the shield can be placed using a variety of products, such as flowable composites, glass ionomers, and even Cavit.

Figure 24.61 **(A)** Clinical example of nonsurgical endodontic retreatment, "safe" bleach barrier placement, and successful esthetic result. An overextended and undersealed endodontically treated discolored lateral incisor with persistent endodontic LEO.

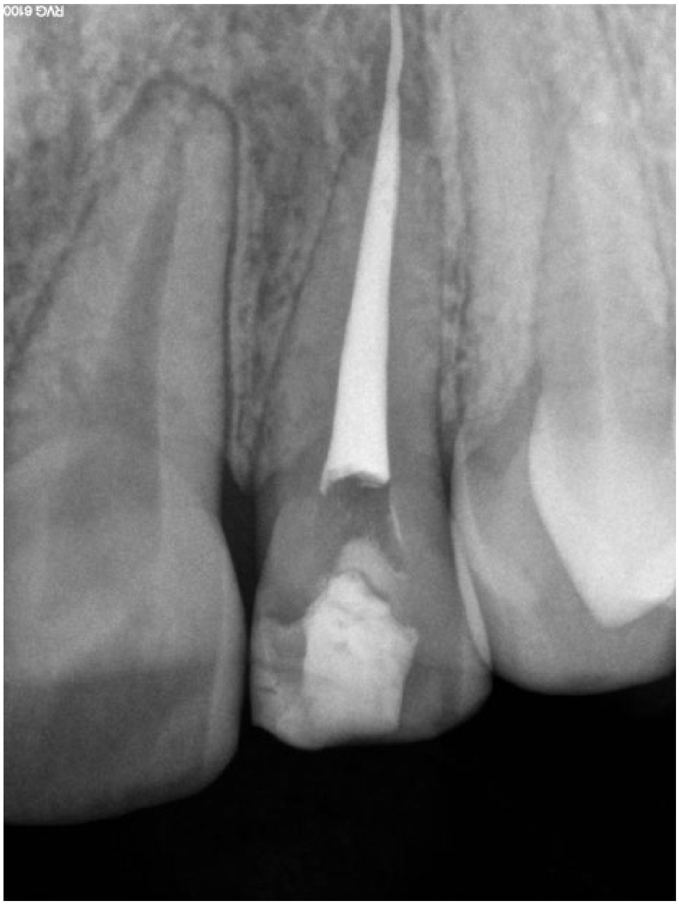

Figure 24.61 **(B)** Periapical image demonstrating radiographic LEO.

Safest bleach barrier

- Tooth became pulpless in a patient older than 25 years.
- Properly positioned bleach barrier 1 mm incisal to epithelial attachment.
- Sodium perborate plus water.

Least safe bleach

- Tooth became pulpless in a patient younger than 25 years.
- No bleach barrier or incorrectly placed barrier.
- Superoxol plus heat.

Case selection for safe pulpless bleaching

There are two criteria for successful internal safe nonvital bleaching: (1) the root canal must be sealed in three dimensions to prevent endodontic failure, and (2) the tooth structure must be intact. Therefore, the ideal tooth for nonvital bleaching is a discolored unrestored crown. If minor restorations are needed, they should be placed before the bleaching but can be modified afterward if needed to match the color resulting from the nonvital bleaching. If larger restorations are present or are required, these teeth need to be treated with a veneer or full crown.

Technique

Once the safe bleach barrier is placed, place a thick mix of sodium perborate and Superoxol or sodium perborate and water. The mixture can usually be carried into the access cavity with a small amalgam carrier dedicated to carrying bleach paste, so that mercury amalgam remnants do not contaminate the paste color. The paste is compacted into place using an endodontic plugger. Excess bleach must be removed from the cavosurface to create a successful temporary seal; otherwise, the bleaching agents may leak out in between appointments. A 2 mm layer of Cavit is placed first around the rim, making a Cavit vortex, followed by a flat second layer. In this way, a Cavit positive seat is placed that prevents squeezing bleach out as well as creating a void when placing Cavit directly into the access cavity. The walking bleach is complete. One word of precaution is that, occasionally, a dramatic result happens overnight, and so it is wise to perform the first walking bleach on a day where you will be in your office the following day. Otherwise, these teeth may actually become too white after several days of inattention. This sequence may take two to four changes in stubborn discolorations. However, with the application of new walking bleach, there is usually improvement. When color is appropriate, place rubber dam, remove all traces of walking bleach and Cavit, etch, bond, and place layered light-activated composite resin. Light cure from the labial surface and then the lingual surface. A well-placed access material will prevent rediscoloration due to access microleakage.

Calcific metamorphosis and walking bleach

Trauma can cause an irreversible pulpitis, necrosis, resorption, or calcification. When a pulp chamber calcifies and pulp remains vital, the tooth can become discolored due to lack of light transmission through the calcified chamber. If the patient wants to correct the tooth discoloration and external bleaching is unsuccessful, a crown or veneer could correct the discoloration but is relatively invasive, especially if no caries or prior restorations are present. Endodontic treatment and bleaching of a tooth with a vital and healthy pulp is also invasive. However,

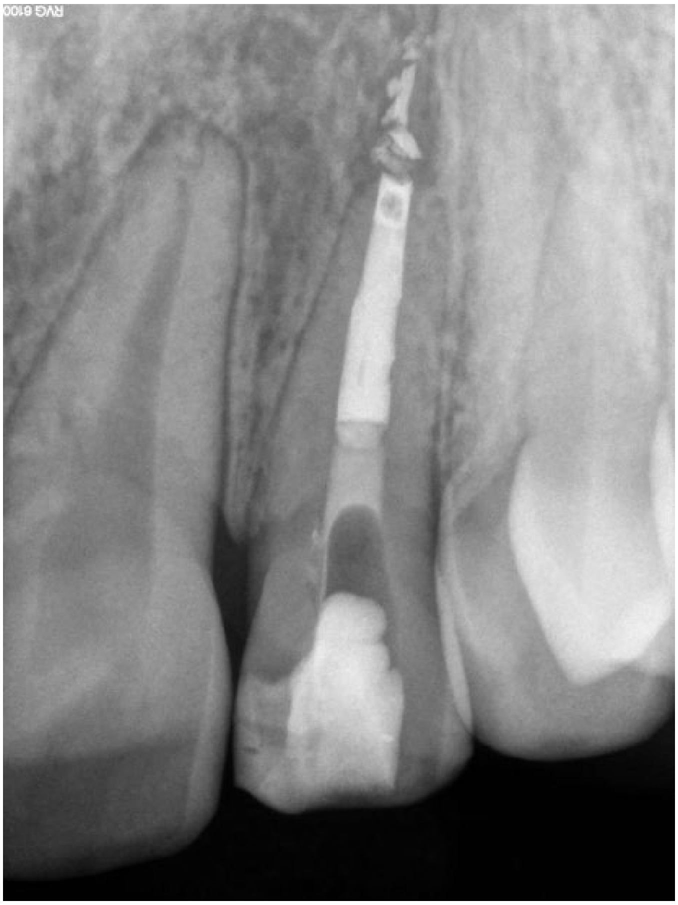

Figure 24.61 **(C)** Nonsurgical endodontic retreatment was finished, and "safe" bleach barrier resembles a "bobsled" cross-section protecting the incisal/apical undulation of the epithelial attachment.

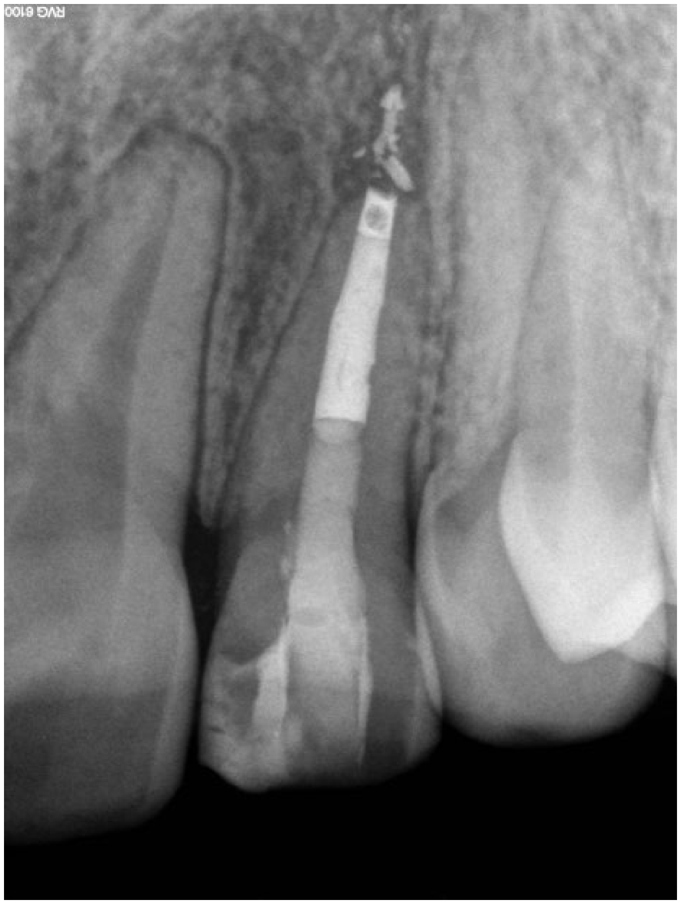

Figure 24.61 **(E)** Access repair finished and patient scheduled for 6-month posttreatment to confirm nonsurgical retreatment healing and color preservation. Color relapse should not occur when careful access cavities are restored properly.

Figure 24.61 **(D)** Improved color after a single day of walking bleach.

a walking bleach can be performed without endodontics if the canal has receded far enough from the access cavity to allow space for a walking bleach without risking damaging the pulp. Figure 24.62A shows a pretreatment clinical of the maxillary left central incisor that reveals discoloration. A periapical radiograph demonstrates calcified chamber (Figure 24.62B). A follow-up periapical radiograph 9 years later shows that persistent chamber calcification has essentially remained unchanged while pulp remained vital to EPT and ice pulp tests (Figure 24.62C). Light could not naturally pass through the calcified chamber, giving the darker appearance to the tooth (Figure 24.62D). An external bleach tray was fabricated and used to improve color (Figure 24.62E). Although slight color improvement occurred with single-tooth external bleaching, it was unsatisfactory. High patient compliance is also required. A 3D CBCT image demonstrated complete calcification to #9 pulp chamber (Figure 24.62F). A sagittal 3D section enables measurement from the incisal edge to the root canal system to be used for vertical access depth determination, which prevents pulp exposure during conservative access preparation (Figure 24.62G). Three-dimensional imaging also enables depth measurement from lingual, so safe access depth can be achieved (Figure 24.62H). A periapical image shows "bobsled" placement of safe bleach barrier and walking bleach sodium perborate paste and access seal (Figure 24.62I). A satisfactory esthetic result occurred during several weeks of walking bleach and prior to permanent restoration (Figure 24.62J). Pulp has remained vital and without symptoms.

Figure 24.62 **(A)** Clinical example of walking bleach in tooth with calcified chamber and vital pulp. Clinical pretreatment of discolored maxillary right central incisor.

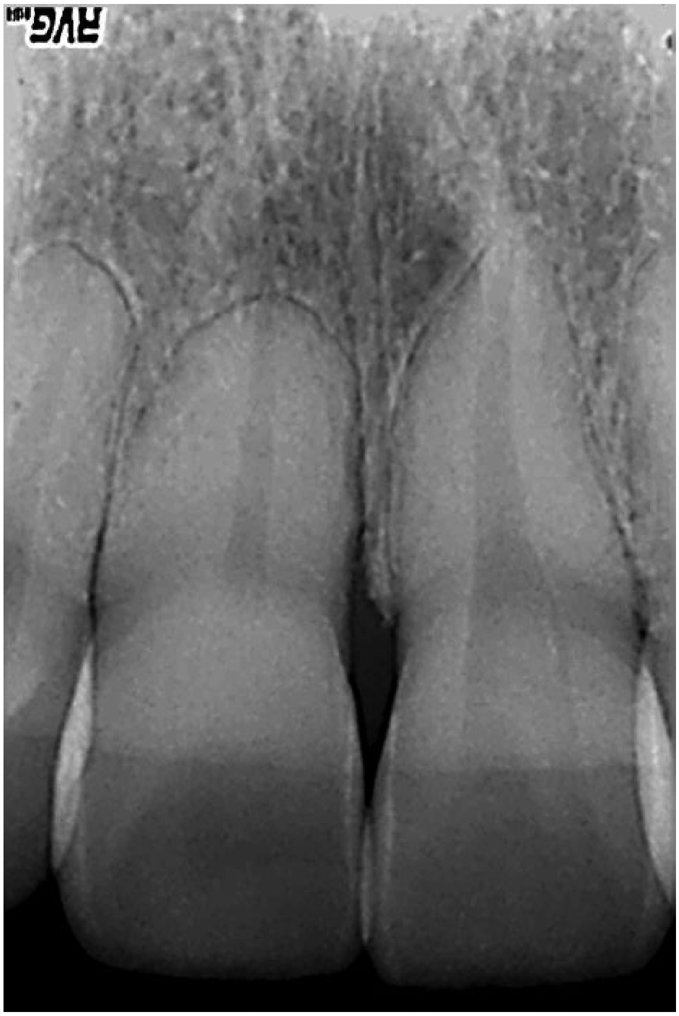

Figure 24.62 **(B)** Pretreatment periapical image of maxillary left central incisor with calcified pulp chamber.

Trauma

The era of the new millennium has been one of participation in sports and speed. With it came the concurrent hazard of dental injury. Any blow to a tooth, regardless of its intensity, can cause pulpal damage or pulpal necrosis. The need for endodontic treatment is predicated on the physiologic response of the pulpal tissue and periodontal ligament.[30] The esthetic interest in traumatized teeth centers more around the hard tissue damage, even though the associated pulpal problems can greatly influence the treatment plan. Crown discolorations, fractured crowns, fractured roots, root displacements, and external resorption are the normal challenges. These problems and their endodontic implications will be discussed individually.

Crown fractures

In the fracture of a crown that does not involve the pulp or so-called uncomplicated crown fracture, the pulp most often survives without further compromise (Figure 24.63). Apparently, when the crown fractures, the force is dissipated and, therefore, is not transmitted to the root or periodontal ligament. For this reason, the internal tissues remain unharmed. When sufficient tooth structure exists to retain a crown or composite buildup, it is recommended to cover the exposed dentin with calcium hydroxide if there is less than 1 mm of dentin covering the pulp. If it is clear from the clinical appearance and/or radiographs that there is more than 1 mm of dentin then there does not seem to be any need to cover the exposed dentin; thus, etch and bond with composite resin until a deferred vitality analysis can be determined at 2, 6, and 12 weeks after the trauma. A true pulpal diagnosis may be determined at this time, and the final restoration may be safely considered.

If the remaining tooth structure is insufficient to adequately retain a restoration, endodontics should be considered. Although an argument may exist to support the use of pin-retained restorations, the degree of injury of pin placement and the risk of fracture predispose elective endodontics and a full crown. The only exception would be a tooth with incomplete root apex formation; then, every effort should be made to retain the vitality of the pulp; at least until the apex is fully formed. Once the root canal treatment is completed, a post and core can be fabricated to provide the ideal restorative condition. However, when the pulp is exposed, endodontic intervention is indicated (Figure 24.64). The root canal treatment is completed if the root is fully formed. or an apexification (root-end induction) procedure is advised for a tooth with an open apex.[38] Innovative solutions are required to provide for the esthetic needs of younger patients (Figure 24.65A–C).

Root fractures

Horizontal fractures of the root present unique problems, and the degree of difficulty is relative to the level of the break. It is very possible, and it occurs in a significant number of cases, that separation of the hard structure of a tooth can occur; yet, the elasticity of soft tissue thwarts pulpal separation. For this reason, no root canal treatment is indicated and should only be considered when signs or symptoms indicate that there is pulpal necrosis and infection in the canal space. Of note is that, most often, only the coronal segment becomes necrotic; the apical has almost always healthy pulpal tissue. Therefore, root canal treatment is only needed for the coronal segment; the apical root segment remains vital and care should be taken not to insert any instrument into that segment. When situations occur that warrant attention, the following alternatives are available.

For those fractures involving the apical third of the root, if the pulp necroses, endodontics is performed to the level of the break and the separated tip is monitored because most likely the pulpal tissue in it is healthy and does not need any treatment. In the case where a periradicular lesion develops, surgical extraction of the apical segment is the treatment of choice (Figure 24.66A and B). Considering restorative implications, there is usually sufficient root length that adequate post preparation can be accomplished without reaching the break level and jeopardizing the seal.

Mid root breaks create more challenging problems, the first of which is mobility. Owing to the crown/root ratio being reduced to less than 1 : 1, stability is impaired and a splint might has to be fabricated (Figure 24.67A–C). Recent studies indicate that there is minimal advantage of the splint for the longevity of the tooth. The advantage is mainly for patient comfort. These teeth must be monitored periodically to check pulp vitality and periodontal ligament damage. Many of these teeth maintain vital pulps and a healthy periodontium and need no endodontic intervention (Figure 24.68A and B). However, if the pulp becomes necrotic, extirpation of necrotic debris is required. Endodontic options

Figure 24.62 **(C)** Nine years later, a new periapical image shows the chamber size of maxillary right central incisor has remained essentially the same for more than 10 years and pulp still tests vital and healthy.

Figure 24.62 **(D)** Light does not transmit through the calcified maxillary right central incisor's chamber.

Figure 24.62 **(E)** A fabricated bleach tray was first used to improve color.

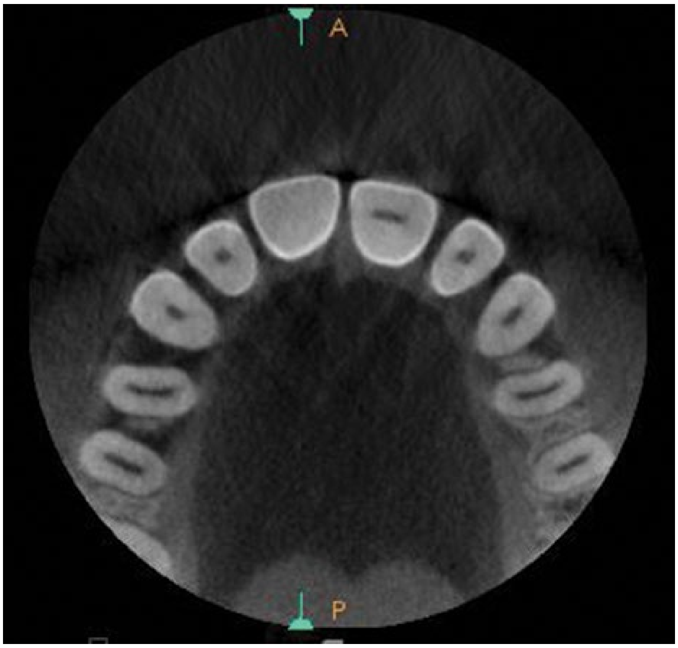

Figure 24.62 **(F)** The 3D CBCT image demonstrates complete calcification of #8 pulp chamber.

are: maintaining and filling the coronal segment to the break; instrumenting both segments and uniting the segments with either gutta-percha or the more solid vitallium pin; and removing the apical segment and inserting a vitallium pin through the coronal segment and extending it to the height of the vacant

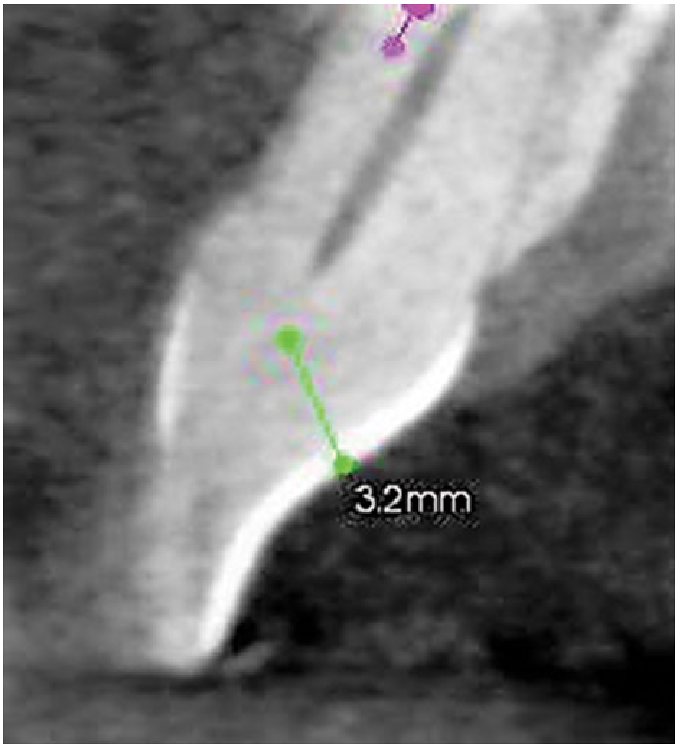

Figure 24.62 **(H)** The 3D CBCT imaging also enables depth measurement from lingual, so safe access depth can be achieved.

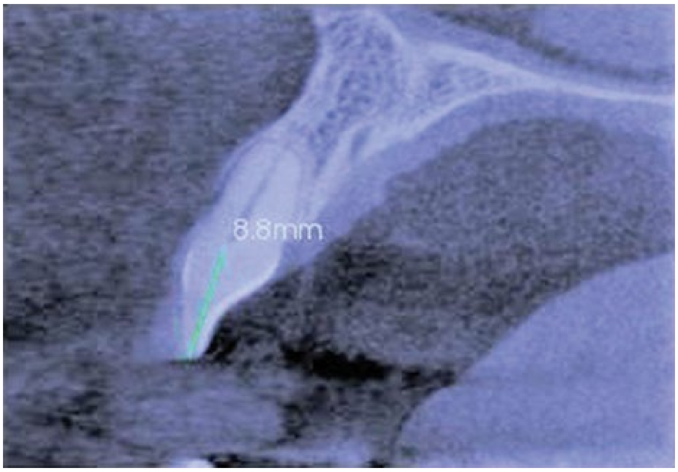

Figure 24.62 **(G)** The sagittal 3D CBCT section enables measurement from incisal edge to root canal system to be used for vertical access depth while at the same time preventing pulp exposure during conservative access preparation.

apical alveolus (Figure 24.69A–C). Such endosseous stabilizers are highly successful as long as there is no communication between the pin and the oral cavity by way of the crown or the periodontium. For this reason, the pin should be reduced to a coronal level within the canal to allow the chamber to be sealed

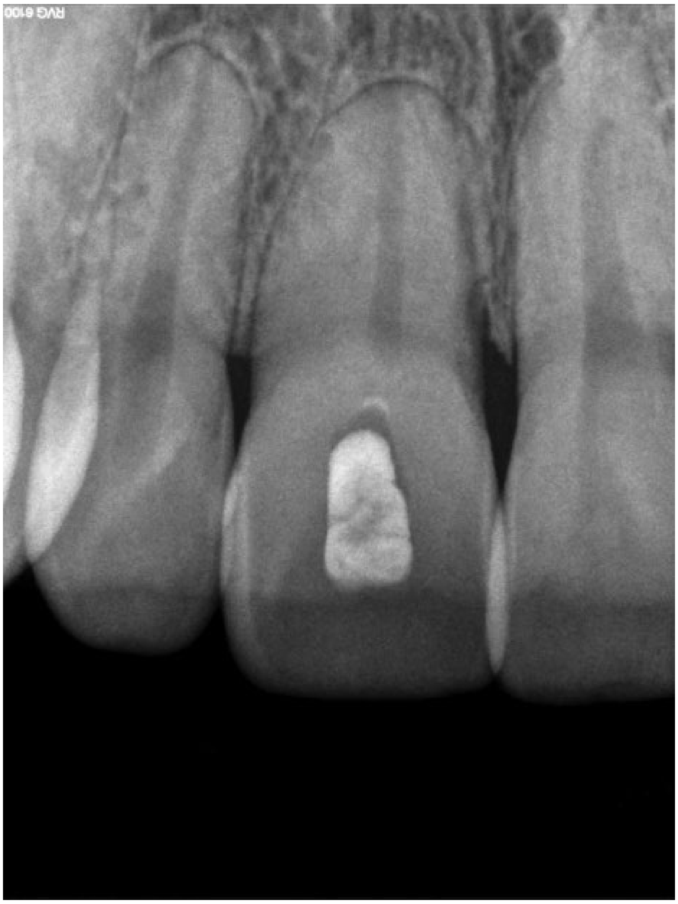

Figure 24.62 **(I)** Periapical image of walking bleach with small but accurately placed safe bleach barrier.

Figure 24.62 **(J)** Posttreatment clinical image of satisfactory esthetic result. Pulp has remained vital and without symptoms.

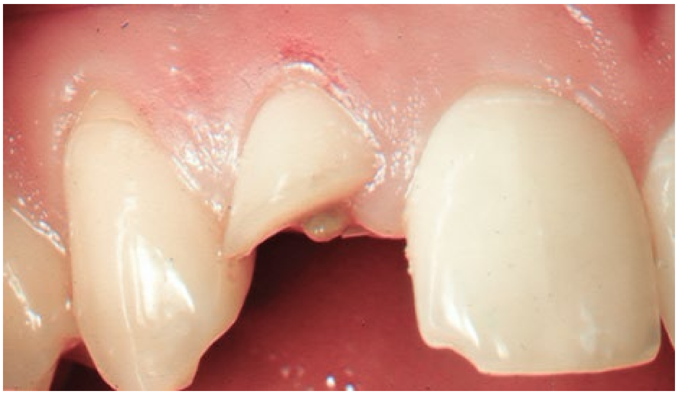

Figure 24.63 Crown fracture, no exposure, and the pulp remained vital.

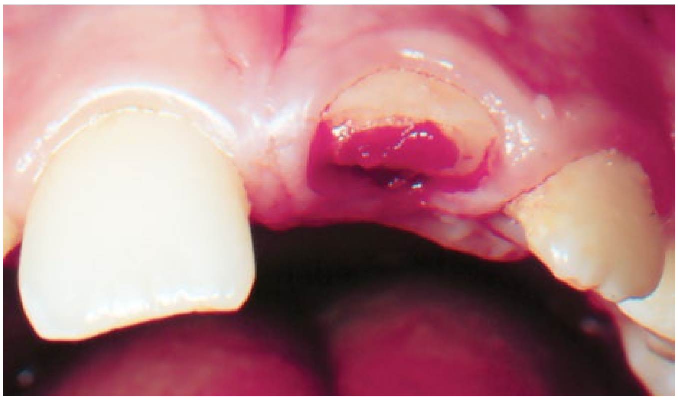

Figure 24.64 Crown fracture exposing the pulp. Root canal therapy was performed.

with a bonded resin filling. This obviously presents a problem when a post and core is needed to provide an adequate crown stump. Realizing post length will be curtailed; dentists must consider splinted units in the final treatment plan or extraction.

Root fractures that occur in the coronal third present by far the most difficult situations. The crown/root ratio is adverse, mobility is critical, and the prognosis is grave (Figure 24.70A and B). The coronal segment is too short to retain and the options for the root segment are extraction followed by a single tooth implant or bridge, vertical extrusion (Figure 24.71), or embedding of the apical segment. The loss of the root would ultimately lead to the loss of the alveolar integrity and the reduction of the alveolar height. Unless ridge augmentation is performed into the vacant alveolus an unesthetic bridge is inevitable. Endodontically treating the segment and further reducing the root coronally to a level at least 2 mm above/below the crestal height will enable bone to form across the coronal root surface. The embedded root will maintain the alveolar shape, form, and height. A fixed partial denture can then be fabricated without fear of alveolar shrinkage.

Perhaps the most favorable treatment would be extrusion of the root segment.[39] Endodontics is performed for the submerged root, and a post space is prepared to the normal depth. A stainless steel pin or post, pre-bent to form a hook that will extend approximately 4 mm into the oral cavity, occlusion permitting, is cemented in place. An arch wire is adapted to the labial surfaces of the two adjacent teeth on either side of the injured tooth. The wire is contoured to bend into the lingual space and create a 180° angle with the long axis of the root segment. The labial surfaces of the adjacent teeth are acid etched, and the wire is bonded in place. Ligature bands are wound around the wire and the hook. Owing to the perpendicular angle forces, the root will extrude into its predetermined position. Once the root segment is extruded to a level beyond the crest, it is prepared and an impression is made. The active force is eliminated, and the root is held in a passive position for a period of 6–10 weeks. This enables the resistant forces of the periodontal fibers to become stable and minimize the possibility of root regression. Occasionally, postextrusion periodontal probing will reveal the need for crown lengthening. Once confident of root stability, the final post and core and crown can be fabricated with certainty. However, extraction of the root and an implant may be part of the treatment planning decision. Displaced vertical root fractures offer very little hope unless the angle of the break terminates at a level that offers the options discussed for a horizontal coronal fracture.

Luxation and avulsion

Prognosis after severe luxation and avulsion injuries has dramatically improved in the last few years because of better understanding of how such injuries should be predictably treated. If a tooth is replaced into its original position within a few hours after the injury or, in the case of avulsion, replanted within 30–60 min after proper storage and then root canal therapy initiated 7–10 days later, the periodontal ligament will in most cases heal without any significant problems.[40] Luxated or avulsed teeth that were not properly treated or that suffered a massive injury to the periodontal ligament could present atypical problems created by subsequent ankylosis and root resorption.

Ankylosis without excessive resorption is not a serious problem unless the tooth fuses to bone in a location that creates an esthetic problem. Such is the possibility when the tooth is replanted in a child before the maxilla has had the opportunity to complete its growth. The maxilla continues to develop to adulthood, at which time the injured tooth is superior and labial to the adjacent uninjured incisors. When extracted, ridge augmentation and grafting are required to close the labial mucosa and reconstruct an esthetic alveolar ridge level. Currently, there is no treatment known to arrest ankylosis once it has started. Root canal treatment will not, in most cases, have any effect on the process because it is initially caused by massive damage to the periodontal ligament and then maintained with normal bone metabolisms of the body, which is impossible to reverse.

Inflammatory root resorption presents a somewhat different situation. It is characterized by rapid root resorption as well as lesions in the adjacent bone. The endodontic objectives are centered on the arrest of the inflammatory processes that were initiated by damage to the periodontal ligament, which are subsequently being maintained by irritation from an infected root canal system and dentinal tubules. Presently, treatment consists of periodic applications of calcium hydroxide dressings within the cleansed canals. If successfully arrested, the normal periodontal ligament will establish itself again over some period and the endodontic seal can be completed. When the damage is so extensive that it intrudes into the canal space from the root surface, additional repair is attempted by surgically exposing the defect, preparing a Class I cavity preparation and filling the defect with a nondiscoloring material. The choice of material depends on the location of the problem; however, Geristore (DenMat), a resin-modified glass ionomer cement, and MTA (ProRoot MTA Tulsa/Dentsply) are presently the materials of choice (Figure 24.72A–F). When the defect extends deep beneath the gingival crest, the crown shoulder may need to be prepared within the repair. This restorative solution, although not a desirable situation, may often be the only "best" alternative. However, Geristore resin ionomer is the material of choice when the preparation repair margin is coronal to the cervical line, since MTA is soluble in oral fluids.

Cracked tooth syndrome

CTS is a frequently misdiagnosed or undiagnosed dental pathology. It is not diagnosed with a periapical image since the pulp is vital without periradicular osseous change. Visual

Figure 24.65 **(A)** Maxillary central incisor teeth. Crown fracture and pulp exposures requiring pulpectomies.

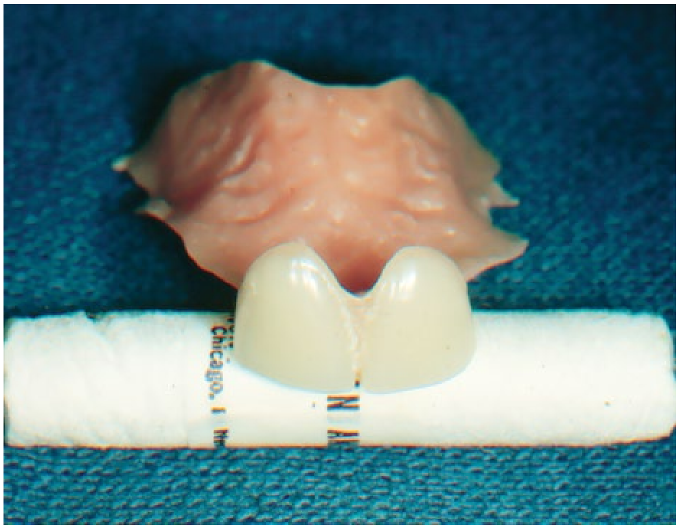

Figure 24.65 **(B)** A flipper was fabricated for this nine-year-old patient to satisfy the esthetic requirement.

Figure 24.65 **(C)** The removable denture in place.

Figure 24.66 **(A)** Root fracture in the apical third. Maxillary central incisors, horizontal root fractures with pulp necrosis.

Figure 24.66 **(B)** Root canal therapy in the coronal segments the apical portions of the roots were surgically removed.

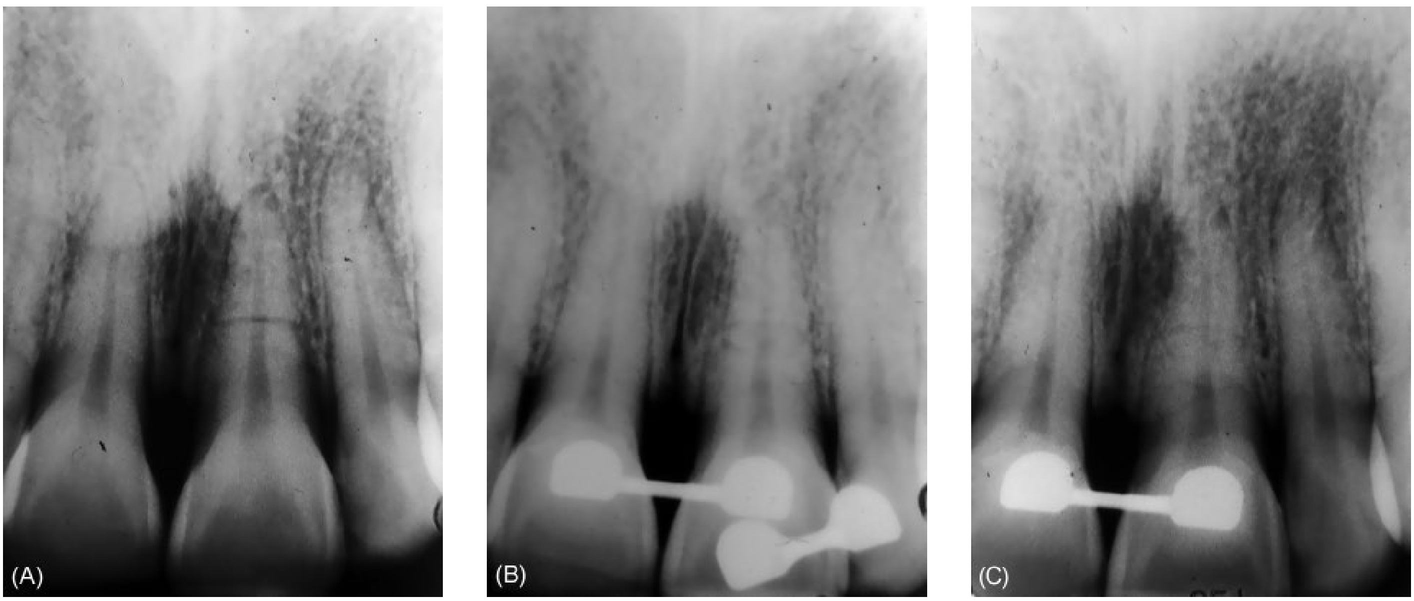

Figure 24.67 **(A)** Mid root fracture maxillary central incisor with minimal displacement. **(B)** Tooth splinted to adjacent teeth. **(C)** Six years postfracture: excellent root healing, and the pulp remained vital. The patient insisted on retaining the bonded bracket–arch bar splint.

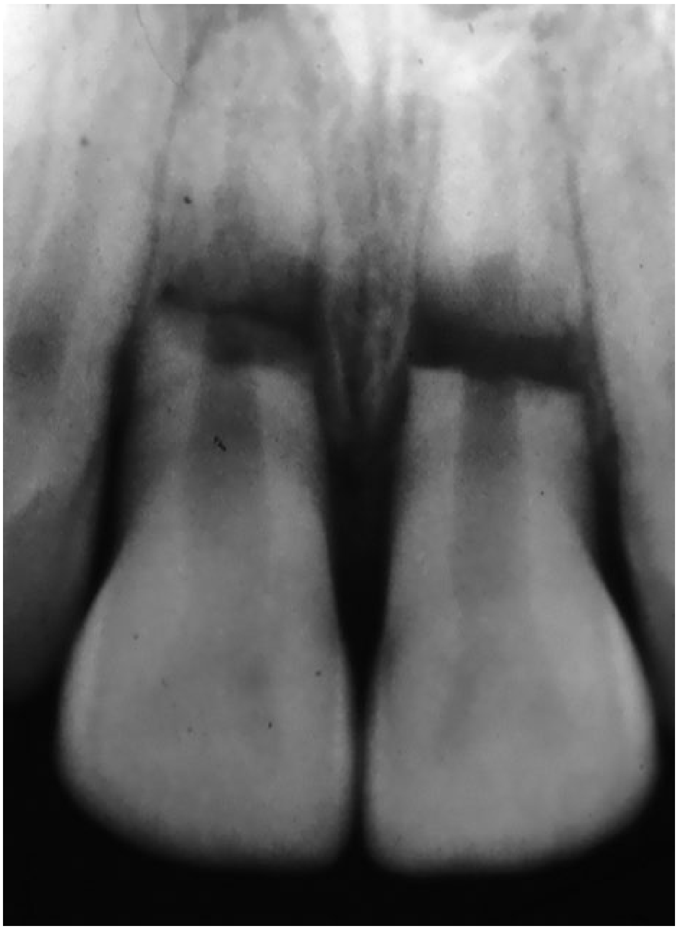

Figure 24.68 (A) Mid root fractures of maxillary central incisor teeth with severe displacement.

Figure 24.68 (B) Five year check radiograph. The treatment consisted of reducing the fracture and splinting with orthodontic brackets and an arch bar for 16 weeks. Vital pulps are present.

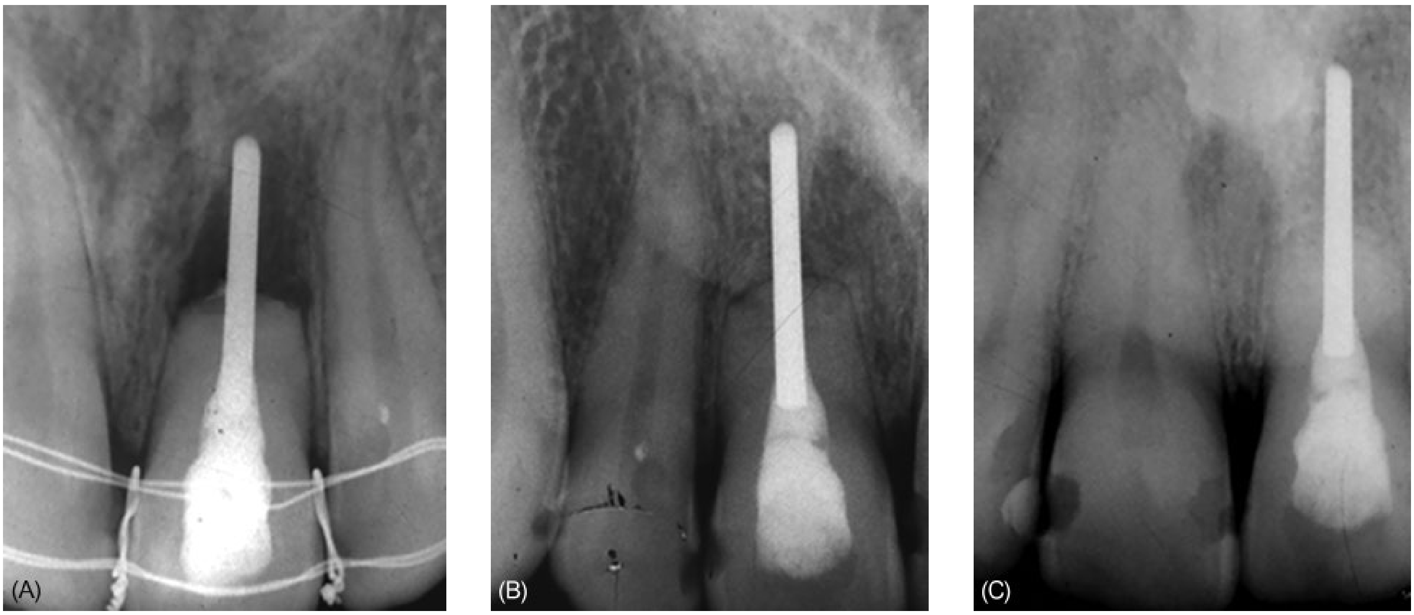

Figure 24.69 (A) Mid root fracture with pulp necrosis and apical periodontitis. Apical half of root extracted. Chrome cobalt endosseous implant (Austenal) cemented in remaining tooth structure. Tooth splinted. **(B)** Five years postsurgery. **(C)** Twenty-four years postsurgery. Tooth asymptomatic.

Figure 24.70 **(A)** Root fractures in coronal third requiring extraction. Maxillary lateral incisor

observation is unreliable since the extent of the hairline fracture cannot be fully observed. It must be diagnosed by properly clinically duplicating the symptoms for CTS. The seemingly elusive CTS is often a progressive condition that can result in an unrestorable fracture.[41]

Increased prevalence

A PubMed search reveals more than 11 500 articles have been published about CTS in the last 35 years. The condition of CTS was originally described by Cameron in 1964.[42] Because pretreatment diagnosis of the severity of the CTS is impossible, patients need to be advised about potential outcomes in diagnosis and how the diagnosis influences the CTS treatment plan and prognosis. Therefore, it is essential for the dentist to understand the guidelines for diagnosis and treatment of CTS.

It is important to note that CTS is one reason a patient may change dentists. The patient tells their dentist that they cannot chew on one side without discomfort. The dentist takes a periapical image of the area and there is no radiolucency. The pulps all test vital. The percussion test is negative. Without understanding the physiology of CTS, the dentist will not choose and interpret the right tests to actually make the diagnosis and recommend the proper treatment solution. The frequency of CTS is on the rise since humans are living longer, which means teeth need to last longer. More restorations are needed to retain teeth longer, and when teeth are more heavily restored they are more vulnerable to breakage.[43] In addition, grinding teeth, which may increase with increased daily stress, may exacerbate CTS. If left undiagnosed, CTS inevitably becomes worse, like a crack in glass. Sometimes the crack goes off to the side and the fragment of the tooth breaks off. The crack may also penetrate to the pulp or even a vertical root fracture. It is here where CTS can be diagnosed and usually successfully treated. Gibbs, who wrote one of the earliest reports on CTS, listed conditions that promote tooth fracture.[44] Cusps weakened by caries, by the shape and size of cavity preparations, and by improper restorations were generally considered the most important causes. He also described CTS as odontalgia secondary to cuspal fracture. His characteristic findings were (1) pain on mastication, (2) difficulty in locating pain, and (3) lack of other duplicable objective or subjective findings. Stanley suggested that considerations in cavity and crown preparations may reduce the incidence of CTS.[45] The restoration and remaining tooth structure must resist structural failure for restoration success. Cuspal protection is essential.

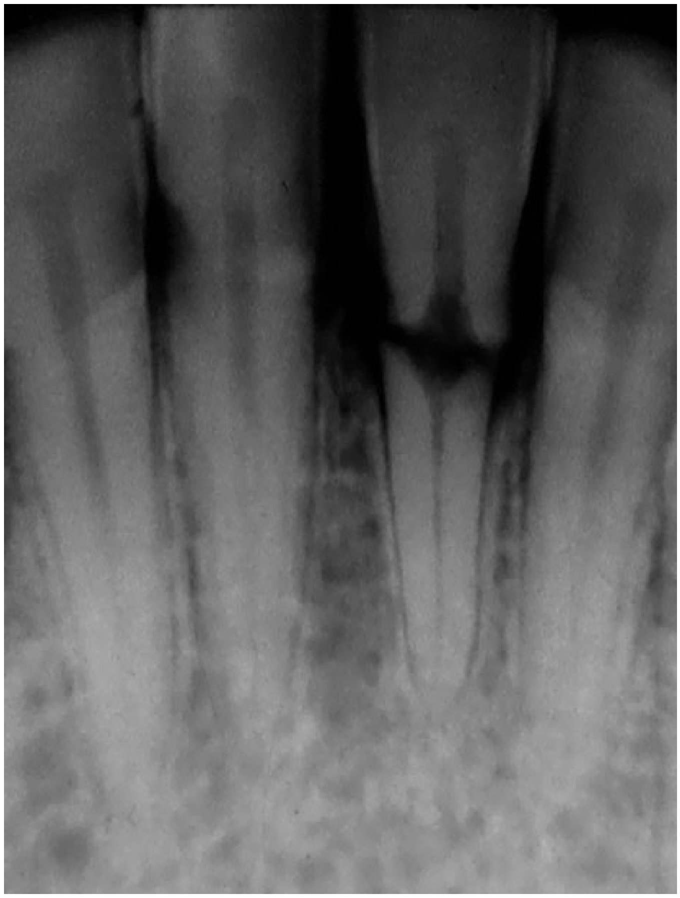

Figure 24.70 **(B)** Mandibular lateral incisor.

Figure 24.71 Maxillary lateral incisor with a root fracture in the coronal third. The root is long enough to consider a vertical extrusion.

Differential diagnosis

As part of the diagnostic process for CTS, the dentist must eliminate all other sources of pain when biting: endodontic acute alveolar abscess, periodontal abscess, pericoronitis, sinusitis, discomfort associated with orthodontic movement, hypersensitivity, poorly placed composite restoration, biologic width invasion, loose temporary or permanent restoration on tooth with vital dentin, open contact, a tooth ready to exfoliate, bruxism and clenching, or a parafunctional habit. Most of these conditions are easy to diagnose, but if the problem is none of these other possibilities the dentist must consider and test for a fractured tooth (CTS). What makes CTS such an elusive dental diagnosis?

Pulpal inflammation and necrosis occur in a coronal–apical direction because the cause of the insult cascade begins at the coronal end of the tooth: caries, restoration, cuspal fracture, new restorative and/or caries, and the insult cycle continues until the pulp cannot recover. Three anatomic conditions compromise the pulp's ultimate capacity for repair: (1) the pulp is surrounded by unyielding walls of dentin, preventing the recuperative swelling benefit of inflamed tissues elsewhere in the body; (2) the pulp is a relatively large volume of tissue for a relatively small blood supply through apical and lateral root canal system portals of exit; and (3) the pulp is an end-type circulation, such as the human appendix, which must be removed due to necrosis rather than repair when irreversibly inflamed. The single exception to the coronal–apical pulpal inflammatory direction would be, for example, the well-intended hygienist or dentist curetting an infrabony pocket and inadvertently severing a lateral blood supply, causing pulpal breakdown from a lateral direction. In this unlikely case, the pulp could test positive if the chamber tissue had not been affected or infected. This situation is more of a theoretical possibility than a clinical reality.

Unlike bone, pulps do not benefit from proprioception. Therefore, teeth with "toothaches," which are actually "pulp aches," cannot accurately identify themselves. The pain from stimuli such as sugar, cold, hot, and percussion must be duplicated by the dentist to diagnose the offending tooth/pulp. Not until the attachment apparatus is affected or infected from the root canal system can the patient reliably elicit pain and identify the pain offender through touching, moving, or biting on the source tooth.

Given the direction of most pulp death, teeth that have vital pulps do not have radiographic osseous lesions of endodontic origin, and teeth that have lesions of endodontic origin first have nonvital pulps and pulp testing must reveal negative electric, ice, and test cavity tests. Herein is the dilemma of CTS: How do you diagnose and treat to optimize the probability of success?

Cracked tooth syndrome classes and treatment

Class I: incomplete vertical fracture

In this class, there is incomplete vertical fracture through enamel and into dentin but not into the pulp (Figure 24.73A).

Symptoms

Class I fracture involves the dentinal tubules, and action potentials are produced when micromovement occurs due to the Class I crack. Although difficult to see without magnification and staining, the Class I fracture can be observed through the operating microscope and further revealed using transillumination. (Note: in the classification system described, Classes I–IV represent a progression of the Class I occlusal induced fracture.) If an early enough diagnosis is made and treated, the situation may not progress beyond a Class I fracture. If, on the other hand, the Class I diagnosis is missed and no treatment is provided, the crack may rapidly progress to Class III–V fractures, rendering the tooth unrestorable. Success depends on an accurate diagnosis, relief of occlusion, and proper cuspal coverage in a sequential and timely treatment plan.

The cleavage plane of a Class I fracture is usually in a mesiodistal direction. The patient with this problem often complains for months, years, or even decades that they experience a sharp pain when chewing. Again, radiographs are of no diagnostic value because there are no osseous changes and the fracture is perpendicular to the radiographic beam. Often, a patient will call one day to report that a portion of a tooth has broken off and the sharp pain has subsided.

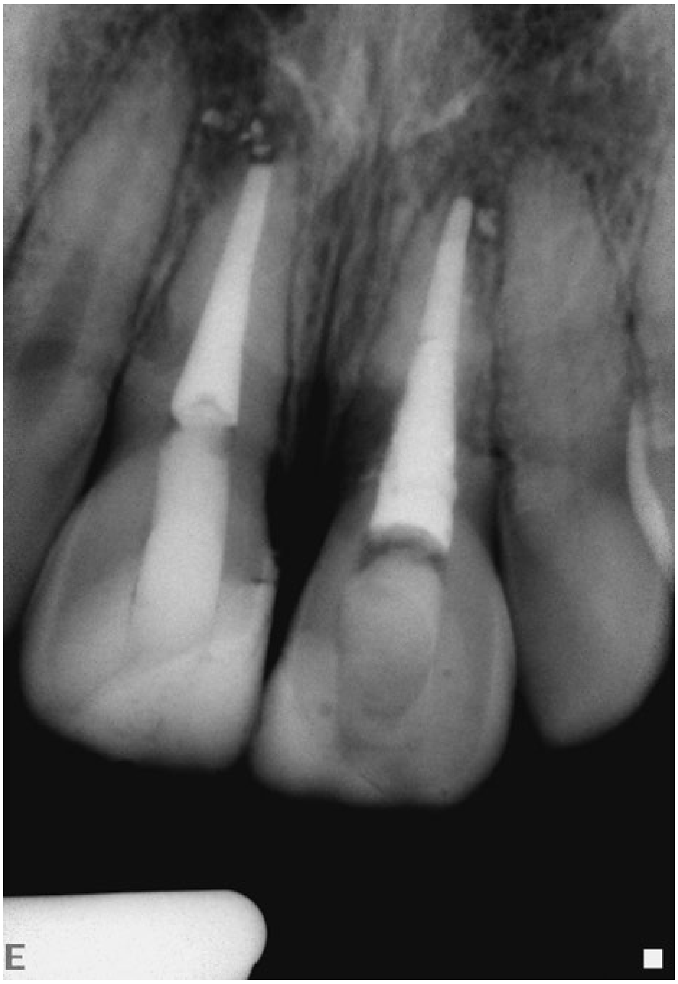

Figure 24.72 **(A)** Maxillary central incisor-surgical repair of resorptive defect 2 years following avulsion and replantation. Radiograph of a resorptive defect at cervical region following replantation, calcium hydroxide treatment, and root filling in a 10-year old patient.

Diagnosis

The key to the Class I CTS is to reproduce or duplicate ("dupe it") the symptoms of the patient's chief complaint or "felt need." The classic symptom is sharp pain when biting and yet the pulp is vital. The pain is often reported especially upon chewing release. A variety of diagnostic aids are available, such as an orange wood stick, "Tooth Sleuth," or wet cotton roll. The problem is the dentist directs the duplicating device and puts the onus on them. It is better to have the patient duplicate "their problem" using the "cotton wad" technique (Figure 24.73B). If they find it eating meals, they can find it now. The "cotton wad" is described as follows: place the patient in a sitting position and ask them to identify a substance that causes pain when chewing. If the answer is gum, for example, then wad and wet a sphere of cotton from a cotton roll that is the size of a piece of chewing gum. If the patient suggests another food, do the same thing and tell them to use their imagination. Have the patient chew with the cotton wad until they duplicate their biting pain. Give them time and some privacy to duplicate. Give them time to locate their own special occlusal position. The patient participates in

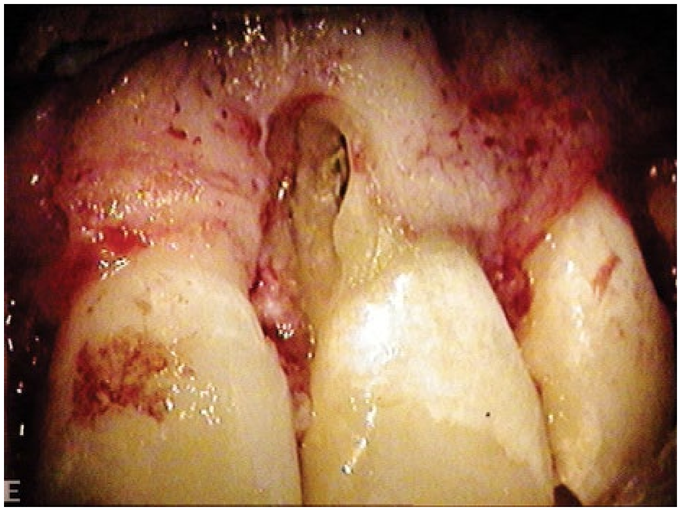

Figure 24.72 **(B)** Photograph showing the extent of the defect on the root.

the diagnosis versus the dentist doing something to them. It may take a few seconds or longer and you may need to change the cotton wad size a couple of times if the pain is not duplicated. The patient is instructed to keep their teeth together once they experience the pain. Then have the patient keep their teeth together and part their lips, so you can see where the cotton wad resides. If it is between two teeth such as the first and second molar, have the patient move the cotton wad to the forward tooth and test and repeat with the distal tooth until typically the patient's eyes squint and exclaims "that's it!" Literally, a wad of cotton is placed into the patient's mouth to simulate chewing and duplicate the symptom of pain when biting (Figure 24.73C). If bite pain duplication occurs, have the patient roll the cotton wad to the distal tooth, bite, and test. If not the second molar, have the patient move the cotton wad to the first molar. This is key to singularly isolating the CTS source. When your patient discovers the tooth by duplicating the symptom, a wince is often elicited (Figure 24.73D). You have diagnosed the bite source.

Treatment

Once the Class I CTS has been made, place a copper or stainless steel band with permanent cement. If the patient is asymptomatic to chewing after 1 week and has no thermal changes discomfort, then the tooth can be predictably restored with a full crown or onlay. In an unpublished clinical evaluation by the author (JDW), 133 cases of Class I CTS became asymptomatic after diagnosis and treatment performed from 1990 to 1993. One hundred patients were recalled in the year 2000, and 5% of the teeth required endodontic treatment, 2% were removed, and 93% were asymptomatic and did not require endodontic treatment.

Class II: pulpal involvement

In this class, the crown fracture is associated with irreversible pulpal inflammation of the pulp (Figure 24.73E).

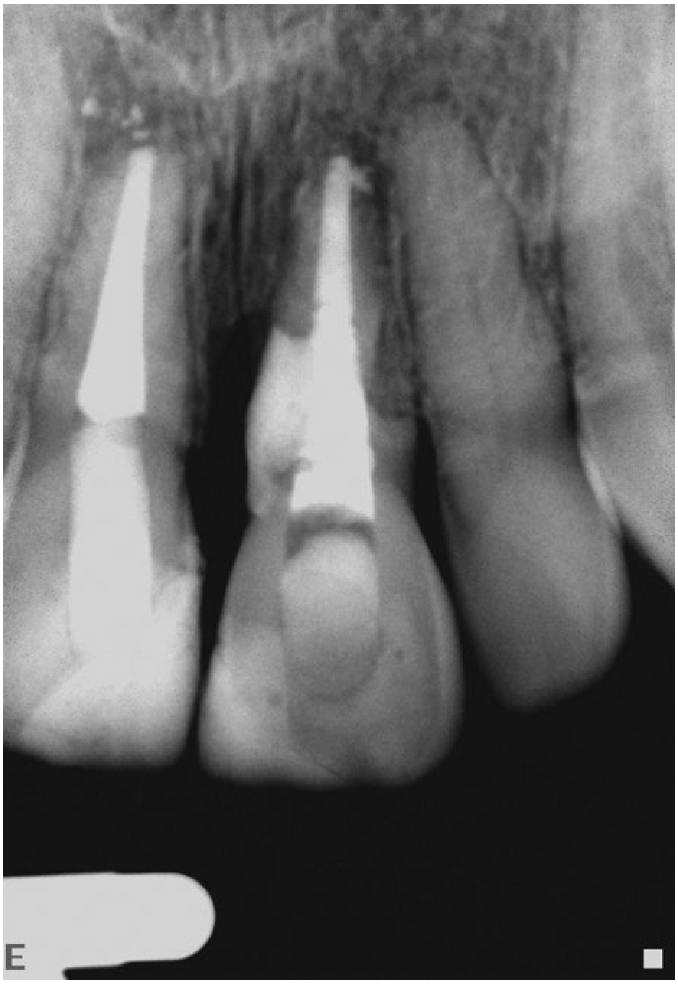

Figure 24.72 **(C)** Geristore repair of the resorptive lacunae.

Figure 24.72 **(D)** Check-up after 4.5 years discloses a return to the normal periradicular bone pattern.

Symptoms

In addition to sharp biting pain, the patient will often experience discomfort with thermal changes and report a recent history of pain with thermal stimuli. The pulps may now have advanced to necrosis or the tooth may have advanced to an acute alveolar abscess. However, there will be a history of pain with thermal stimuli. The history is essential in identifying the class of the CTS. If the patient is questioned about when they had pain with biting—that is, was the pain first with biting or to thermal change—the patient will report that the pain occurred first with biting. This should lead to a diagnosis of a vertical fracture in the crown. If the fracture is not diagnosed, and the patient is treated just for pulpitis or acute alveolar access, failure will result. The reason for failure is that the tooth was not treated for the combined problem; that is, fracture and pulpal involvement.

Teeth in the Class II CTS category need to be treated with a copper or stainless steel band and cemented with permanent cement followed by initial endodontic treatment once the tooth has become asymptomatic. If the tooth is asymptomatic to chewing after the beginning of endodontic treatment, then endodontics should be finished and restored with a crown or at least cuspal coverage. It should be emphasized that the tooth must be completely asymptomatic to chewing or biting before preceding otherwise the symptom correction is unpredictable. Do not expect the tooth to be less symptomatic with the crown in place than it was with the cemented band.

Diagnosis

Duplicate symptoms of biting and pulpitis.

Treatment

Adjust the occlusion so that the tooth is not in occlusion. Band the crown immediately. Treat the pulpal pain appropriately. Check the mesial and distal surfaces for increased probing depth. If an isolated periodontal defect is observed, the fracture may involve the root surface in an apical direction and the prognosis is poor. If the tooth remains symptomatic to biting after the band is placed and endodontic treatment is complete, consider removal of the tooth. The reason the tooth remains symptomatic is that the fracture line has extended into the periodontal ligament and the patient experiences pain from the periodontal ligament and not the pulp. The symptoms will not improve when a crown is placed. If the tooth is asymptomatic with the band and following endodontic treatment, then continue with a cast crown. Within the next couple of years, some teeth in Class II

Figure 24.72 **(E)** Nine years postsurgery, 12 years posttrauma.

Figure 24.73 **(A)** CTS. Class I fracture occurs into dentin but does not involve pulp.

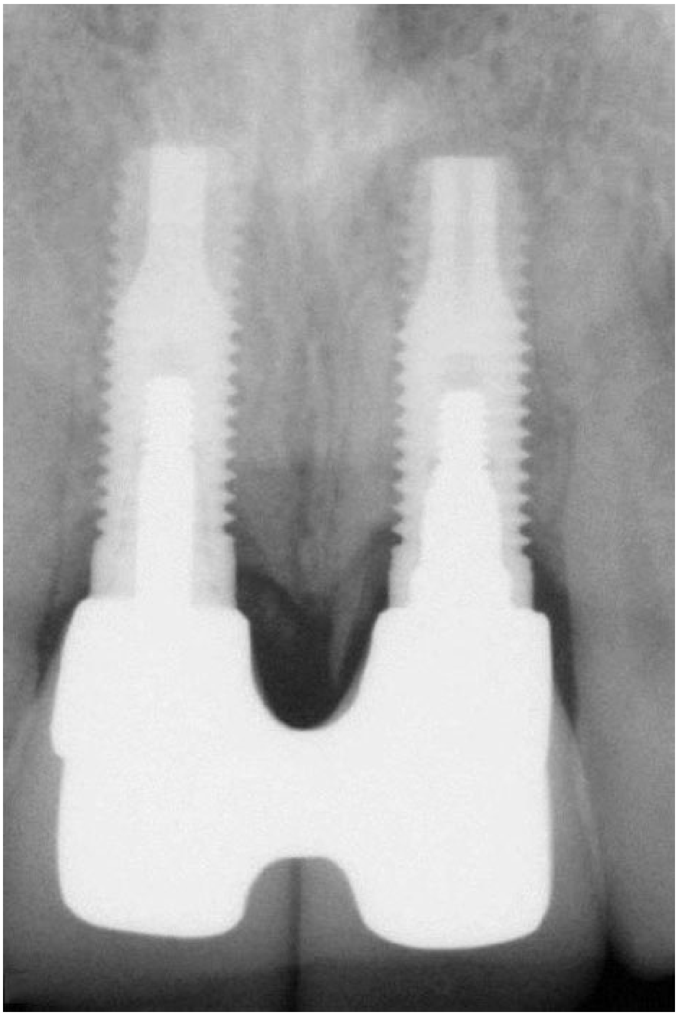

Figure 24.72 **(F)** Fourteen years post trauma. The combined treatment preserved the tooth as an esthetic "space maintainer" until there was sufficient jaw development to allow for implant placement in the now 22-year-old.

CTS will fail, but the majority will be as serviceable as any other endodontically treated tooth. Ultimately, it is difficult to measure the relationship of the depth of the fracture and pulpal involvement except measuring the patient symptoms after band placement. In summary, there are three possible outcomes after band placement (Figure 24.74A–D).

Class III: attachment involvement

The Class III CTS fracture is the most difficult to treat because the periodontal defect associated with the fracture is important to the prognosis. This dilemma was described by Hiatt;[46] he concluded that as the fracture proceeds deeper into structure of the tooth, bacteria invade the pulp or periodontal tissue and may result in pulpal lesions, periodontal lesions, or combined lesions. The attachment apparatus is often involved.

Symptoms

If the pulp is necrotic there are few symptoms.

Diagnosis

Often there is a history of Class I and Class II symptoms. Periradicular bone loss can often be seen radiographically.

Treatment

In most cases, the best treatment is extraction. However, certain procedures may be attempted if the tooth is particularly strategic either functionally or esthetically and an implant or bridge is not desired. The dentist can band the tooth, treat an acute symptom, and observe the result. Cleaning the root canal system will eliminate the endodontic component. If the tooth has shallow probing depths in the area of the fracture line and if the tooth becomes asymptomatic with biting following banding, then the dentist can consider proceeding with endodontic treatment and a crown. This should not be the treatment plan unless the patient fully understands the prognosis is uncertain.

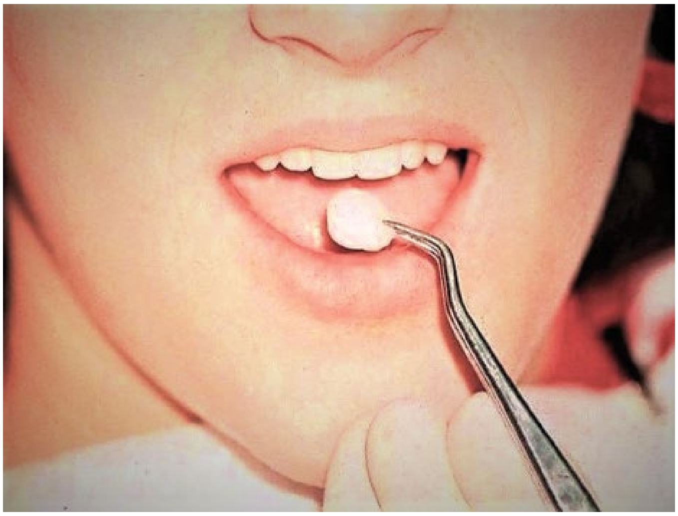

Figure 24.73 **(B)** Literally a wad of cotton is placed into the patient's mouth to simulate chewing and duplicate the symptom of pain when biting.

Class IV: complete separation of tooth fragments

This type of fracture is through the crown, extends subgingivally, and one or more parts of the tooth are mobile. The mobile portion needs to be removed; if the remaining tooth structure is restorable, endodontics is performed and the tooth is restored. Usually, however, insufficient sound tooth remains after the fractured and loose portions are removed.

Figure 24.73 **(C)** Cotton wad is between first and second molar.

Figure 24.73 **(D)** When the patient discovers the tooth by duplicating the symptom, a wince is often elicited. You have diagnosed the bite source.

Figure 24.73 **(E)** Class II CTS involves the pulp.

Symptoms
History of fracture symptoms, bite pain, and gingival inflammation and swelling.

Diagnosis
Deep and narrow periodontal defect usually in two locations around the circumference of the tooth.

Treatment
Extraction of all or a portion of the tooth if it were restorable.

Class V: retrograde root fracture

These fractures originate at the apex and travel coronally. They are iatrogenic in nature, resulting from overzealous root canal preparation and a resulting weakened root, forcible endodontic obturation, or from active post placement.

Symptoms
Tooth discomfort, but often vague.

Diagnosis
Radiographic, history, and observation during removal or endodontic microsurgery.

Treatment
Extraction or endodontic surgery.

Lastly, CTS occurs most frequently in the mandibular second molars followed by the maxillary first molars, mandibular first molars, and maxillary first premolars.[45]

Summary of cracked tooth syndrome guidelines

- Identify CTS tooth with patient chewing on cotton wad.

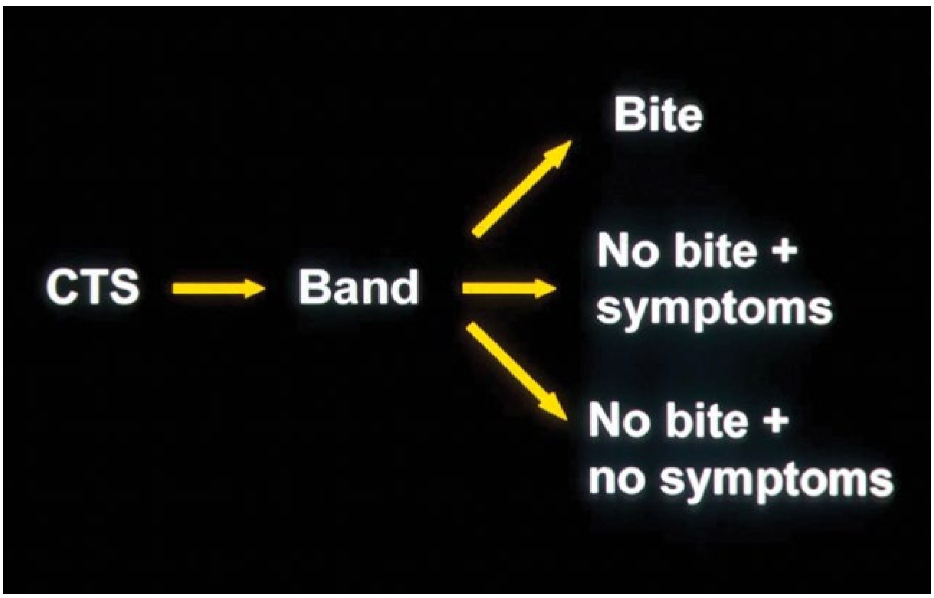

Figure 24.74 **(A)** Three possible outcomes once the diagnostic orthodontic band has been placed.

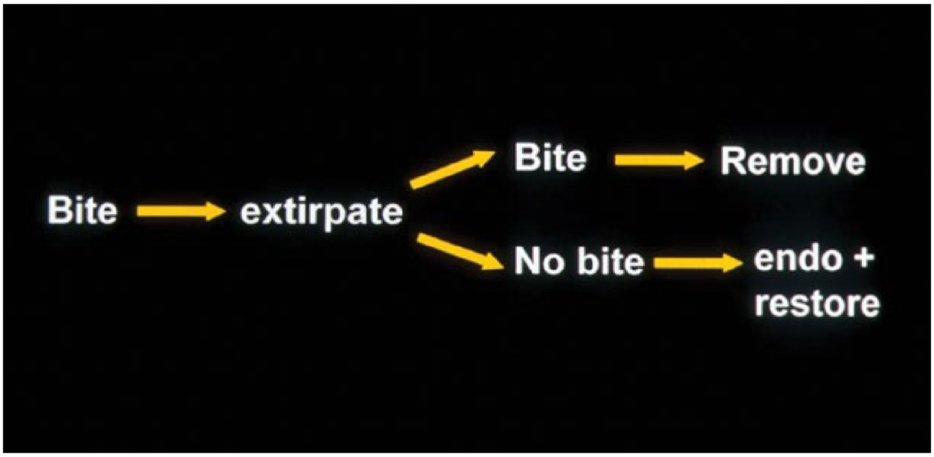

Figure 24.74 **(B)** Possible outcome #1.

Figure 24.74 **(C)** Possible outcome #2.

Figure 24.74 **(D)** Possible outcome #3.

- Treat Class I CTS fractures with band and restore. Eliminate all centric and working contacts in noncentric holding cusps; that is, lingual cusps of mandibular posterior teeth and buccal cusps of maxillary posterior teeth.
- Treat Class II CTS fractures with band plus endodontic treatment and restore unless symptomatic (see flowchart).
- Treat Class III CTS fractures with band and perhaps endodontic treatment and restore, but extraction is likely.
- Treat Class IV CTS fractures by removal or root resection.
- Treat Class V CTS fractures by removal or endodontic surgical repair.

Conclusion

CTS presents both a diagnostic challenge for the dentist and an opportunity for the patient and the dentist. CTS is the reason many patients have a favorite side to chew on. In unpublished data, the author (JDW) has discovered approximately half of patients, when asked what their favorite side to chew on is, choose one side or the other. Approximately half of those patients, in other words, as many as a quarter of the patients in a dental practice, may have undiagnosed CTS that can and should be diagnosed and appropriately treated. But the dentist or hygienist must make this question part of every comprehensive dental examination or recall/cleaning appointment to diagnose this "silent" endodontic condition. In addition, CTS cases are increasing due to increased patient longevity, more wear, more restorations, and more stress.

Endodontic surgery

Although the technological advancements in endodontics have improved the rate of success, the demands of the populace to save teeth presents degrees of difficulty that test the best of endodontic mechanics. In an effort to satisfy these demands, dentists are often called on to overcome anatomic, iatrogenic, or traumatic complications by intervening surgically. Sealing portals of exit surgically, for example, post perforations (Figure 24.75A–D), root resorption lesions (Figure 24.72A–F), and inadequate root fillings, where nonsurgical treatment is not practical (Figure 24.76A–C). These modes of treatment constitute an extension of endodontic treatment and are an alternative to extraction.

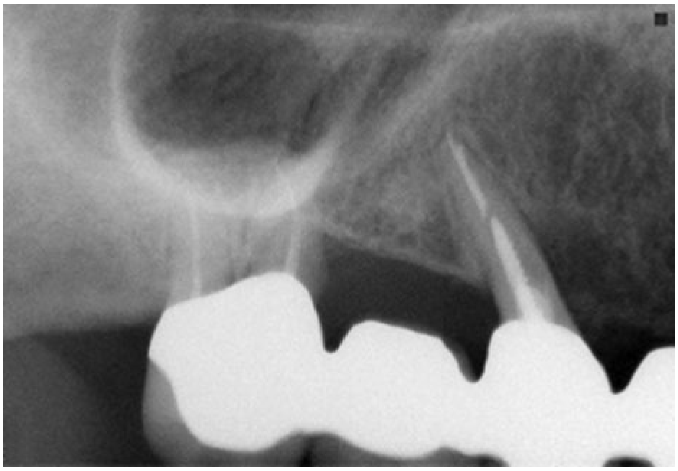

Figure 24.75 **(A)** Post perforation repair. Post perforation maxillary second premolar tooth.

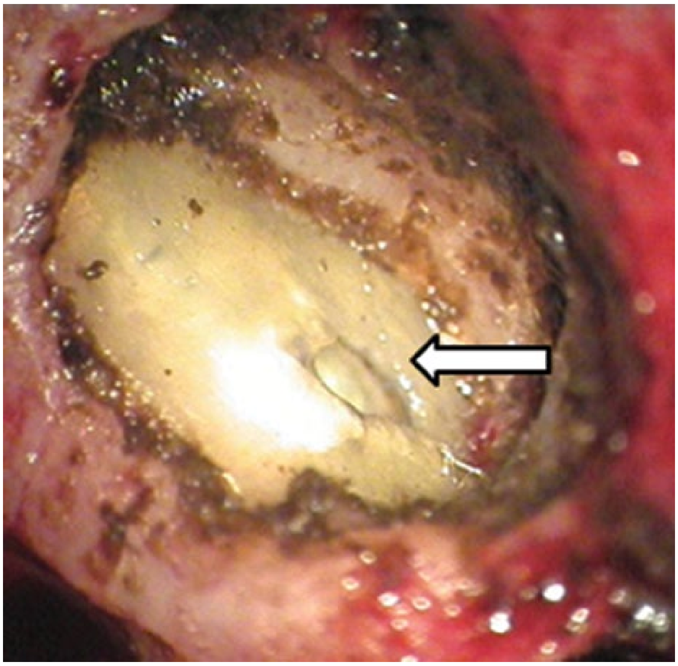

Figure 24.75 **(B)** Perforation defect uncovered and cavity prepared.

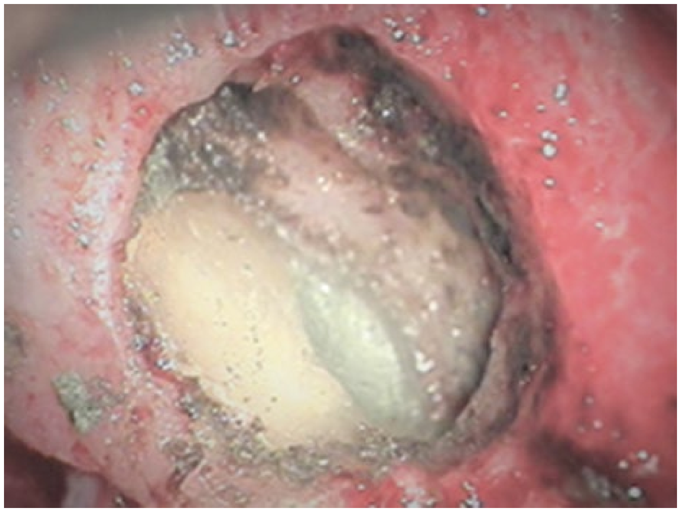

Figure 24.75 **(C)** Postoperative image perforation repaired with MTA repair.

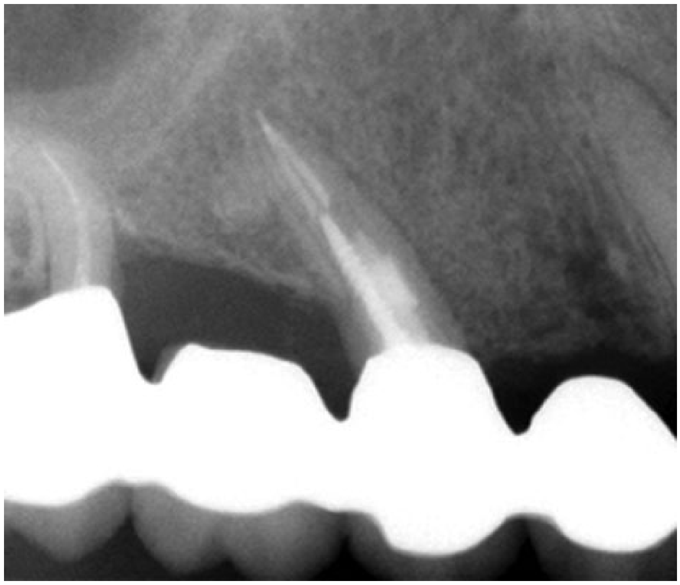

Figure 24.75 **(D)** Six years postsurgery. Complete bone regeneration, and tooth is asymptomatic.

Within the Endodontic community, there is an emphasis to retreat wherever possible and feasible rather than to choose endodontic surgery as the first treatment option. The advent of sophisticated techniques, equipment, and materials allows for the nonsurgical retreatment of teeth that were previous candidates for extraction (Figure 24.77A–C).

Since endodontic surgery requires incising and elevating the soft tissue from bone, the obvious esthetic consequences can be recession and scarring. For these reasons, the choice and location of the surgical flap must be carefully evaluated before a scalpel ever touches tissue.[47] There are several major flap designs that could be used, depending on existing restorations and anatomical factors.

Tissue discoloration (tattoo)

In the past, silver amalgam was the material of choice for retro filling, post perforation repairs, and sealing resorption defects. In a tissue environment, this material is notorious for its discoloring effect (Figure 24.78A and B). Once a black tattoo occurs, corrective treatment may require removal of the cause, excising the tattoo and grafting tissue across the defect. Such treatment can now be avoided by using Super EBA (Henry J Bosworth), Geristore (DenMat), or white MTA (ProRoot MTA Dentsply Tulsa Dental Specialties) Biodentine (Septodontics) because these products do not cause the staining/tattoo that is associated with the amalgam.

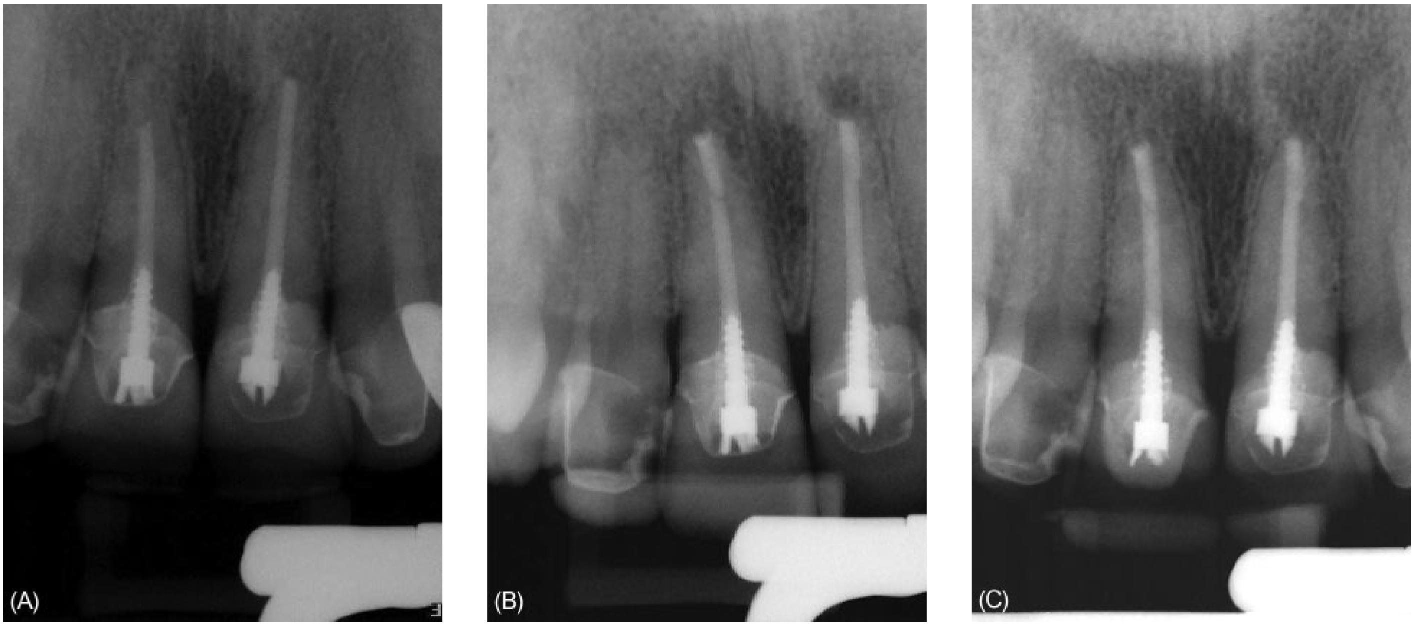

Figure 24.76 **(A)** Surgical retreatment of maxillary anterior periapical lesions. Preoperative radiograph. **(B)** MTA seals of the maxillary central and lateral incisors. **(C)** Ten-year checkup radiograph shows evidence of bone deposition.

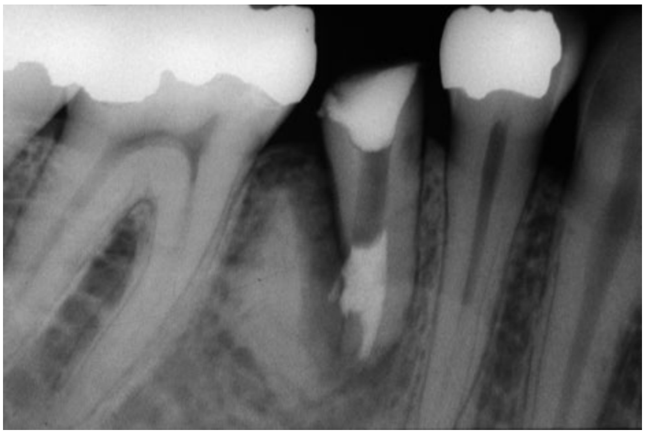

Figure 24.77 **(A)** Nonsurgical post perforation repair. Post perforation of a mandibular premolar tooth. The position of the strip perforation on the distal surface obviates the possibility of surgical repair.

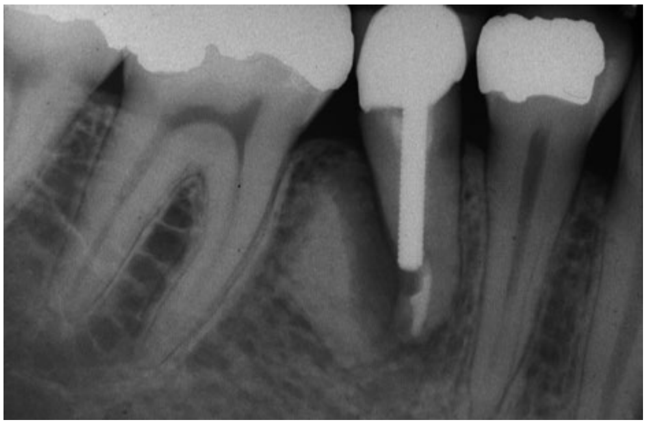

Figure 24.77 **(B)** The crown, core buildup, and the post were removed. The perforation was sealed with MTA. The tooth was restored with a cast post and a PFM crown.

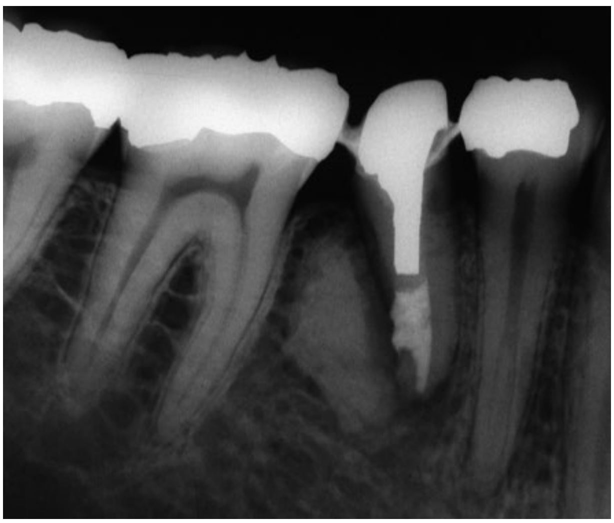

Figure 24.77 **(C)** Sixteen years after repair, the tooth is asymptomatic and there is complete regeneration of the bone in the defect site.

Figure 24.78 **(A)** Amalgam tattoo; 25 years after placement of an apical amalgam seal in the mesiobuccal root of a maxillary first molar and other apical amalgam repair procedures in the vicinity.

Figure 24.78 **(B)** Permanent tissue discoloration from the amalgam filling.

Summary

Endodontic treatment can be the key to long-term success of esthetic restorations. Since success and survival rates of endodontically treated teeth are equal to implants,[48–50] root canal treatment should be considered in the earliest phases of interdisciplinary treatment planning of endodontically diseased teeth. It is essential that your patient is aware that there are alternative methods to restoring the dentition to form, function, health, and esthetics. A well-informed patient will continue to be a trusting patient who values your services throughout their life and the life of the dental procedures.

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PART 5
ESTHETIC CHALLENGES OF MALOCCLUSION

Chapter 25 Oral Habits

Ronald E. Goldstein, DDS, James W. Curtis Jr, DMD, Beverly A. Farley, DMD*, and Daria Molodtsova, MS

Chapter Outline

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Oral habits can, and all too frequently do, cause esthetic and/or functional problems in the mouth. For this reason, destructive habits need to be diagnosed and corrected as early as possible. Most patients are unaware that their oral habits are causing permanent damage to their teeth, such as bruxism, holding their eyeglasses between their teeth, or chewing on ice. Adequate diagnosis of damaging habits requires a thorough evaluation of each patient's stomatognathic state. This must include examination of the form and function of the teeth and the status of the temporomandibular joints and related musculature.

Oral habits should be foremost in the examination and diagnosis of pediatric patients. Later in life, the permanent teeth and mouth should be carefully examined for changes related to oral habits that often occur in response to stress. Hygienists can play a key role in initially detecting wear patterns in teeth that could be arrested. Most people are surprised, but pleased, that their destructive habits can be stopped or the damage from them can be controlled. Dental procedures and corrective behavioral techniques may be helpful in breaking such oral habits. However, unless these habits are totally discontinued, treatment will inevitably serve as only a temporary measure.

Digit sucking

Digit sucking is a habit that usually begins and ends in childhood (Figure 25.1). Failure to stop this behavior can result in adult arch deformities that make correction more difficult (Figure 25.2A–C).

* Deceased

Ronald E. Goldstein's Esthetics in Dentistry, Third Edition. Edited by Ronald E. Goldstein, Stephen J. Chu, Ernesto A. Lee, and Christian F.J. Stappert.

Figure 25.1 This unusual photograph demonstrates the early age (18-week-old fetus) at which thumb sucking may be manifested. Whereas many habits may be acquired, some seem to be genetically inbred, as evidenced in this magnificent photograph. Reproduced with permission from Nilsson.[1]

Figure 25.2 **(A)** This 33-year-old education director told of sucking his thumb as a child, which graduated into a finger-biting habit. Note the position of the thumb during the biting habit.

Figure 25.2 **(B)** Both maxillary and mandibular left central incisors are in labioversion as a result of the finger-biting habit.

It is estimated that roughly 4 of 10 children between the ages of birth and 16 years of age engage in digit sucking at some time during their lives. This habit may also involve several digits or fist sucking as well. Chandler, in 1878, was among the first dentists to correlate thumb- and finger-sucking habits with specific facial deformities.[2] He felt that displacement of teeth, as well as frequent elongation and narrowing of the bones of the nose, resulted from this habit. Much attention has been given to this widespread habit and the adverse dental effects that prolonged frequent digit sucking can produce. Digit sucking may damage the primary dentition and contribute to an atypical resorption pattern of maxillary primary central incisors.[3,4] Detailed reviews of the effects of prolonged thumb and finger sucking on the dental, soft-tissue, and skeletal structures have been written by numerous authors.[5–11] These orofacial malformations are usually unesthetic and may cause malocclusion and speech dysfunction. What is striking about the anomalies described in such abundance in the pediatric dentistry and orthodontic literature is the frequency with which some self-correction occurs if the behavior can be stopped.

For example, Larsson has presented the results of longitudinal studies of children using lateral cephalometric radiographs and observation of the occlusion.[6–8] In the younger children, thumb sucking increased the incidence of open bite with proclined and protruded maxillary incisors, a lengthened maxillary dental arch, and anteriorly displaced maxillary base. He found that finger sucking frequently caused a unilateral abnormal molar relationship on the sucking side of the mouth when the child consistently sucked a thumb. Finger sucking was also an important etiologic factor in the development of a posterior cross-bite in the primary dentition. However, if the children stopped thumb sucking, these malocclusions were somewhat corrected by increased growth of the alveolar process and the eruption of the incisors. Similarly, others have found a tendency to an open bite and an elongated maxillary arch length among children with

Figure 25.2 **(C)** Treatment in this type of habit sometimes consists of orthodontics and/or prosthodontics, depending on whether bone loss is present. Since there was considerable bone loss in this patient, treatment consisted of extraction of maxillary and mandibular left central incisors, plus additional periodontal therapy. Maxillary and mandibular resin bonded fixed partial dentures followed.

strong sucking habits between ages 7 and 16 years.[11–13] The dental effects of the thumb sucking were primarily in the anterior region of the mouth, with 80% of the children shoving the tongue over the lower incisors during swallowing. Eliminating the sucking habit tended to produce spontaneous closure of the open bite and cessation of the tongue thrust.

Bowden found yet other disturbances in persistent thumb suckers: significant increases in the proportion of the protrusive maxillary dental base relationships, tongue thrust activities, tongue-to-lip resting positions, and open bite tendencies.[14] Haryett et al. noted crowding of the mandibular incisors and facial asymmetries resulting from tooth interferences in the molar area because of maxillary contraction from sucking.[15] Infante's study of preschool children found posterior lingual cross-bite and protrusive position of the maxillary molars relative to the mandibular molars to be more prevalent and pronounced among those children who were thumb suckers.[16] Popovich and Thompson concluded that, as the habit persisted, the probability increased that a child would develop a Class II malocclusion.[17] In each of these studies, the problems appeared to diminish in prevalence and severity as digit sucking declined, usually occurring naturally as the child grew older.

Massler believes that some of these displacements can be self-corrected by the molding action of normal labial and lingual musculature once thumb sucking is discontinued. For example, the continued and forceful placement of the thumb against the long axis of the erupting tooth may temporarily displace the erupting anterior teeth.[18] Massler suggested that more marked protrusions probably have a genetic basis. Although this protrusive tendency can be maximized by thumb-sucking behaviors, it can also manifest itself in children who have never been habitual digit suckers.

In addition to the orofacial effects caused by digit sucking, other injuries may arise as a result of this habit. Rayan and Turner described hand complications that may develop from prolonged digit sucking.[19]

Because thumb sucking is such an obvious oral habit, and perhaps because it occurs at a time when parental attention is most focused on the child, the general public has taken part in a sometimes acrimonious open debate over the possible permanent effect of the habit. The debate extends to when, or even if, the parent and/or dentist should intervene. In the 1930s and 1940s, pediatricians, pediatric dentists, and parents were frequently united in their battle against thumb sucking to prevent malocclusion. Infants were sometimes wrapped in elbow cuffs or had the sleeves of their nightgowns tied to prevent fingers from reaching their mouth. However, as Massler described, the result was "that we now are treating a generation of tongue suckers with anterior open bites and lip suckers with the so-called mentalis habit."[18] These habits, he pointed out, persist much longer than thumb sucking and are considerably more difficult to discontinue.

The accepted wisdom of our own age is that most children give up sucking by the age of 3–7 years. Until a child passes this age, it is just as well, and much simpler, to avoid intervention. There is much agreement that digit-sucking habits are unlikely to produce permanent damage to the orofacial structures if the habits are abandoned by 4–5 years of age. Beyond this period, the likelihood of harmful effects is increased. At that time, the help of a behavioral therapist or psychiatrist may be warranted. Techniques available for eliminating the habit include (1) prevention of the habit, (2) positive reinforcement, and (3) aversive conditioning methods.

Management of the habit should involve enlisting the parent and child in a cooperative effort to stop the digit sucking.[20–22] Treatment may require the insertion of a fixed intraoral appliance to stop the sucking activity. For example, a palatal crib appliance blocks the habitual placement of the thumb, alleviates the suction stimuli, and works to restrain the tongue from thrusting against the incisors.

Negative adult oral habits

None of us outgrows the need for oral gratification. Few adults lack some type of learned oral habit to meet these needs. Levitas explains that an action repeated constantly becomes a habit.[23] Usually, the original stimulus or cause quickly becomes lost in the unconscious. Because the need for oral gratification never quite disappears, even as adults, the most common of the unconscious habits center in and around the mouth.

It is the dentist's responsibility to detect habits that are destructive. Unlike children, adult patients seldom make your task easier by displaying the action. Most often, you cannot look for the habit itself but rather only the byproducts of the habit. Unfortunately, by the time the problems are visible, the habit has been present for a long time and is fairly ingrained. This is even more reason for vigilance in detection. Evaluate the patient's stomatognathic state, including examination of the teeth in form and function and the temporomandibular joints and related musculature.

Signs of destructive oral habits

The following are signs that reveal destructive occlusal habit patterns:

- Loss of enamel contour, especially on the incisal edges of the anterior teeth.
- A change in the smile line over the years. This can be observed by asking the patient for earlier photographs beginning at age 13 or 14 years and studying the progressive facial changes. An 8× loop should magnify photographs enough to see these changes.
- Changes in vertical dimension showing facial collapse.
- Wear facets that are destroying the natural esthetic contour of the teeth. In particular, any change in the canine's silhouette form should be noted.
- Newly apparent spaces in the mouth or the enlargement of previously existing spaces.
- Newly flared, erupted, or submerged teeth.
- Ridges, lumps, or masses in the tissue of the tongue, lips, or inside the mouth.

Bruxism

The most damaging, most frequently seen, and most frequently missed of all of the destructive oral habits is bruxism, which can destroy the form and integrity of the incisal edges of the anterior teeth (Figure 25.3A).

Esthetic treatment of the ravages of bruxism first involves habit correction control and or treatment. Second, if possible, restore the lost tooth form with bonding, veneering, or crowning combined with cosmetic contouring (Figure 25.3B) of the opposing teeth.[24–27] This usually consists of beveling the opposing teeth and replacement of the worn tooth structure. Sinuocclusal pathways must remain the same; try not to contour areas that are involved in excursive movement. If it is not possible to restore missing tooth structure, it may be possible to restore esthetics through cosmetic contouring. Also, if the anterior teeth have worn evenly, reshape the laterals to create more interincisal distance. This technique can be effective in achieving an illusion of greater incisal length, thus providing enhanced esthetics.

Bruxism may be a learned behavior that is a reaction to stress associated with various dental or medical conditions, such as malocclusions, missing or rough teeth, infections, malnutrition, and allergies.[28–33] These conditions may contribute to the extent to which bruxism is manifested (Figure 25.4A and B). Studies by Hicks and colleagues showing an increase in bruxism among college students implicated stress as a major etiologic factor.[31,34]

Figure 25.3 **(A)** This 30-year-old teacher had worn her left canine flat due to bruxism.

Figure 25.3 **(B)** After treatment for the condition, which consisted of appliance therapy, the anteriors were cosmetically contoured rather than adding to the tooth surface. In cases like this, it is important for the patient to wear an appliance afterward to make certain that additional bruxism will no longer destroy enamel.

Figure 25.4 **(A, B)** This 50-year-old man was completely unaware of his nocturnal bruxism. In fact, during waking hours, it was difficult for him to get his teeth to fit together in the eccentric position.

Cigarette smoking has been shown to exacerbate nocturnal bruxism.[9,35] Numerous reports have shown bruxism to be related to sleep disorders and sleep apnea.[36–39]

Bruxism can sometimes begin after orthodontic treatment for crowded teeth. After incisors are realigned, the patient can develop a habit of clinching and grinding in the anterior region that can eventually destroy incisal anatomy.

Bruxism with temporomandibular joint pain

Esthetic destruction of the patient's teeth can be sufficient to enable us to recognize the disease process of temporomandibular joint pain long before the patient actually begins treatment.[40–48]

The following case illustrates this position. A young woman had been treated without success by several physicians for headaches, dizzy spells, and neck, back, and shoulder pain (Figure 25.5A–E). Her problems with pain, as well as with the destruction of her teeth, appeared to be related to her bruxism. When asked to open her mouth, she deviated sharply to one side. The intraoral muscles (pterygoid and masseter) and ligaments were in acute spasm and tender to palpitation. Treatment began with insertion of a maxillary bruxing appliance. (With bruxism patients, it is important to obtain study casts to determine if there are wear facets, where they are located, and why they occurred.) The bruxing appliance was constructed to help stop the incisal wear. The patient's teeth were then reshaped to improve the smile line. Most pain and headaches stopped within a period of 3–6 weeks after the insertion of this appliance, together with muscle therapy to the affected areas.

The patient must realize the importance of continuing to wear the bruxing appliance to maintain the esthetic correction and to avoid reintroducing temporomandibular joint pain and dysfunction.[49]

Figure 25.5 **(A)** Bruxism was the chief cause of wear for this 31-year-old woman.

Figure 25.5 **(B)** Note how she would unconsciously put the tongue behind the front teeth to hide the space that shows a jagged outline. In addition to poor esthetics, the patient also suffered constant headaches and neck and back discomfort because of further temporomandibular joint dysfunction.

Figure 25.5 **(C)** A removable appliance was made to correct the temporomandibular joint dysfunction and prevent teeth from further wearing away. Following 3 months of temporomandibular joint treatment to cure the symptoms and relax the muscles, the patient wore the appliance only at night.

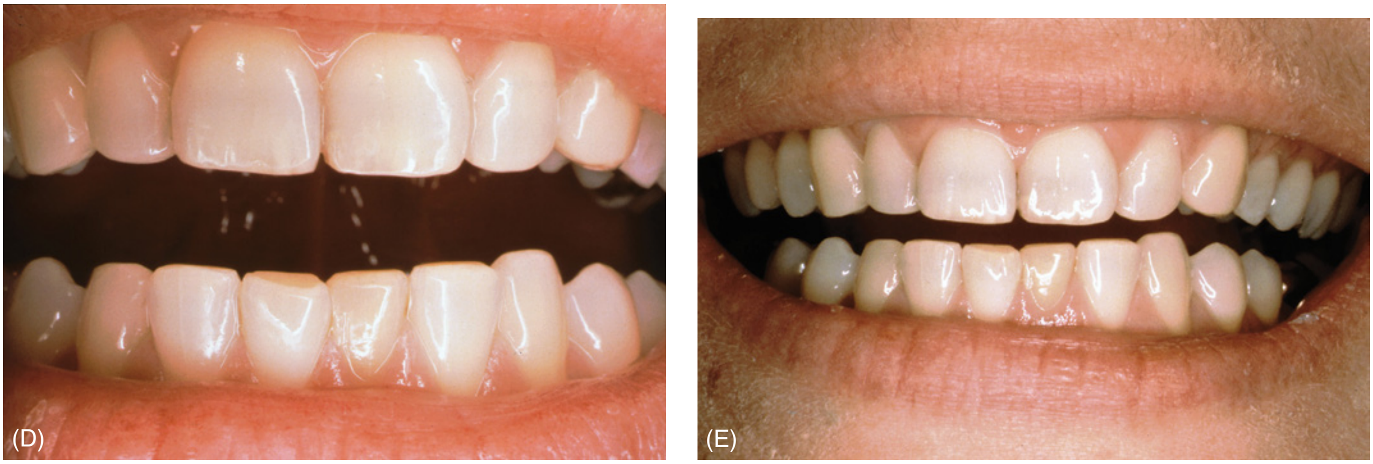

Figure 25.5 **(D, E)** After several months of appliance therapy, the square, masculine-looking upper and lower teeth were cosmetically contoured to produce a more feminine and attractive smile.

Chewing habits

The use of smokeless tobacco is another habit that causes excessive wear on the dentition, in addition to the potential of causing oral cancer.[50–52] The lingual cusps of maxillary teeth and buccal cusps of mandibular teeth are the most affected, often worn to the gingival margin. Staining of exposed dentin is also readily apparent.

Dark brown/black stains on the teeth, marked abrasion of anterior teeth, and pathologic changes of the oral mucosa are seen in many eastern countries, such as India, Malaysia, and Thailand, in those who chew betel nuts for medicinal and/or psychological purposes[53–55] (Figure 25.6). Patients who refuse or cannot stop the habit should be on monthly "cosmetic" cleanings. This type of prophylaxis is most readily accomplished using a high-powered, mildly abrasive spray. These patients should be warned that the sharp edges of the betel nut may cut the gingiva, leading to ulceration. In addition, the betel nut contains carcinogens that can lead to the development of oral cancer in habitual users. Coca leaf chewing was shown to cause similar effects on the dentition in ancient cultures.[56]

Tongue habits

The tongue is one of the strongest muscles in the human body. The most frequent signs of tongue thrust are protrusion of the tongue against or between the anterior teeth and excessive circumoral muscle activity during swallowing. Although pushing the tongue against teeth, particularly between spaces in the teeth, does not invariably cause harm, it is certainly a potential cause of damage. Either maxillary or mandibular teeth can become involved (Figure 25.7). Indentations in the tongue have been reported to provide an indication of clenching.[57] Gellin, however, feels that anterior tongue positioning does improve with time, and the continual growth and development of the lower face allow for diminishing anterior tongue positioning.[20] Various studies showed the relationship between tongue thrust and malocclusion.[58–60]

There are clinicians who have observed a large number of patients with malocclusions who demonstrate a protrusive tongue tip pattern against or between the anterior teeth while speaking or swallowing. This group suggests that tongue thrusting is one of the primary etiologic factors in open bite and incisor protrusion. There is also much controversy concerning the use of removable appliances in the treatment of tongue twisting.

Figure 25.6 This 35-year-old male had the habit of placing betel nuts under his tongue, which helped to produce the black stain shown.

Figure 25.7 This 47-year-old teacher developed a habit of forcing her tongue between her maxillary and mandibular incisors. Note the large space created as a result of years of tongue pressure.

The young woman in Figure 25.8A and B would like to advance her modeling career, but a space between her teeth appears as a black hole in photographs. Consequently, she poses with her tongue pressed behind the space in her teeth in an attempt to hide the darkness. This trick helps with the photographic illusion, but if she presses her tongue too much in a labial direction, the space can increase over the years. The habit of putting the tongue between the teeth to disguise a space will almost certainly cause the space to increase with time (Figure 25.8C). Treatment of spaces between the teeth is usually best handled through orthodontic care and possibly myofunctional therapy to promote a more positive resting and swallowing tongue position. However, some patients may not mind, and may even prefer their teeth with a space. Although no space should be corrected without approval from the patient, even these patients need to be referred to an orthodontist for monitoring and control of any further widening that might have functional implications.

For those patients who desire closure of the diastema, referral to an orthodontist can determine if repositioning of the teeth is appropriate. In discussing the referral with the patient, make certain that it is understood that orthodontics does not need to be a matter of metal brackets. One of the most common solutions to gaps is the construction of a retainer that the patient wears at night. After the teeth have stabilized, the retainer can be worn a few nights each week to maintain tooth position and prevent reopening the space.

An alternative or compromise treatment consists of bonding composite resin to close the spaces. Crowns and porcelain veneers can also serve this function, but bonding has the advantage of reversibility. The patient could later elect to have orthodontic treatment, especially if the spaces continue to widen.

Sometimes, orthodontics may not be the patient's choice, and the following case illustrates an alternative, restorative means of treatment. The young man shown in Figure 25.9A–H was extremely self-conscious about a space between his central incisors caused by a tongue thrust. He was referred for orthodontics, both to correct the space and to correct his destructive habit. However, the appliance needed to correct the spacing between this young man's teeth gave him what he considered a freakish appearance, and he asked for an alternative treatment. Treatment was then planned using composite resins, which, although not permanent, produce immediate results.

Figure 25.8 **(A)** This 23-year-old model had a diastema between the maxillary central incisors.

Figure 25.8 **(B)** When smiling, she would place her tongue behind the two front teeth to hide the space, which would otherwise show up dark. Note how the tongue creates a pink filler similar to gingival tissue. Many models unconsciously develop similar habits, which can create additional space because of the tongue pressure if done over a long period of time. It is much wiser to either close these spaces orthodontically or compromise with restorative means.

Figure 25.8 **(C)** The habit of placing the tongue between the teeth to disguise a space will almost certainly cause the space to increase with time.

Figure 25.9 **(A)** This 32-year-old was self-conscious about a space between his front teeth that was originally caused by tongue thrusting.

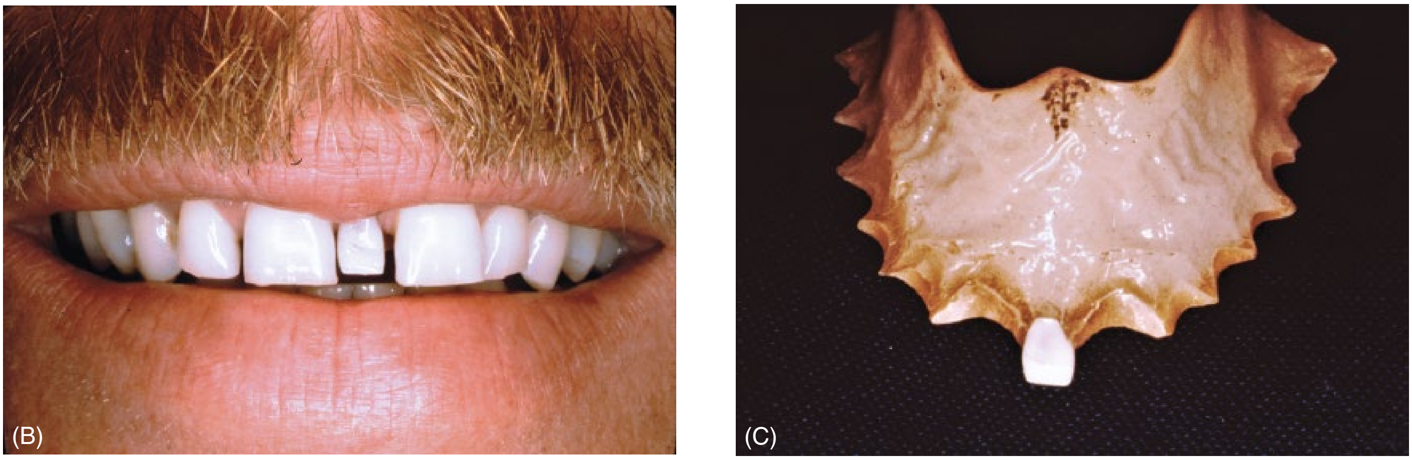

Figure 25.9 **(B, C)** The patient shown in 25.9A felt that people were noticing his smile, and since he did public speaking, he wanted to improve his appearance. This replacement had been in the mouth for 16 years.

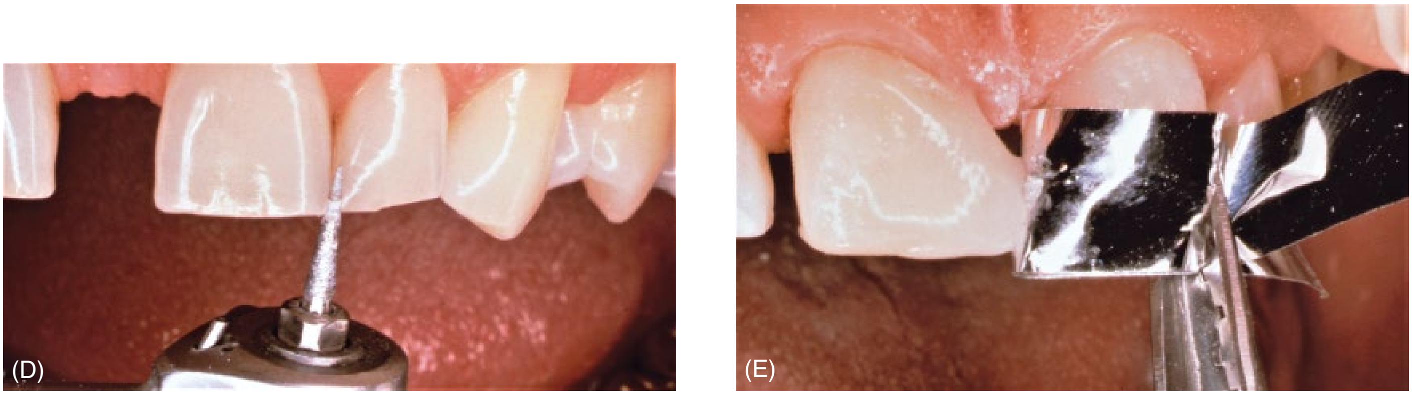

Figure 25.9 **(D, E)** The patient was referred for orthodontic consultation but elected to have composite resin bonding as a compromise treatment.

Figure 25.9 **(F–H)** Although closing the space created a disproportionate overbuilding of the two central incisors, through judicious carving of the finished bonded restorations, a more proportionate and not unattractive arrangement can be achieved. This consisted of opening the incisal embrasures, as well as creating a greater interincisal distance.

Lip or cheek biting

The signs of lip or cheek biting are usually telltale marks from the teeth (Figure 25.10A and B). Glass and Maize have described the appearance of oral tissues that have been chewed or bitten over a period of time.[61] This results in the appearance of hard fibrous knots or masses known as morsicatio buccarum et labiorum. Sometimes, the patient uses the teeth to suck or knead the altered tissue. If the habit continues over an extended period of time, it can also cause tooth abnormalities by enlarging any small diastema or interdental space. The more a patient chews or sucks, the more pressure is created between the teeth and the wider the space.

Other lip habits, such as lip wetting or lip sucking, and a swallowing pattern that includes a hyperactive mentalis muscle can cause damage to developing orofacial structures in children. Lip wetting is frequently unnoticed by the average dental practitioner. Clinically, the entire lip looks soft and moist and does not have a sharply demarcated vermilion border.

Cheek biting is one of the most frequently seen destructive oral habits and can reflect a circular pattern (Figure 25.10C). Sometimes, loss of part of a tooth or an entire tooth can initiate cheek biting. The presence of resulting fibrous tissue may cause the patient to pull the knot of tissue between the teeth and begin to suck. Diagnosis of cheek biting can be made by examining the inside border of the cheek for a flickered, sometimes white fibrous ridge midway between the arches.

Treatment of lip biters and cheek biters consists of several steps. The first usually involves reshaping the teeth to round, smooth, and polish any sharp edges. It is also important in working with such patients to find out if there has been any recent crowning, lengthening, or shortening of the teeth or other changes that might have induced this habit. If so, they may need to be modified.

Figure 25.10 **(A)** This 29-year-old woman felt that her upper teeth were "growing down more" and irritating her lower lip. She was told to let us know exactly when she closed her lip and felt that it was fitting tightly into the teeth.

Figure 25.10 **(B)** During her next appointment, she stated that she realized that she is both sucking and biting down on her lip at the same time.

Figure 25.10 **(C)** This 50-year-old woman had a habit of biting her cheek. Note the pattern of white fibrous tissue.

Figure 25.10 **(D)** Since her external pterygoid muscles were in spasm, it was also felt that she could be grinding her teeth, so an upper temporomandibular joint appliance was constructed, rounding the labial incisal angle in particular.

Figure 25.10 **(E)** After 5 months of wearing the appliance, at first all of the time and then at night only, the patient's tissue returned to normal. In addition, her muscle spasms disappeared, and all other symptoms subsided.

Figure 25.11 **(A)** This 50-year-old man had been sucking the lower left lip into an open interdental space between the mandibular left central and lateral. Note the lesion created on the lower left inner border of the lip due to the patient's sucking habit.

Figure 25.11 **(B)** A vacuform matrix was made to close up this area to see if the patient could break the sucking habit. Unfortunately, the only time the patient could eliminate the habit of sucking was when the appliance was being worn.

Figure 25.11 **(C)** It was decided to bond the mandibular incisors to eliminate space and thereby help to eliminate his sucking habit. Had the patient been able to alleviate the habit with the matrix, it would have been possible to eliminate the need for closure of this space.

Figure 25.12 **(A)** This young lady developed a habit of sucking her upper lip.

The second part of treatment usually involves creating an appliance to prevent the patient from biting the lip or cheek (Figure 25.10D and E).[62] This should be as thick as feasible and rounded on the labial surface. As a temporary measure, a removable acrylic interdental spacer or a vacuform matrix can be used to prevent the patient from biting or sucking (Figure 25.11A–C).

One of the added advantages of such devices, which are worn around the clock during the early phases of treatment, is that they make the patient more aware of the intensity and frequency of such habits and the circumstances under which they most often manifest themselves. Many patients are not aware that they bite or suck their lips or cheeks, especially in relation to stress. Once the patient stops biting the lip, the use of the appliance can be reduced to evenings only. Most patients will require between 3 and 6 months to correct the problem (Figure 25.12A–D).

Finally, any space between the teeth can be corrected via orthodontics or the application of composite resin bonding or porcelain veneers to close the diastema (see Figure 25.11C). The use of full crowns would be a third choice to close the space.

Mouth breathing

Common in childhood, mouth breathing is the habit of using the mouth instead of the nose for respiration regardless of whether the nose is obstructed. However, there are often specific reasons for mouth breathing, such as allergies, enlarged nasopharyngeal lymphoid tissues, and asthma.[64–67] The prevailing hypothesis is that prolonged mouth breathing during certain critical growth periods in childhood causes a sequence of events that results in dental and skeletal changes. Excessive eruption of the molars is almost always a constant feature of chronic mouth breathing. This molar eruption causes clockwise rotation of the mandible during growth, with a resultant increase in lower facial height. The increased lower facial height is often associated with retrognathia and anterior open bites. Low tongue posture is seen with mouth breathing and impedes the lateral expansion and anterior development of the maxilla.[68–79] The dentofacial effects that develop in children persist into adulthood, and the mouth-breathing and tongue-thrusting behavior may continue. Barber has found that mouth breathing can lead to dryness and

Figure 25.12 **(B)** A bulbous lesion was the result of the constant suction action that prompted the patient to seek treatment only for the lip but not the obvious caries. *Source:* Reproduced with permission from Goldstein.[63]

Figure 25.12 **(C)** A removable maxillary appliance was made for the patient to wear full time until she completely broke the habit. Note also advanced caries, which needed to be treated.

Figure 25.12 **(D)** It required only several weeks for the patient to gain back her normal-appearing lip. Then the patient could focus her attention on her other dental treatment.

irritation of the throat, mouth, and lips, as well as chronic marginal gingivitis.[80] Also, it is strongly associated with both lip-biting and lip-wetting habits. It may be necessary to treat the mouth-breathing habit prior to or in conjunction with the treatment of the lip habit.

Eating disorders and poor dietary habits

Anorexia nervosa and bulimia are psychosomatic eating disorders that have associated oral symptoms. The exact prevalence of these eating disorders is unknown. However, they are most frequently seen in young women, ranging from adolescence into early adulthood. In some studies,[81–84] it has been estimated that eating disorders affect up to 20% of the women on college campuses. As our culture continues to emphasize outward appearance, it is likely that this problem will not resolve soon. Dentists are often the first health-care professionals to recognize the signs of eating disorders, particularly bulimia. It may well be that the obsession to improve outward appearances that drives some individuals to develop eating disorders may also fuel their desire for esthetic dental services. Thus, practices that have a strong emphasis on esthetic care should be diligent in assessing their patients, especially young women, for signs of eating disorders.

The bulimic patient ingests large amounts of food, followed by voluntary or involuntary purging. The purging may occur with the use of high doses of laxatives or induced vomiting. In those bulimics who purge by vomiting, the pH of the gastric acid is low enough to initiate dissolution of the enamel. Further compounding the problem is the frequent vigorous tooth brushing that is used to rid the mouth of the taste and telltale odor of the vomitus. Brushing the teeth immediately after they have been exposed to gastric acids will accelerate the loss of enamel. Numerous studies show that a high percentage of patients seen with bulimia exhibit lingual erosion of the maxillary anterior teeth caused by regurgitation of gastric acids (Figure 25.13A–D).[85–89] If the disorder persists, the erosion will eventually affect the occlusal surfaces of the molars and premolars. If the bulimia is not controlled, the entire dentition may be destroyed, necessitating complete dental rehabilitation with full-coverage restorations. Unfortunately, if the habit persists after the rehabilitation, these patients are likely to develop recurrent caries around the margins of the crowns.

Patients with anorexia nervosa pose an entirely different set of problems. Although bulimia and anorexia are disorders that involve a severely altered self-perception, individuals with anorexia may tend to fully lose self-esteem and fall into a state of total oral neglect. In its severest form, patients with anorexia may present with rampant caries and notably dry mucosa (Figure 25.14A–C). They are very prone to the effects of metabolic imbalance and should be treated cautiously in the dental office.

In addition to the intraoral ravages of bulimia and anorexia, outwardly visible signs of these disorders can be seen. Figure 25.15 shows a 35-year-old female who suffered from both bulimia and anorexia. Notice the swelling of the parotid gland, clearly seen at the angle of the mandible. This hypertrophy of the gland is commonly seen in bulimics. It is caused by repeated vomiting and is present bilaterally. Also, on close examination of the photograph, a fine, downy facial hair can be detected. This facial hair is called lanugo and may be found in anorexics.

The dental manifestations of eating disorders can be treated immediately, but treatment must be limited to emergency, preventive, and/or temporary measures until the disorder is brought under control. Preventive measures to reduce the damaging effects of gastric acids can be immediately employed. The first measure is to have the individual refrain from brushing the teeth after vomiting. Second, oral rinses to reduce the pH in the mouth can be extremely helpful. Water can be used to rid the mouth of the acids that are present. If available, sodium bicarbonate (baking soda) rinses can neutralize the acidity in the mouth following an episode of vomiting. Various topical fluoride preparations will aid in minimizing the acidic destruction of the enamel and dentin. Because of the psychosomatic nature of anorexia and bulimia, it is imperative for the dentist to approach these patients in a factual, nonconfrontational, concerned manner that will encourage them to seek proper medical attention.

People who habitually eat or suck on lemons or drink large amounts of lemon-flavored water may exhibit acid erosion (Figure 25.16A and B). This erosion is seen on the labial surfaces

Figure 25.13 **(A)** Preoperative upper anterior palatal view of a bulimic patient shows extreme erosion of the lingual and occlusal surfaces. *Source:* Figure courtesy of Dr Vincent Celenza.

Figure 25.13 **(B)** Final restorations in place. *Source:* Figure courtesy of Dr Vincent Celenza.

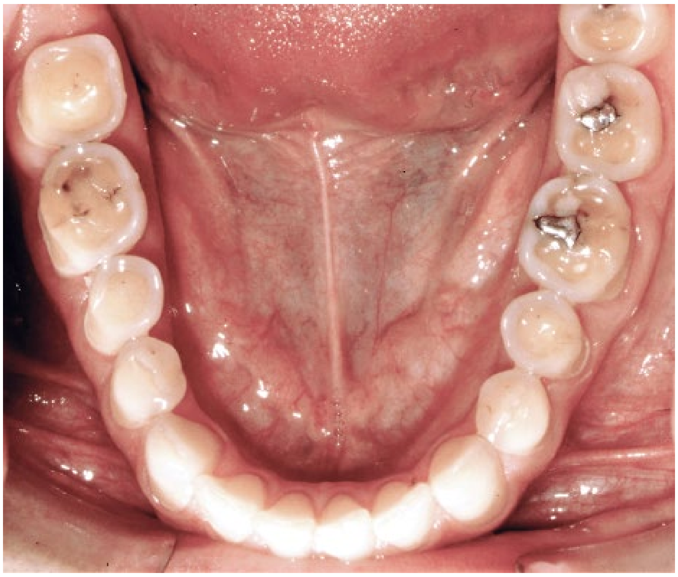

Figure 25.13 **(C)** Preoperative occlusal view of the lower arch showing extreme occlusal acid erosion. *Source:* Figure courtesy of Dr Vincent Celenza.

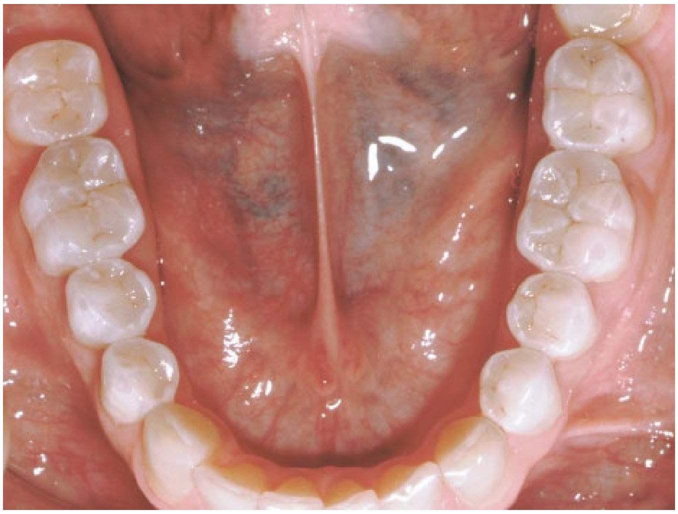

Figure 25.13 **(D)** Full arch view, 2.5 years after placement. *Source:* Figure courtesy of Dr Vincent Celenza.

(A)

(B)

Figure 25.14 **(A, B)** This 28-year-old female had been anorexic since age 17. She had unsuccessfully participated in numerous counseling programs, and her self-image continued to be extremely poor. Although she weighed only 92 lb, she perceived herself to be grossly overweight. She was so focused on her body's appearance that she totally neglected her oral health. Note the loss of teeth and decay.

Figure 25.14 **(C)** Although not completely visible, this photograph illustrates drying and atrophy of the oral mucosa as seen on the lateral and ventral surfaces of the tongue.

Figure 25.15 Bulimia and anorexia can occur in the same patient. This 35-year-old female initially manifested her eating disorder as bulimia when she was about 15 years old. Over the years, she has continued her purging, and while in college she began to exhibit behavior characteristic of anorexia. She is now firmly entrenched in both bulimia and anorexia. Her parotid hypertrophy is a manifestation of her bulimia. The lanugo (fine facial hair) is a sign sometimes seen in anorexics.

of the anterior teeth if they suck the fruit or the lingual surfaces if they chew it. Those who actually eat lemons may present with lingual erosion that mimics that of bulimia. Excessive consumption of fruits and drinks with high acid such as kombucha content can cause decalcification of enamel and dissolution of dental tissues (refer to Chapter 22).

In cases of dental erosion, the teeth first exhibit a diminished luster. As continual erosion leads to smoothing of enamel pits, the eroded areas eventually appear smooth and polished. Advancing erosion results in exposed dentin that wears down rapidly and often exhibits extensive sensitivity.

Early detection of erosive lesions and identification of patients at high risk for developing erosion are most important. If you detect erosion, it is essential to ask if the patient has changed their eating habits or diet recently.

Caries is frequently seen in patients who have a habit of sucking hard citrus-flavored candies with high sugar content (Figure 25.16C). Thus, rebuilding the lost tooth structure offers only palliative therapy. Dietary changes must be made in these patients who insist on continuing with this habit pattern. Dental management of patients with these disorders should be

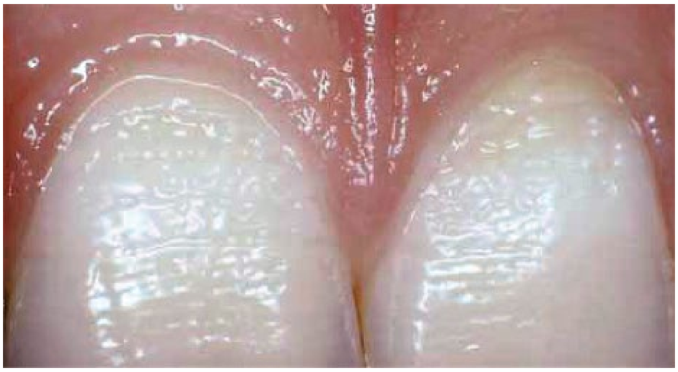

Figure 25.16 **(A)** People who have a habit of sucking lemons seldom are aware of the potential for damage to their enamel. This patient was diagnosed early in her habit, so a minimum of damage was done.

Figure 25.16 **(B)** Composite resin bonding was the treatment of choice.

Figure 25.16 **(C)** This 63-year-old had a habit of sucking one pack of Lifesavers candy daily. In addition, she ingested two tablespoons of vinegar and 500 mg of vitamin C. Her maxillary teeth showed considerable damage due to caries and erosion. Treatment included full-mouth restoration with full crowns on the maxillary teeth.

conservative. Bonded composite resin or glass ionomer materials may reduce sensitivity and prevent the erosion from progressing. Any extensive dental treatment, such as crown and bridge, should be postponed until the disorder/habit itself is controlled or stabilized. Otherwise, dental treatment may not be effective.

Alcohol and drug abuse

Chronic alcoholism is another disorder that has oral implications (Figure 25.17). Case studies describe patients with a history of chronic alcoholism that have extensive wear of the teeth.[90–92] All had loss of lingual and incisal surfaces of the maxillary anterior teeth consistent with regurgitation erosion. This regurgitation results from a gastritis that is produced by ingestion of excessive amounts of alcohol.

Abuse of specific drugs has been shown to have adverse effects on the dentition. Individuals who regularly use methylenedioxymethamphetamine ("ecstasy") may have excessive wear of the teeth.[93,94] This occurs through a dual mechanism of decreased salivation and hyperactivity of the muscles of mastication. In essence, this drug evokes a form of bruxism that occurs in a dry mouth. Although not reported, other amphetamines may cause similar conditions. Cocaine has been reported to cause dental erosions because of its acidic nature.[95] Some abusers obtain their high by wetting the tip of their finger, dipping it into the cocaine, and wiping the drug into the buccal vestibule or onto the gingival tissues. When the acidic drug comes in contact with the tooth surface, erosive lesions can develop.

Other substances such as anabolic steroids can also be detrimental to oral health. It was found that the use of anabolic steroids by athletes caused gingival overgrowth.[96] Gingival overgrowth is a condition in which the gingival tissues become swollen and grow over the teeth. Overgrown gums make it easier for bacteria found in plaque to accumulate and attack supporting structures of the teeth, potentially leading to severe periodontal infection.

Figure 25.17 Chronic alcoholism is a habit that can produce various intraoral problems. This retired gentleman is a good example of how loss of self-respect can lead to greater oral disease. He quit caring about his appearance and completely gave up oral hygiene, as evidenced in this image.

Furthermore, cigarette smoking is one of the most addictive habits in contemporary life. People who smoke are more likely to accumulate calculus and plaque due to reduced salivary flow. Tobacco also limits blood flow to gum tissues, restricting the necessary nutrients to the bone and periodontal support of the teeth, thus leading to gum recession and bone loss. Cigarette smoking has also been shown to exacerbate nocturnal bruxism, which induces loss of tooth structure.[9,35] In addition, tobacco smoke contains a number of carcinogens, and leads to the development of oral and/or lung cancer.

Foreign objects in the mouth

Another habit that can produce permanent damage to the dentition relates to placing foreign objects in the mouth. The resultant damage is caused by abrasion, which is a term used to describe wear or defects in tooth tissues resulting from contact with a foreign object. The following are some of the more common types of habits that can cause this damage.

Fingernails

Since the fingernail is an extension of the finger, one may wonder if the common practice of placing the fingernails between the teeth is a continuation of a previous thumb- or finger-sucking habit. It may also begin suddenly, well into adult life, because of a chipped or spaced tooth or some roughness in the mouth that acts like a magnet for some people, perhaps in an effort to smooth out the roughness.

The most destructive of the fingernail habits involves the patient's wedging the fingernail in an interdental area that eventually becomes a space (Figure 25.18A–D). Treatment involves closure of the space. It is important that the patient be aware that continuation of this habit can quickly reopen the space. In some cases, it may be necessary to restrain the individual by constructing a vacuform matrix to cover the entire arch or an orthodontic retaining appliance (see Figure 25.18C and D). The patient should wear this appliance full time for 6 weeks. Closure of the space during this period, together with a 3-month retaining period, should be sufficient to break the habit. You can help ensure that the habit does not recur by cosmetically contouring the teeth to remove any rough or sharp edges.

Nail biting is also a learned habit that may provide a physical mechanism for stress relief. Encourage your patients to have short, well-manicured nails. Rough edges in the nail may cause the patient to smooth the nail unconsciously by rubbing it in the incisal embrasure. Also, advise the nail biter to carry a fingernail clipper at all times so that "nervous energy" can be converted into self-manicuring the nails when a possible urge to bite the nails exists. Behavioral techniques to reduce stress levels will aid in eliminating this type of habit.

Pins placed between the teeth

Placing various types of pins, needles, or even bobby pins in one's mouth is not an uncommon habit, particularly among people

Figure 25.18 **(A)** This 30-year-old developed a habit of putting her nail between her lower incisors.

Figure 25.18 **(B)** Note the space created between the lateral and central incisors on the lower right side due to fingernail pressure.

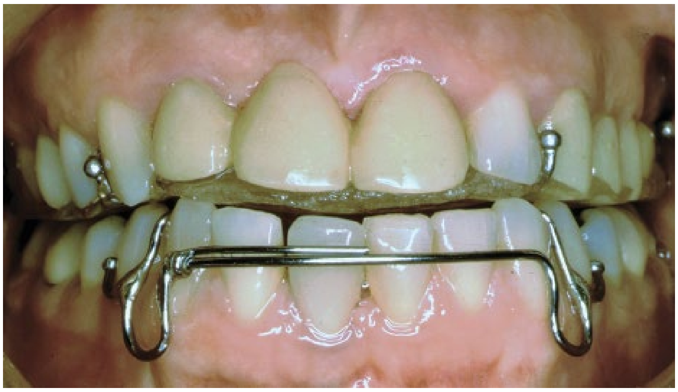

Figure 25.18 **(C)** A removable Hawley-type orthodontic appliance was constructed to reposition the lower anteriors. Because of the nature of this appliance, it also helped the patient to break the habit, since she could not put the fingernail into the same space.

Figure 25.18 **(D)** The final result after approximately 6 months of treatment.

who knit and sew. People suffering tooth deformity from this habit usually hold the pin or needle between their anterior teeth (Figure 25.19A–D). Diagnosis can often be made by checking the patient's protrusive end-to-end relationship to see if a perfect matching groove is present. It is helpful to ask patients about their work and hobbies. Taking a thorough habit history, such as the one in Figure 25.20, is helpful. Treatment follows the pattern of other habits described in this section; that is, appearance is restored and whatever appliances and means necessary to discourage continuance of the habit are used. With this problem, it is also useful to tell the patient to at least vary the location where the pins are held.

Thread biting

Thread biting may produce notches in the incisal edges of anterior teeth. This is an occupational habit. Patients who are seamstresses should be warned against this behavior. Sharp edges of enamel that produce irritation should be eliminated by careful rounding or restorative treatment (Figure 25.21A and B).

Oral piercing and metal mouth jewelry

Metal mouth jewelry is often the culprit in cracked or broken teeth. Plastic jewelry reduces this risk, though cannot eliminate it entirely. For piercings of the lips, the "backside" of the jewelry, attached inside the mouth, can be a source of irritation to the opposing tissue. As the metal or plastic rests on the gum tissue, it can abrade and literally wear it away as it moves back and forth. For this reason, it is especially important to check the tissue around and touching any metal or plastic in the mouth regularly to ensure the continued health of these tissues. If the jewelry is causing damage or infection, it is essential to discover this early in the process (Figure 25.21C–F).

Stim-u-dents or toothpicks used as wedges

Toothpicks or Stim-u-dents can provide an effective means of cleaning tooth surfaces. If the object is forced between the teeth, however, it can create unwanted spaces. Patients should be told to use the toothpick or Stim-u-dent like a soft brush to clean plaque or debris from the smooth surface of the tooth (Figure 25.22A and B).

Figure 25.19 **(A)** This 39-year-old interior designer had a habit of holding sewing needles and pins between her cuspids.

Incorrect use of dental floss and toothbrush

Abnormal tooth wear may result from improper oral hygiene procedures. Misuse of dental floss may cause abnormal tooth wear. Excessive and strenuous use of dental floss apical to the cementoenamel junction may result in notching of the root surfaces. In addition, tooth abrasion may occur from incorrect use of a toothbrush. Toothbrush abrasion can be extreme, particularly if related to obsessive or compulsive behavior (Figure 25.23A–C).

Finally, incorrect use of dental floss can lead to abnormal loss of interdental space. Figure 25.24A–D shows a patient who has had bonding of her anterior teeth and unfortunately developed an incorrect method of flossing.

Pen or pencil chewing

This habit became considerably more destructive when pencils changed from wood to the newer plastic types (Figure 25.25A–E). It is not uncommon to see this habit in business people who spend a great deal of time at their desks working figures. Treatment involves wearing an appliance that prevents the patient from placing the pen or pencil between the teeth.

Figure 25.19 **(B)** The patient had actually worn a small groove in the biting edge of the teeth that exactly fit the sewing needle she used. In addition to cosmetic contouring or composite resin bonding to add to the worn spot, be sure to have the patient avoid consistently placing any foreign objects between the teeth.

(C)

(D)

Figure 25.19 **(C, D)** This patient wore a small groove in her tooth from constant use of bobby pins.

Habit Questionnaire
Does Your Habit Affect Your Smile?

(Please check the appropriate space)
Do you now or did you ever

	Yes	No
1. Chew your lips or cheeks?	_____	_____
2. Suck your fingers, thumbs, or lemons?	_____	_____
3. Chew ice?	_____	_____
4. Bite your fingernails?	_____	_____
5. Hold pins or needles in your mouth?	_____	_____
6. Chew pencils or plastic pens?	_____	_____
7. Chew or hold your glasses in your mouth?	_____	_____
8. Crack nuts or ice with your teeth?	_____	_____
9. Play a musical instrument that requires you to hold the instrument with your teeth?	_____	_____
10. Smoke a pipe, cigar, or cigarettes?	_____	_____
11. Bite or suck your lips?	_____	_____
12. Use Stimudents or toothpicks?	_____	_____
13. Keep your tongue pressed against the upper teeth?	_____	_____
14. Place your tongue in a space between your teeth?	_____	_____
15. Grind or clench your teeth?	_____	_____

If you answer “yes” to two or more of the above questions, you may have a habit problem. Ask your dentist to see if your habit or habits are causing potential damage to your teeth.

Figure 25.20 The first step in either preventing or stopping a destructive oral habit is to help patients to discover their habits. *Source:* Reproduced with permission from Goldstein.[63]

Figure 25.21 **(A)** This 55-year-old woman developed a habit of cutting sewing thread with her incisors.

Figure 25.21 **(B)** The patient eventually wore a groove in the maxillary right central incisor.

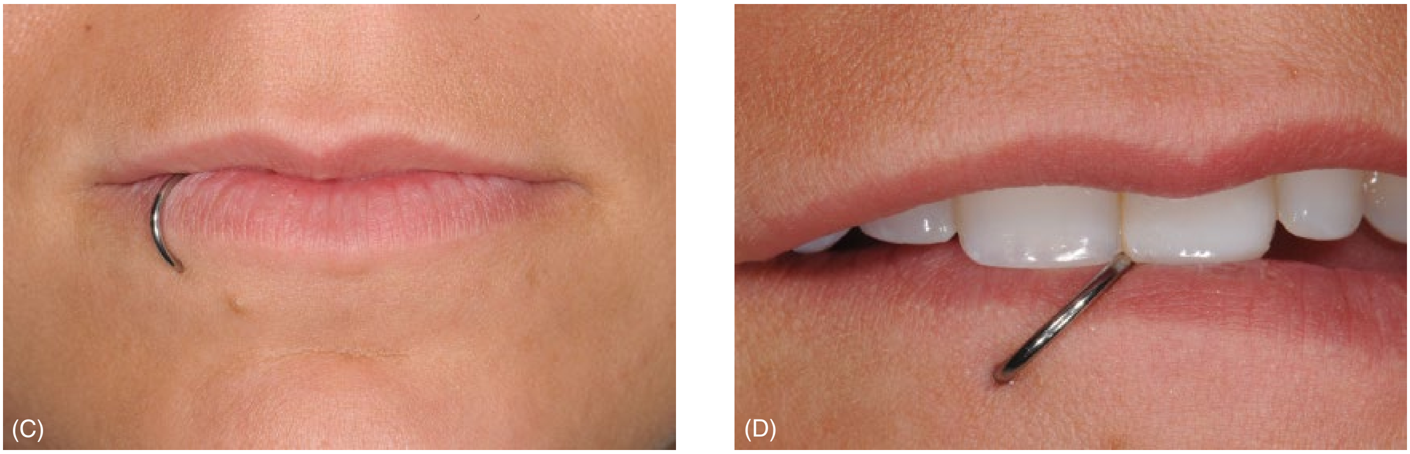

Figure 25.21 **(C, D)** This 25-year-old female had a habit of biting on her lip piercing.

Figure 25.21 **(E)** As a result of her bad habit, she chipped the mesial of her left central incisor.

Figure 25.21 **(F)** Composite resin bonding was used to restore the chip in her tooth. In addition, the patient was advised to quit the habit or remove the lip piercing.

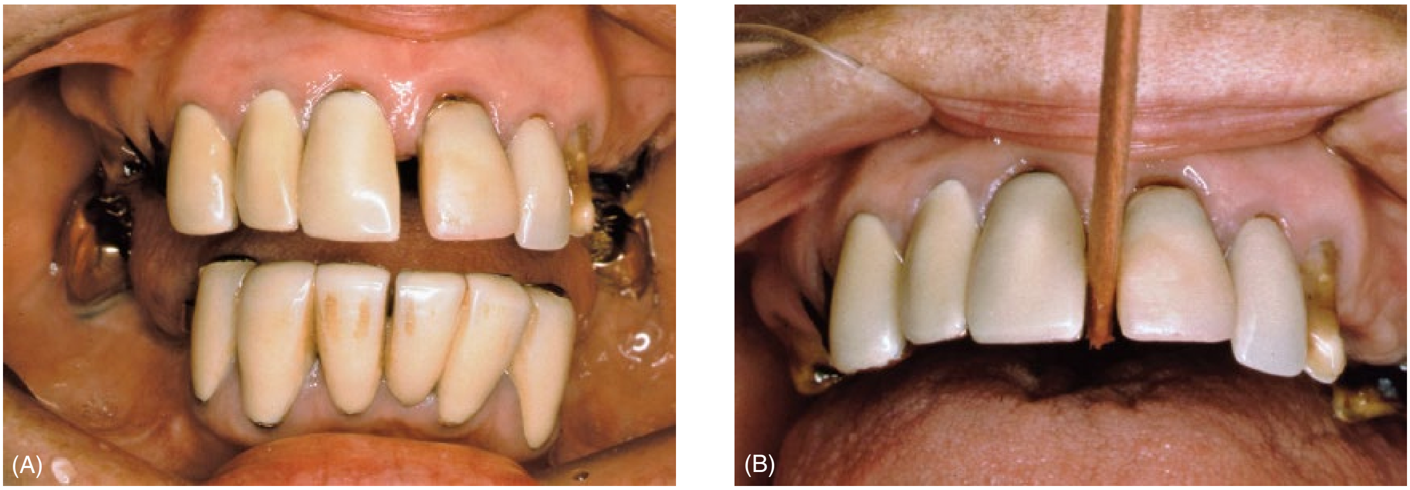

Figure 25.22 **(A, B)** These photographs show a patient who constantly placed Stim-u-dents between her front teeth. Although these teeth were originally together with no spaces, the patient quickly separated the teeth to create a space. Her goal was to expand her arch to give more fullness to her face. She had previously been referred for orthodontic treatment but rejected this treatment plan.

Figure 25.23 **(A–C)** This is severe toothbrush abrasion and gingival recession seen in a 37-year-old male with a known obsessive–compulsive disorder. The aggressive brushing of his teeth was one of his extreme habits (see also Chapter 22, Figure 22.10B and C). Composite resin bonding was done to restore the cervical deformities.

Figure 25.24 **(A)** This 25-year-old originally presented with a maxillary diastema.

Figure 25.24 **(B)** Composite resin bonding was chosen to close the space between the central incisors and convert her canines into laterals. Note that the interdental space looks good between the central incisors.

Figure 25.24 **(C–D)** At a two week post-operative visit, we noticed her interdental tissue had receded. After questioning the patient about habits, she was requested to demonstrate exactly how she flossed her teeth. What she was doing was pushing the floss into the teeth on one side and then going straight across to the other side without coming back into the contact area; thus, she was "guillotining" her interdental papilla away. Treatment involved new oral care instructions to prevent further tissue loss and provide an opportunity for the gingiva to regenerate and fill in the interdental space.

Figure 25.25 **(A)** This 21-year-old developed a habit of chewing pencils.

Figure 25.25 **(B)** Eventually, wooden pencils were replaced with plastic ones, which he began to turn with his fingers, causing incisal wear.

Pipe smoking

Any kind of smoking creates its own unesthetic results, staining the teeth and affecting the health of the oral soft tissues. Pipe smoking has the most potential for changing tooth relationships. Continually holding a pipe in one location may cause large notches in several teeth. The problem is that the patient usually places the pipe stem in the same position, most often the premolar area. These teeth then become worn or submerged (Figure 25.26A and B).

Treatment involves correcting the deformity and helping the patient break the habit. In this case, it may be easier to teach the patient to change the pattern of holding the pipe rather than give up the habit altogether. At the very least, this would make certain that the occlusal forces are distributed among many teeth. Although the submerged teeth can usually be orthodontically repositioned, restorative means may provide an easier solution. However, some tooth structure would probably have to be removed so that the bonded restoration could be attached using the etched occlusal surface enamel.

Eyeglasses or other objects held between the teeth

Most persons who consistently place eyeglasses, plastic swizzle sticks, or other objects in their mouths are not aware of the habit, much less the resulting functional and esthetic deformity (Figure 25.27A and B). Treatment is the same as noted earlier.

Ice chewing

Patients seldom realize the damage that chewing ice, a seemingly innocuous habit, can cause. Chewing ice can fracture the teeth and can also produce microcracks in the enamel.

Figure 25.25 **(C)** Note the amount of damage caused by the pencil chewing. Composite resin bonding was used as an economic and immediate esthetic replacement for the missing tooth structure. The patient was also given a plastic bite appliance for the maxillary arch that he would wear anytime he felt the need to put a pencil in his mouth.

Figure 25.25 **(D)** He successfully broke the habit, and the bonding held up for approximately 12 years, when, unfortunately, the patient restarted his previous habit.

Figure 25.25 **(E)** This 46-year-old man had an unconscious habit of not only placing plastic pens in his mouth but also sliding the pen in and out. This wore a groove in the center of the incisal edge.

Figure 25.26 **(A)** This 56-year-old had a long-standing habit of pipe smoking.

Figure 25.26 **(B)** After the pipe was removed, and the patient bit down, the amount of damage caused by the pipe being held in the premolar positions was evident. Particularly note how he favored the right side, which showed a greater amount of abnormal space.

Figure 25.27 **(A)** This 31-year-old had a habit of holding his eyeglasses with his teeth.

Figure 25.27 **(B)** He always held them in the same position, causing the left canine to flare out, thus creating an unattractive and unnecessary space between his front teeth. Patients should always be advised never to hold anything but food between their teeth.

The microcracks themselves are usually not visible to the eye, but they stain much more readily than normal, especially with coffee, tea, and soy sauce. If the person chewing ice has defective restorations, a sliver of ice can also act as a wedge that can split the tooth.

Cracking nuts with the teeth

Using teeth to open the shell of a nut may be the handiest way to reach the nutmeat, but it may also be the quickest way to break a tooth. A common offender is the pistachio nut. The harder the nut is, the more chance there is of a fractured tooth. The only preventive measure you can take is to warn patients of the potential damage, particularly if any incisal edge has been bonded with composite resin.

Diagnosis and treatment of damaging oral habits

There are many more examples of damaging oral habits, but the principles of diagnosis and treatment are similar for all of them. There are two most important principles to remember:

1. Early diagnosis means prevention.
2. Treating the symptoms is only a temporary solution—the patient must break the habit.

Keys to helping patients break damaging oral habits include the following:

- Precise diagnosis of the exact nature of the habit.
- Help the patient recognize the habit and tactfully suggest counseling or other methods to deal with stress and tension.
- Correct the damage caused by the habit so that rough edges, open gaps, or tissue changes do not contribute to resumption of the habit. Preventive appliances are also useful in helping to make patients more aware of these behaviors and break the cycle of "habit–sign–habit."

The treatment of children's oral habits, particularly digit sucking, is somewhat easier because there is usually an adoring adult to reinforce changed behavior. The therapists who participated in a convention of speech pathologists concerned with such behavior almost uniformly suggested methods that require commitment on the part of the patient, removal of guilt about the habit, and a willingness of the parent to give the child some extra attention as the habit is relinquished. Charts with checkmarks or gold stars are often used as reinforcement, as are kisses and praises.[21]

Tips for adult patients to modify their negative oral habits are as follows:

- An extremely precise diagnosis of the problem is an essential first step since many adults may not realize that they have a destructive habit.
- Once the patient has become aware of the habit, they can monitor the behavior, writing down when, how intensely, and under what circumstances it occurs. This will reinforce the patient's awareness of the habit, provide some clues as to what evokes it (such as cheek biting occurring most often in stressful situations or when tired), and provide many occasions in which not using the habit can be reinforced. Suggest to your patient that they enlist the assistance of someone else to help identify various aspects of the habit. A colleague would be a good source if the habit occurs primarily during working hours. Spouses, relatives, or friends may provide assistance if the habit takes place during nonworking hours.
- Some behavioral scientists believe that one habit replaces another. Certainly, it is easier to create a habit than to break one, so it could be suggested to patients that they attempt to temporarily replace the destructive oral habit with a less destructive one, such as chewing sugarless gum.
- Finally, the use of orthodontic devices such as those described in this chapter will help the patient recognize and break this habit.

An important part of treatment, as well as the record of each new patient, should be a completed thorough habit questionnaire, such as the one in Figure 25.20. The patient can fill this out unless they are so young that a parent or guardian would be a more appropriate source of information. This questionnaire should be updated as regularly as a patient's medical history. Destructive habits can start anytime, and it is the dentist's responsibility—and opportunity as a professional with diagnostic ability and an inquisitive nature—to identify these habits and stop them before more damage is done.

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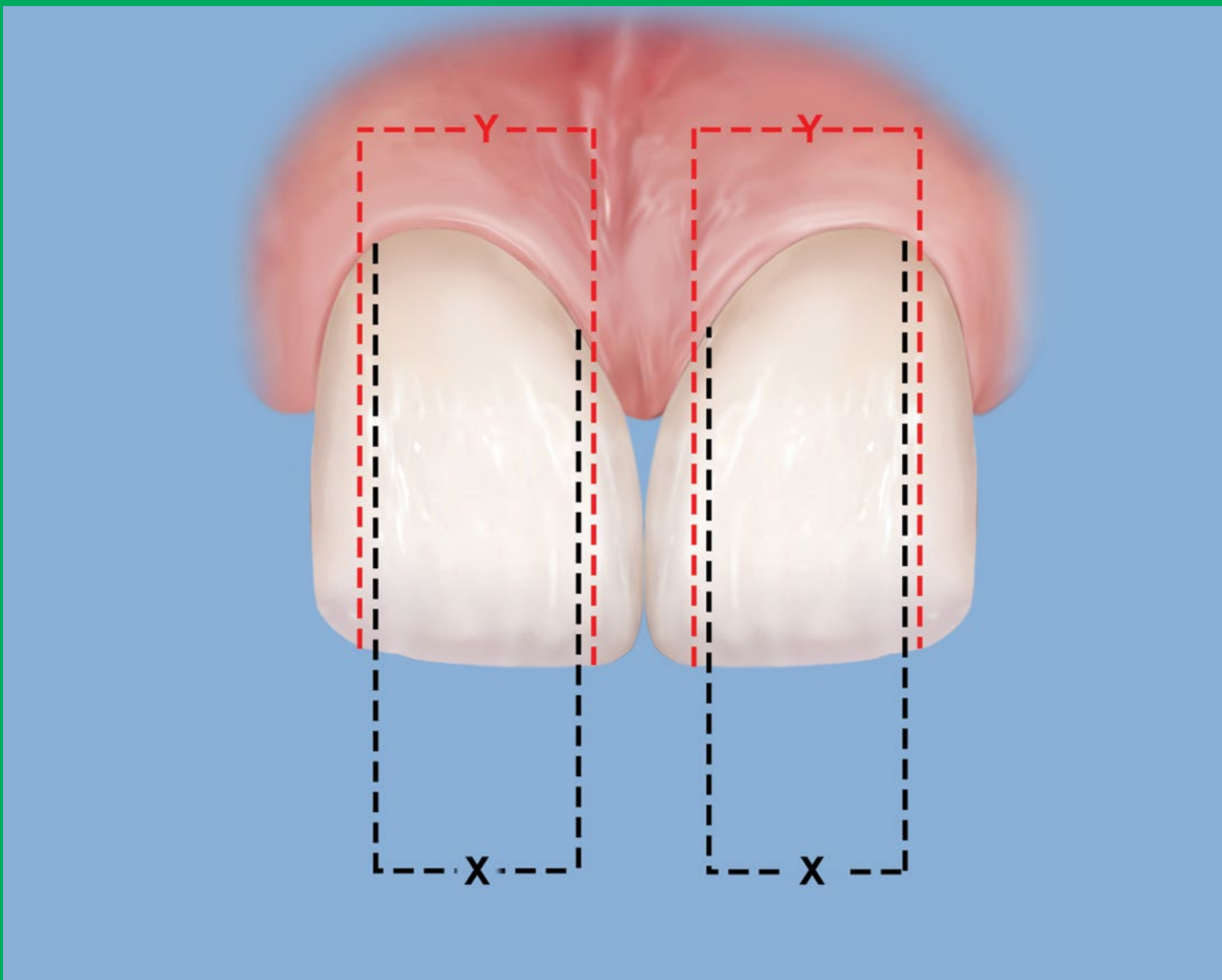
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Chapter 26 Restorative Treatment of Diastema

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One of the most challenging tasks of modern restorative dentistry is resolving the dilemma of spaces between the anterior teeth. The presence of a diastema is desirable in some cultures; however, it is always a matter of personal choice for those who believe closing it will improve the appearance of their smile.[1] Self-consciousness, low self-esteem, and awkward attempts to conceal a perceived anatomical defect are frequent consequences of smiles that are perceived as esthetically compromised.[2] A diastema usually distorts a pleasing smile by concentrating the observer's attention not on the overall dental composition but instead on the interdental space.[3]

The general public has been shown to have definite preferences for anterior tooth variations. Rosentiel and Rashid observed that 90% of the interviewed adults preferred an image without a diastema against one with even a minimal diastema as small as 0.5 mm.[4] Those who dislike the appearance of a diastema often attempt to hide it with intentional habits, such as lip or tongue posturing.[5] Some patients have even resorted to daily applications of wax or cotton to disguise the spaces (Figure 26.1A and B). The use of removable veneers has increased in popularity and they can be worn in public to disguise a myriad of dental deficiencies (including diastemata) or to preview proposed esthetic changes (Figure 26.2A and B). However, the personal values and preferences of the patient are the principles that are most important. Consideration of the patient's needs and expectations is paramount. Satisfaction with the final treatment outcome is ensured by careful questioning about their preferences.[6]

Treatment planning to correct a diastema may include orthodontics, restorative dentistry (by direct or indirect methods), surgery, or a combination of several therapies. Like most esthetic problems, diastema treatment requires careful analysis and often involves an interdisciplinary approach for more complex

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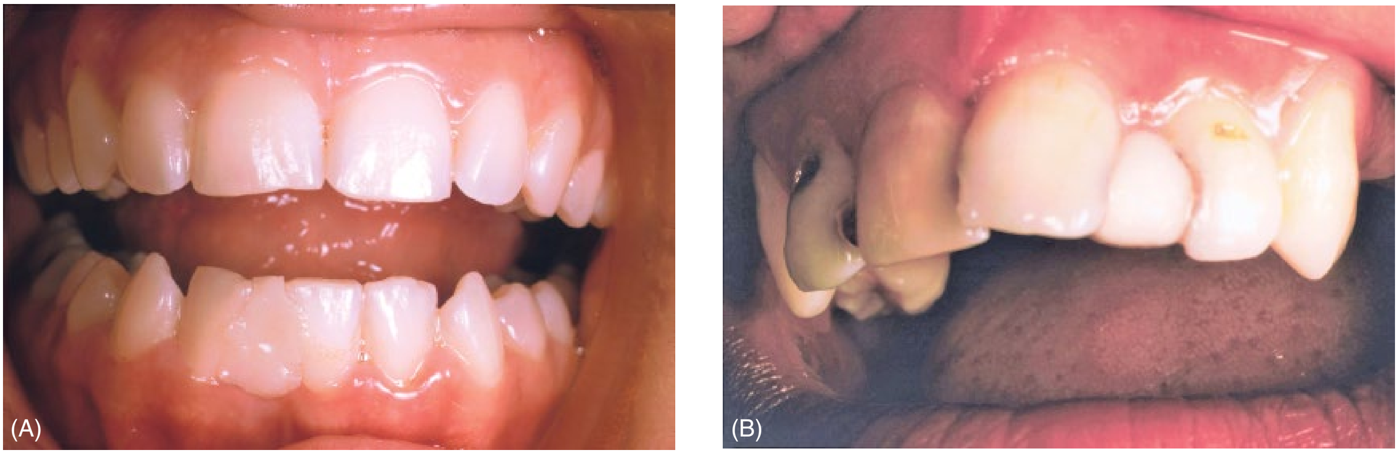

Figure 26.1 **(A)** Some patients resort to daily applications of materials such as wax **(B)** Or cotton to disguise a diastema.

Figure 26.2 **(A, B)** A removable Snap-On Smile has been inserted by the patient to close the spaces and improve her smile as desired for social occasions. *Source:* Reproduced with permission of Denmat© Corporation.

scenarios. While closure of these spaces in many cases can be relatively straightforward, obtaining a result that is esthetically pleasing and stable requires careful analysis of tooth positions as they relate to facial esthetics, tooth proportions and shape, soft tissue architecture, periodontal health, and occlusion. Besides the clinical exam, access to diagnostic casts, radiographs, photographs, and digital imaging may be necessary to thoroughly evaluate a diastema and develop a suitable treatment plan. Before providing treatment to close an anterior diastema, one should attempt to identify and treat the underlying cause(s) if possible and applicable. All appropriate options, along with advantages and disadvantages of each, should be presented to allow the patient to be fully informed, and thus able to make the most appropriate choice in terms of treatment modality and preference of materials.

Etiology of diastema

The etiology of diastemata (multiple diastemas) may be attributed to hereditary and/or developmental factors (Table 26.1).[7,8] Since hereditary determinants play a major role in causing diastemata, there is nothing that can be done to prevent most of them; however, many of the developmental causes of diastema formation are preventable or manageable. It is important to distinguish the origin of such spaces to determine whether they are hereditary or developmental, since the latter category often indicates instability within the oral cavity as a result of tooth loss, reduced periodontal support, and/or occlusal trauma.[9] Although racial and gender differences for diastemata prevalence have been found to exist, approximately 50% of all children between 6 and 8 years old exhibit maxillary midline spaces that typically decrease in size with age,[7] except for approximately 6% that persist into adulthood.[10]

Table 26.1 Factors Contributing To Diastemata

Hereditary Factors	Developmental Factors
Congenitally missing teeth	Habits
Tooth/jaw size discrepancy	Periodontal disease
Supernumerary teeth	Tooth loss
Frenal attachments	Posterior bite collapse
Tooth shape	Occlusal trauma

Figure 26.3 **(A, B)** This patient had a habit of forcing her tongue between both maxillary and mandibular anterior teeth, which caused her diastema to continue to enlarge.

With the exception of third molars; maxillary lateral incisors and mandibular second premolars are the most commonly congenitally missing permanent teeth.[10] A missing tooth creates an obvious space problem in the immediate area and may lead to undesirable spacing in adjacent regions as the position of several teeth in a quadrant (or the opposing quadrant) can be affected by the absence of a single tooth. Small teeth and large jaws (tooth size/jaw size discrepancy) can lead to generalized spacing, whereas unerupted supernumerary teeth can create a diastema by their position between the roots of other teeth.[11] Microdontia, a condition seen in conjunction with other hereditary conditions (e.g., exhibited in higher incidence in patients with dental agenesis),[12] often leads to diastemata as well. Anatomic factors such as those seen in atypical frenum positions may also contribute to diastema formation[13] and may require a combined surgical/restorative and/or orthodontic approach for long-term stability.

Among the most common developmental causes of diastemata are habits, one of which is tongue thrusting. Large tongues (macroglossia) or abnormal swallowing patterns can cause tooth separation by the habitual forcing of the tongue into the lingual embrasures of teeth (Figure 26.3A and B) creating pressure that can eventually wedge them apart. Pernicious habits such as chronic lip biting may also contribute to tooth movement and diastema formation, in a similar manner as tongue thrusting, through chronic labially directed pressure.[7] Periodontal trauma with resultant spacing between the incisors can be caused by habits such as wedging a fingernail, toothpick, or other foreign object between the teeth (see Chapter 25). Other developmental causes of diastemata are obvious, such as the loss of a permanent tooth, or more subtle, such as chronic periodontal disease.[14] Tooth loss in the posterior region has been associated with anterior diastema formation as a result of posterior bite collapse or from mesial–distal drift or tipping of posterior teeth.[15] In this case, the loss of posterior occlusal contacts alters the pattern of occlusal function, often leading to tooth migration and the potential for decreased vertical dimension. The indirect result of this condition can be a labial flaring of the maxillary incisors (pathologic tooth migration) with resultant space formation. Prevention of tooth loss, preventive or corrective occlusal therapy to maintain vertical dimension or minimize occlusal trauma, and maintenance of periodontal health can reduce the likelihood of diastema formation that results from deterioration of the normal structure and function of the oral cavity. Although it was shown by Martinez-Canut et al. that bone loss is the factor most often related to pathologic tooth migration, it was also concluded that pathologic tooth migration was rarely the result of any one single factor.[15]

The presence of fibrous frenal attachments (often found in the maxillary midline) can result in a persistent midline diastema that often requires surgical intervention to enable space closure or prevent relapse. In these cases, consultation between the restoring dentist, the orthodontist, and the periodontist is highly recommended to determine the appropriate timing for frenal resection as a part of the overall treatment.

The etiology of diastema and the prognosis for successful closure following treatment, along with patient's desires, must all be factored into the decision as to whether or not to treat, and, if indicated, the appropriate mode of treatment chosen. Understanding the reason(s) for the spacing and attempting to correct or minimize the causative factors can improve the odds for success of corrective therapy.

Diagnosis and treatment planning

Although the presence of a diastema and an initial opinion regarding its treatment may seem obvious, careful evaluation and thorough planning is essential prior to rendering treatment to obtain a successful, esthetic, and stable result. As previously discussed, the etiology of diastema may be attributed to hereditary and developmental factors. Upon identifying these factors, the dentist should include the patient in the treatment planning process by presenting appropriate treatment alternatives, prognoses, and fees.

Identifying the cause(s) of a diastema will often indicate the most appropriate corrective treatment plan.[16] For example, diastemata due to periodontal problems cannot be corrected predictably with restorations alone if alveolar bone has been lost and the teeth are mobile. When periodontal disease is causing the teeth to drift and separate, any active pathology (acute or chronic) must first be resolved. Referral for a periodontal consultation is often warranted as the disease process itself may be advanced and carry a poor or guarded prognosis. Once the periodontal condition has been treated and stabilized, other therapies can be instituted, such as orthodontics and/or restorative dentistry. Either option may also include splinting to compensate for lost periodontal support. Properly sequenced treatment in these cases enables the clinician to achieve a final esthetic result that may be performed with better confidence for a more stable and predictable result.[17]

Although restorations are usually indicated to close multiple diastemata due to small teeth, other coordinated therapies may be needed to achieve an optimal esthetic result. Tooth repositioning may be necessary to create uniform or more manageable spaces prior to restoration placement. However, if one is considering orthodontics to close spaces but the associated teeth need restorations to restore lost form or function, then restorative therapy alone may be an acceptable option depending on the size of the spaces and proportions of the teeth. Short teeth diastemata cases may require periodontal surgery to provide additional clinical crown height to balance the increase in tooth width (i.e., create more pleasing tooth proportions; specifically, width-to-length ratios) from planned restorations intended to close spaces. Part of the diagnostic phase should include evaluation of tooth and gingival exposure, in the full and exaggerated smile, to assess whether additional treatment (e.g., crown lengthening) purely for esthetics is even warranted. Short or hypermobile upper lips, supra-eruption of teeth, and vertical maxillary excess can contribute to excessive tooth/tissue display that may require consideration for additional therapy, beyond that of diastema closure, to achieve the most ideal esthetic result. However, if only a small part of the vertical height of the teeth is seen (even in the exaggerated smile), then the additional cost, time, and discomfort of elective periodontal treatment may not be worth it to the patient. Additional teeth not directly affected by a diastema may also need to be included in the restorative treatment plan to provide a proportional smile. Anytime a patient is considering extensive restorative treatment, they should first be given the opportunity to change their existing tooth color. Prerestorative bleaching can improve the esthetic result of any type of restorative therapy and should always be considered when extensive dental treatment is planned. Tooth-whitening procedures allow thinner or more translucent restorations to be used (e.g., porcelain veneers, all-ceramic crowns with reduced core opacity, or direct composite resin bonding) when dark/stained tooth structure does not have to be masked.[18,19] The preceding factors illustrate the importance of thorough diagnosis and comprehensive treatment planning for all types of diastema cases.

As patient acceptance of ideal treatment is the ultimate objective for the dentist in this phase, it is often necessary to allow the patient to visualize and approve the anticipated result.[5] For simple diastema closures involving restorations, the chairside application of tooth-colored wax or unbonded composite resin (for an esthetic preview or "mockup") to the patient's proximal tooth surfaces should provide a good preview of the proposed result. For complex cases that involve several teeth or combination therapies (orthodontics and restorations), a diagnostic wax-up and/or computer imaging may be required to enable the patient to fully appreciate the anticipated result of extensive treatment (see Chapter 3).[20] Alternatively, and when applicable, a more detailed esthetic preview can be utilized to confirm the proposed changes or need for additional refinement. The use of laboratory-fabricated templates or removable veneers (i.e., Snap-On Smile®) (see Figure 26.2A and B) or bis-acryl-type provisional materials added to the teeth via a matrix (fabricated from a diagnostic wax-up) (see Figure 26.4A–C) can be a valuable adjunct for the patient to enable them to preview their new smile directly in their own mouth and provide valuable diagnostic information to the clinician. When multiple disciplines are involved, such as orthodontics, surgery, and restorative dentistry, a case presentation conference (or teleconference) with all involved clinicians and the patient may facilitate acceptance of complex treatment plans.

Pre- and postoperative photographs or digital images can provide many benefits. Photographs of the results of treatment completed for other patients with similar conditions can be used to help current patients envision the possibilities associated with their own treatment and inspire confidence in the dentist's abilities to treat these types of cases. If computer imaging is utilized to enable patients to visualize anticipated treatment results, it would be advisable to provide both close-up and full-face before and after images for best patient and doctor visualization of the possible outcome. However, care must be exercised to present the proposed treatment in a way that does not imply a "guarantee" of results. One must always remember that due diligence is required in the diagnostic phase to give the best chance for a successful outcome based on achieving realistic patient expectations. Photographs used to document the procedure can also be used to improve the chances for reimbursement from third-party payers in certain cases. A duplicate set of pre- and posttreatment images given to patients following treatment helps to prevent "buyer's remorse" by reminding them of their presenting condition, and allows them to serve as marketing advocates for the office when dramatic, successful before and after photographs are displayed to family and friends.

Treatment options for correction of diastemata

Esthetic considerations in restoring diastemata

When restorations are indicated for diastema closure, several esthetic factors must be considered. First and most obvious is how the teeth fit within the frame of the face and the smile, the so-called macroesthetics.[21] Second are the considerations associated with the esthetic appearance of the individual teeth, the microesthetic component. Regarding the macroesthetic factors, it is necessary to evaluate the elements that make up facial composition before focusing on the teeth. Considering the teeth first will reduce the scope of the investigation. Frontal and lateral examinations of the subject, including analysis of the position of the eyes, nose, chin, and lips, allows identification of the reference points and lines that are indispensable to the diastema closure. The facial features have an important influence on the perception of an individual's personality. The somatic traits are in fact often correlated with precise psychological characteristics, and some features are associated with specific individual aspects. Analysis of these features is made using horizontal and vertical reference lines which allow correlation of the patient's face and dentition.[22]

A variety of factors should be considered when determining the most appropriate treatment for closing anterior spaces. Clinical evaluation of the lateral facial (profile) view should be one consideration. Anterior tooth position can affect lip support, lip fullness, vermillion exposure, and the nasolabial angle. When space closure includes incisor retraction, its effect on the lips must be considered.

Both restorative and/or orthodontic treatment can produce changes in lip support, and thus if not well planned may compromise the final treatment outcome. Taking into account perioral tissue contours will minimize the potential of producing an orthodontically induced unesthetic facial profile. The patient with thin lips or minimal muscular tone is most at risk of losing lip support when incisors are retracted to close anterior spaces.

Figure 26.4 **(A)** Patient is unhappy with the unevenness of her teeth and wants a straighter, more uniform smile.

Changes to the position and outline of the maxillary central incisors can significantly impact the treatment result. These changes should not interfere with the tooth's position of equilibrium, between the tongue lingually, the lips labially, and the cheeks laterally. Alterations of this type could alter the positional equilibrium of the teeth, thereby increasing the chance of tooth movement in the form or crowding or spacing, as well as negatively affecting the patient's unique facial form in an undesirable fashion.[22]

Conventional wisdom would dictate that alignment of the facial and dental midlines is desirable. In nature, this occurrence is rare. Kokich et al. have found that discrepancies between the facial and dental midlines that are 4 mm or less are not readily noticeable to either patients or general dental practitioners.[23] Therefore, as a rule, limited midline discrepancies need not affect treatment considerations unless requested by the patient.[22]

During speech and facial expression, a different amount of tooth exposure may be seen. The face and lips together create a dynamic, constantly changing frame. The fluid nature of the relationship between soft and hard tissues must be considered in the treatment plan for diastema closure. The dentolabial analysis is essential for evaluating the correct ratio between the teeth and lips during the various phases of speaking and smiling. When the mandible is in the rest position, the teeth do not come into contact, the lips are slightly apart, and a portion of the incisal third of the maxillary incisors should be visible. This "incisal display" varies from 1 to 5 mm, depending on the length of the upper lip and the patient's age and sex.[22,24]

Patients who require prosthetic treatment frequently request a younger looking smile. Tooth wear and loss of perioral muscle tone, common to the aging process, diminish the amount of maxillary incisor visibility. Consequently, there is a greater exposure of the mandibular incisors as part of the aging process.

Figure 26.4 **(B, C)** Patient is able to preview the proposed changes for her smile from the bis-acryl template applied to her teeth chairside. Diagnostic wax-up compliments of Viet Tran (Master Ceramist, The Dental College of Georgia at Augusta University) and intraoral diagnostic mockup performed by Dr. Eduardo Britton (Dental College of Georgia Prosthodontic Graduate Resident). *Source:* Reproduced with permission of Gerard Chiche.

Maxillary incisor tooth display, with the lips at rest, is a major determining parameter in justifying incisal edge lengthening.[22] Incisal edge lengthening can work in the patient's favor during diastema closure. In a best case scenario, to maintain the correct tooth proportion, the teeth widened during the diastema closure must also be lengthened. When esthetically and functionally appropriate, this approach will result in an incisal edge display, which is usually consistent with the patient's desires.

Incisal edge position

Appropriate vertical tooth position (incisal edge position) and vertical gingival margin control are as important as correcting horizontal deficiencies in achieving an ideal result when closing diastemata.[25] Identification of the position of the incisal edge, in both the apicocoronal (incisal curve) and anterior–posterior (incisal profile) directions, represents a fundamental aspect of the esthetic diagnosis for diastema closure. Many of the procedural choices that the clinician and dental technician will make, to provide suitable prosthetic restorations, are significantly affected by the correct incisal edge position.[22] An esthetically pleasing and functionally stable final result must begin with correct determination of the incisal edge position of the maxillary anterior teeth. It is this incisal edge position that plays a major role in determining the proper width-to-length ratio of the clinical crowns.[25] Providing the appropriate amount of maxillary incisor display with the lips at rest is a key factor in the development of a more "youthful" smile.

The incisal plane, as a rule, when observed from the front, has a convex curve that follows the natural curve of the lower lip. Maintaining or reestablishing an incisal curvature in harmony with the lower lip is integral to ideal diastema closure treatment. In closing diastemata, esthetically pleasing tooth shape and proportion are enhanced by ensuring parallelism with the lower lip.[22] Even in patients with a relatively flat lower lip contour, it is still desirable to provide at least some degree of curvature to the upper incisal smile line.

The incisal profile is the position of the incisal edge in the anterio-posterior direction and, as a rule, is contained within the inner border of the lower lip. Properly positioned incisal edges allow for adequate closure of the lips without interference. The incisal plane is the anterior portion or continuation of the posterior occlusal plane. When viewed from the front, it should be parallel to the horizontal reference lines, such as the interpupillary line and the labial commissural line (assuming they are horizontally level), to maintain natural facial harmony.[22] If the teeth are too far forward and if proportions allow, the use of orthodontics to close the spaces should be considered. Prosthetic or direct restorative rehabilitation in such cases should involve modifying the incisal profile as needed to correct for any deficiency in this horizontal plane and allow for proper lip closure and speech.

Tooth proportion

The optimal mesiodistal width to incisogingival length (width-to-length ratio) proportion for Caucasian patients as described by Magne, Sterrett, Duarte, and Chu for naturally appearing, esthetic maxillary central incisors ranges from 72% to 81%.[26] When these proportions are violated, as often happens when large diastemas are closed solely with restorations, the restored teeth look "wrong" because they are out of proportion (see Chapter 9). Methods available to compensate for the extra tooth width include lengthening the anatomic crown with a restoration, increasing the clinical crown length with periodontal surgery, or using restorative "optical illusions" to make a wide tooth appear narrower (see Chapter 8). Lengthening a tooth by extending the incisal edge is the simplest method of maintaining proportionality of the individual tooth when additional width is required to close spaces. However, the patient's occlusal scheme may not allow for the additional incisal length needed to compensate for the added width. Potential complications include a steepened bite with the possibility for increased muscle force and interference with speech or lip closure. A complete examination and thorough analysis of the patient's occlusion should reveal this potential complication prior to starting the treatment phase along with trial lengthening by addition of composite resin to confirm or refute these concerns. Lengthening the clinical crown by gingivectomy or an apically repositioned flap with osseous recontouring may provide the needed length to offset the additional width without creating potential occlusal interferences. However, a careful periodontal evaluation must be rendered to ensure an adequate crown-to-root ratio remains following osseous surgery and that sufficient interdental soft tissue will remain to reduce the risk of open gingival embrasures (i.e., "black triangles") following placement of restorations.[27] Either of these tooth lengthening options can allow for diastema closure with natural-looking, proportional restorations, although the esthetic harmony of all of the anterior teeth should also be considered as a whole.

The concept of the "golden proportion" or "divine proportion" as applied to a smile and described by Lombardi, Levin, and others[28–30] was based on a ratio (1 : 1.618) of the apparent width of each anterior tooth (as viewed from a direct facial perspective) compared with the tooth immediately anterior and posterior to it. This concept was utilized for many years as the most harmonious or appealing tooth-to-tooth ratio for an esthetic smile. In more recent years, however, it has been shown that the majority of beautiful smiles do not have proportions coinciding with the golden proportion formula[31] and that this proportion does not occur naturally in the average natural dentition, although it can still provide an esthetically pleasing result.[32–34] Although the golden proportion can be a valuable aid as a starting point for esthetic evaluation and diagnostic modeling, the reality is that any interdental width ratio from 65% to 85% can be esthetically acceptable, and thus the golden proportion ratio should be used as a tool, not as a rule.

More recently, an alternative option for determining tooth-to-tooth relationships was introduced, the "recurring esthetic dental" (RED) proportion.[33,35] Using this method, the clinician may choose any proportion that looks appropriate, as long as it remains consistent as it proceeds from the midline distally in the arch. Seventy-five percent of North American dentists preferred using the RED proportion when designing smiles with normal length teeth over using the golden proportion.[36] The 70% RED proportion has been recommended for normal length teeth (with a 78% width : length ratio of the maxillary central incisors). Using this concept and the 70% ratio, the width of the maxillary lateral incisor is 70% of frontal view width of the maxillary central incisor, and the canine is 70% of the width of the resulting lateral incisor width. RED ratios of 62–80% are recommended, dependent on the teeth length (larger ratio for shorter teeth and smaller ratio for longer teeth). The mean maxillary tooth widths for the anterior teeth as shown by Chu were 8.5 mm for the central incisor, 6.5 mm for the lateral incisor, and 7.5 mm for the canines and that 82% of patients fell within ±0.5 mm of the mean values.[26] Other ratios that can be used with esthetic success include restoring the optical width of the maxillary lateral incisor at about 65% of the central incisor and the canine at approximately 75–80% of the optical width of the lateral incisor.[37] Studies by Magne et al. showed ranges of unworn maxillary central incisor widths from 8.46 to 11.07 mm, lateral incisors from 5.51 to 8.22 mm, and canines from 6.8 to 9.02 mm with average width-to-length ratios of 78% for unworn centrals, 73% for laterals, and 73% for canines.[38] Regardless of the ratio used, when treatment planning esthetics for the anterior part of the mouth, the central incisors should "dominate" the smile in terms of both position and size.[30,39] However, as stated by Magne and Belser, dominance must be measured according to personality (see Chapter 9).[40]

Gingival esthetics

There are esthetic considerations for periodontal surgery that, in many cases, are as important as those for teeth. The appearance of the teeth and gingival tissues must act in concert to provide a balanced and harmonious smile. A defect in the surrounding pink tissue may not be adequately compensated for by the quality of the dental restoration and vice versa.[41] In the past decade there has been a remarkable upswing in interdisciplinary collaboration between dentist, orthodontist, and periodontist in smile enhancement. In fact, the pseudo-specialty of "cosmetic periodontics" has evolved in conjunction with the pseudo-specialty of cosmetic dentistry.[42]

In creating an esthetically pleasing and natural smile, the perfect balance between white architecture (teeth) and pink architecture (gingiva) is often difficult to achieve.[43] Evaluation of the smile line also reveals the amount of exposure of the anterior teeth (including the cervical portion of the teeth) and soft tissue when smiling. Based on the amount of dental and gingival display of the anterior maxillary arch, Tjan and Miller identified three types of smile lines: low, average, and high. A pleasant smile can be defined as one that exposes the maxillary teeth completely, along with approximately 1 mm of gingival tissue. Gingival exposure that does not exceed 2–3 mm is nevertheless considered esthetically pleasant, while an excessive display (>3 mm) is generally considered unattractive.[44]

When closing diastemata in patients with a high smile line, recommended treatment will often include increasing tooth length apically to offset the increase in tooth width. Periodontal plastic surgical procedures are often needed and utilized to correct tooth–soft tissue relationships or to improve tooth proportions. Resective surgeries (e.g., gingivectomy, osseous crown lengthening) or additive surgeries (e.g., gingival grafting, coronal soft tissue repositioning) are recommended when discrepancies in the soft tissue interfere with the proposed tooth proportion.[25] Ideally, the position of the midfacial portion of the free gingival margin of the maxillary central incisors and the canines should be at the same height, with the free gingival margin of the lateral incisors being slightly more coronal to a line drawn between the central incisors and canines.[45–47] Symmetry of tissue height and contour between the maxillary central incisors is, however, the more critical factor over bilateral symmetry between the central and lateral incisors and canines.[45] Crown lengthening one tooth to achieve width-to-length proportionality may result in a decreased esthetic result because of the asymmetry of the gingival margins. Gingivectomy or apically positioned flap procedures should usually be carried out over as many teeth as needed to maintain esthetic harmony of the gingival contours. Occasionally, a single tooth may exhibit an improper gingival contour due to supra-eruption or malposition within the arch (e.g., a palatally inclined maxillary incisor will likely have a more coronally placed free gingival margin), and in this case a periodontal procedure for the individual tooth may be appropriate.

Altering soft tissue levels can also be accomplished successfully in many cases through orthodontic intrusion or extrusion. Among the benefits of the nonsurgical orthodontic approach are the preservation of supporting tissues and maintenance of the crown-to-root ratio. From an esthetic perspective, a major advantage for considering orthodontic correction is the ability to restore ideal cervical gingival morphology and emergence profile. In addition, the possibility of inadvertently surgically exposing the root portion of the tooth, with its inherent negative consequences is eliminated.[25]

Esthetic illusions

A wide tooth can be made to appear smaller (narrower) than it is in reality by altering its contours and using different color values in various parts of the tooth or by selecting a darker shade. The apparent face of the tooth (*X*) is that portion of the facial surface that is isolated by the facial/interproximal line angle (Figure 26.5A and B). The mesiofacial and distofacial line angles will influence what the eye perceives as the apparent width of the facial surface of a tooth. A wide tooth can be made to look narrower by moving the mesiofacial and distofacial line angles closer together and rounding slightly the tooth surfaces lateral to these line angles (*S*), opening the incisal embrasures (IE) and rounding the incisal line angles (Figure 26.5C and D). Thus, two adjacent teeth with different actual mesiodistal widths can be made to appear similar in width if the distance between the facial line angles is the same (maintaining the same "apparent face width") along with the use of other artistic illusions. Proximal contours, facial surface features, and color values can

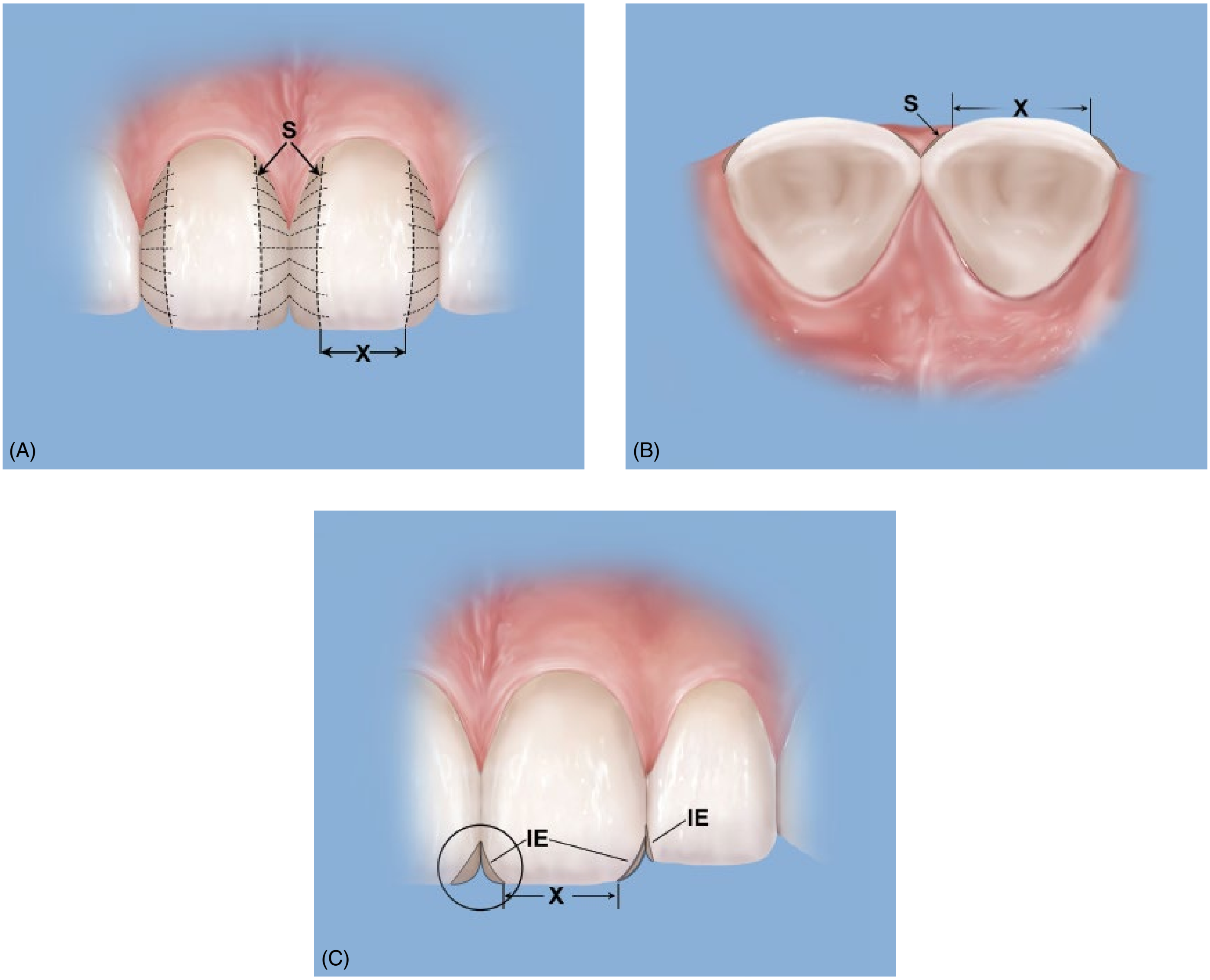

Figure 26.5 **(A–C)** Principles for closing a diastema. The apparent width of a tooth ("X") can be altered to appear wider or narrower by moving the facial interproximal line angles mesially or distally, rounding the tooth surfaces lateral to these line angles ("S") along with the line angles themselves, opening the incisal embrasures ("IE"), and rounding the incisal line angles (see text for more details). (S = Shaping, IE = Incisal Embrasures). *Source:* illustrations by Zach Turner.

further enhance the illusion provided by line angles. Wide and deep facial embrasures with lingually positioned contact areas give the illusion of narrow teeth, whereas constricted and shallow facial embrasures make teeth look wider. Horizontal or vertical "lines" (e.g., developmental depressions or other secondary anatomical features) added to the facial surfaces of teeth can make the tooth look artificially wider or longer as needed. Lighter color values on the facial surface of a tooth and darker values on the proximal surfaces will further contribute to the deception of tooth size. These illusions enable the dentist to make several teeth of different actual sizes look proportional in their widths by manipulating line angle location, proximal contours, surface texture, and color value. They can be valuable adjuncts to treatment when compromises have to be made and ideal conditions are not available for closing diastemata and maintaining tooth proportionality and harmony within the overall smile.

Functional considerations in restoring diastemata

The requirement that the occlusion be stable following diastema closure holds true regardless of the esthetics achieved, and whether the result was achieved by means of orthodontics, restorative space management, or a combination of both. Careful attention must be given to avoid converting a stable occlusion into an unstable occlusal scheme in the process of diastema correction. The signs of a stable occlusion are asymptomatic, normally functioning temporomandibular joints, firm teeth with no signs of excessive wear, teeth that do not migrate from their position, and supportive structures that can be maintained in a healthy condition.[48] A dentition composed of spaces can present with varying occlusal patterns, including an increased or decreased overjet or overbite. The treatment of the malocclusion can be a challenge because of these spatial discrepancies.

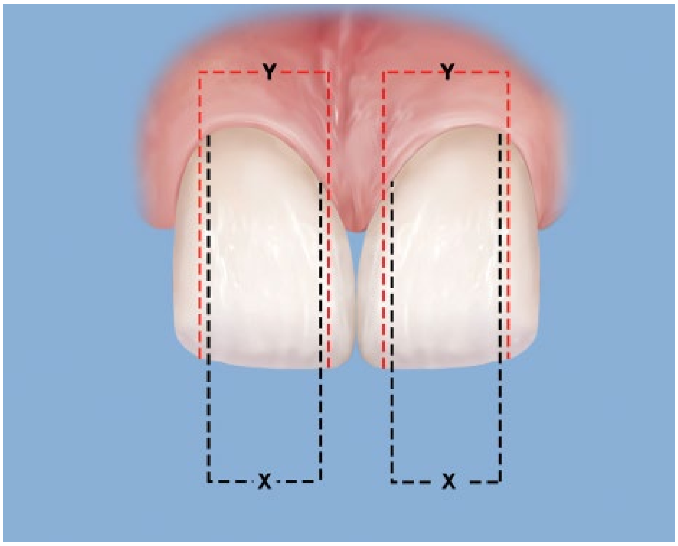

Figure 26.5 **(D)** When teeth are too wide, they should be contoured so that the labial surface does not appear as wide. Thus, the line angles should be more to the center of the tooth or closer together (*X* instead of *Y*). *Source:* illustration by Zach Turner.

Therefore, an occlusal analysis should be included in the treatment planning process, and the best option for incorporating orthodontics, restorative, or a combination of both must be clearly identified to achieve the most predictable esthetic and functional result.[25] The envelope of function must also be considered when planning to close spaces that exist in the esthetic zone. Any preexisting, nonpathogenic neurologically programmed tooth closure pattern may be interrupted when the diastema is closed, especially if tooth position is altered. The mandible has a favored pathway of motion. Occlusal instability may occur as a result of teeth or restorations that interfere with this jaw closure pathway. Signs of instability may include fremitus, excessive wear, tooth movement, and fracture of restorations[49] or any combination of these.

Orthodontics, operative (direct restorative) dentistry, prosthodontics, or combinations of these therapies are the most suitable of suggested options for the closing of diastemata. Orthodontics requires the use of appliances, which means a more complex, longer, and often more expensive treatment. Prosthodontics requires indirect and more invasive procedures with laboratory involvement at an increased cost to the patient. Factors such as the number and size of the diastemata influence the choice of restorations or other treatment options. Direct adhesive composite resin restorations and indirect porcelain veneer restorations present excellent treatment alternatives to reestablish the esthetics, function, and biologic characteristics of oral tissues when closing diastemata.[43] The advantage of modern materials and techniques often allows for preservation of tooth structure by means of conservative, less-invasive procedures.

The specific goals of treating diastemata remain unchanged regardless of the technique used: (1) create a tooth form in harmony with adjacent teeth, arch, and facial form; (2) maintain an environment for excellent gingival health; and (3) attainment as well as maintenance of a stable, functional occlusion. The final result should be one that is harmonious and pleasing to the patient. These goals, and consequent clinical success, can be met and achieved by applying contemporary principles of smile design and following an appropriate sequence of treatment.[25]

Restorative treatment options

Direct bonding with composite resin

Simple diastema

Use of directly bonded composite resin is considered by many to be the first line of treatment for a single diastema or when ultra-conservative restorations are indicated (e.g., young patient, unrestored teeth, need for reversible procedure). In the hands of a skillful clinician, the use of composite resin can yield very acceptable results that, when maintained properly, can last for years. Other advantages of using composite resin include: accurate mock-ups for color verification and approval; relative ease of repair; maximum conservation of tooth structure, since mechanical tooth preparation is often unnecessary;[50] the ability to complete the procedure often in one visit, allowing for immediate results; and lower cost (compared with indirect restorations).[51] Thus, the ability to save time, money, and tooth structure makes composite resin a popular choice with many dentists and patients. By choosing a conservative restorative option, such as direct composite resin bonding, both the patient and the clinician have the full range of treatment options available (since most of the pretreatment tooth structure remains) for whatever subsequent treatment is available or recommended in the future. As mentioned previously, patients should always be given the chance to alter their tooth color through bleaching prior to restorative treatment. If tooth bleaching is accepted as a part of therapy, it should always be performed prior to adhesive dentistry with bonding being delayed for 10–14 days following completion of bleaching to allow for tooth color stabilization and tooth–resin bond strength levels to return to normal values.[52–54]

One key element to closing diastemata with composite resin is developing a natural interproximal emergence profile that will eliminate or at least minimize unesthetic gingival embrasures and allow for proper oral hygiene. Figure 26.6A and B shows how facial, mesial, and lingual surfaces are contoured to close the interdental space (gingival embrasure). Improper emergence contours can lead to food entrapment and greater difficulty in cleaning with dental floss. Figure 26.6C and D depicts correct versus incorrect gingival embrasure contours and is applicable whether restoring with direct composite resin or by indirect means (i.e., crowns or veneers). With wider diastemas or gingival embrasures, it may be necessary to reshape (using electrosurgery or soft tissue laser) or displace (with retraction cord or semi-rigid metal matrix) the interdental papilla in order to develop better interproximal emergence contours. In most cases involving a wide diastema, however, the patient must be accepting of a less than ideal interdental papilla or resort to restorative options such as the use of pink porcelain (or

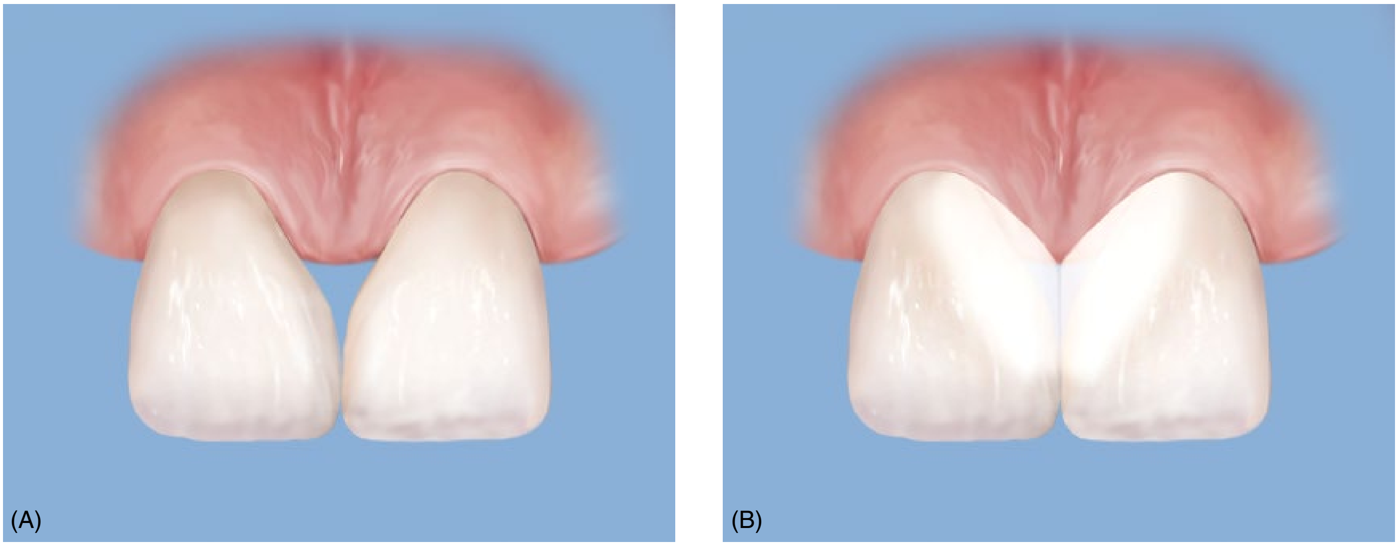

Figure 26.6 Composite resin bonding is the most conservative method to close a cervical interdental space ("black triangle"). **(A)** Before the restoration. **(B)** After the restoration, outlining the surfaces involved with the restoration. *Source:* illustrations by Zach Turner.

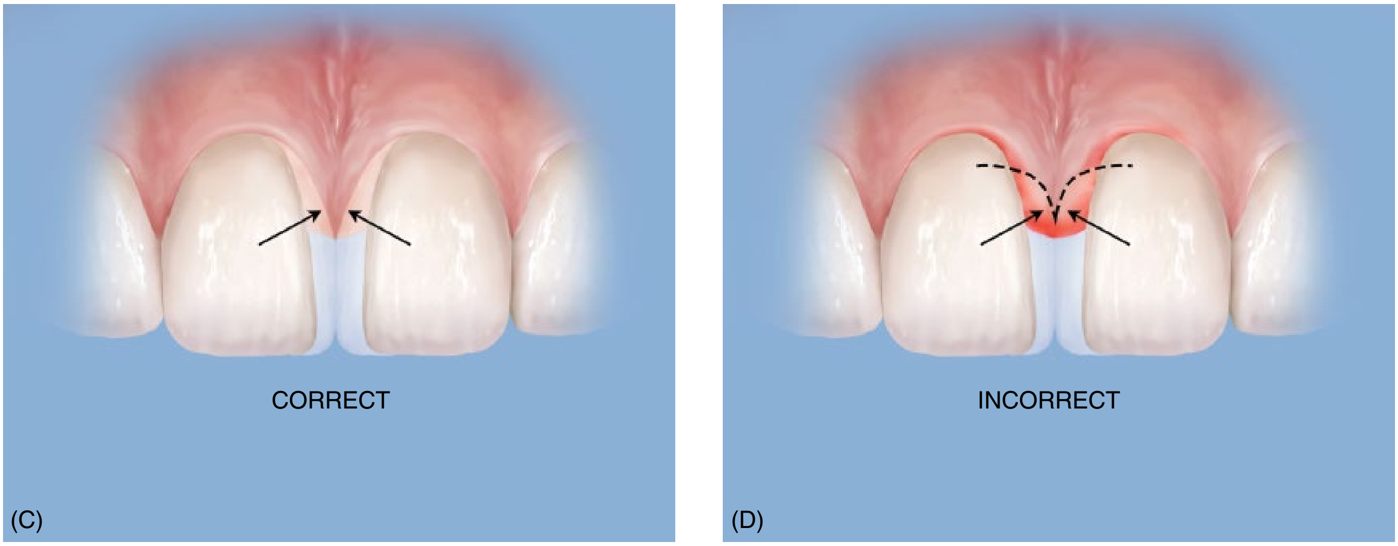

Figure 26.6 **(C)** The proper form in which the composite resin must be contoured to mask the interdental space while still allowing easy cleaning with dental floss. **(D)** The improper form. *Source:* illustrations by Zach Turner.

composite resin) or longer interproximal tooth contacts to lessen the visual effect of missing soft tissue. The reshaping of the papilla is most commonly performed by electrosurgery or laser treatment, which will subsequently allow for bonding at the same appointment. In cases of smaller diastemata, contouring the restorations at the cervical interproximal aspect to apply lateral pressure to the papilla will typically result in coronal migration of the interproximal soft tissue.

Figure 26.7A–F depicts closure of a midline diastema by direct composite resin. There are at least three pretreatment measurements needed before closing even the most straightforward or uncomplicated single diastema: the width of each tooth adjacent to the space, the width of the space, and the width-to-length ratio of these teeth. If the teeth are equally wide and their length can proportionally accommodate the additional width necessary to close the space, it is a simple matter of equally dividing the space closure requirement between the two teeth regarding how much composite resin to add. Unevenly wide teeth, unbalanced post-treatment ratios, or asymmetry within the smile require broader considerations and planning beyond a simple local space closure. Assuming that the incisors are the same width (preoperatively), an equal amount of composite resin should be added to each tooth (one tooth at a time) and the width measured again with calipers to ensure that following reshaping and polishing that 50% of the space has been successfully closed with the first addition of resin. Some clinicians, however, may choose to add composite resin to the adjacent teeth at the same time. This option can be acceptable as long as composite resin is added and contoured equally between the adjacent teeth and corrected as needed prior to polymerization. Note how in Figure 26.8A–C that the addition of composite resin to only one tooth or unequal application to both teeth will typically lead to a less than ideal

Figure 26.7 **(A)** The most practical method for closing a simple diastema is with composite resin bonding.

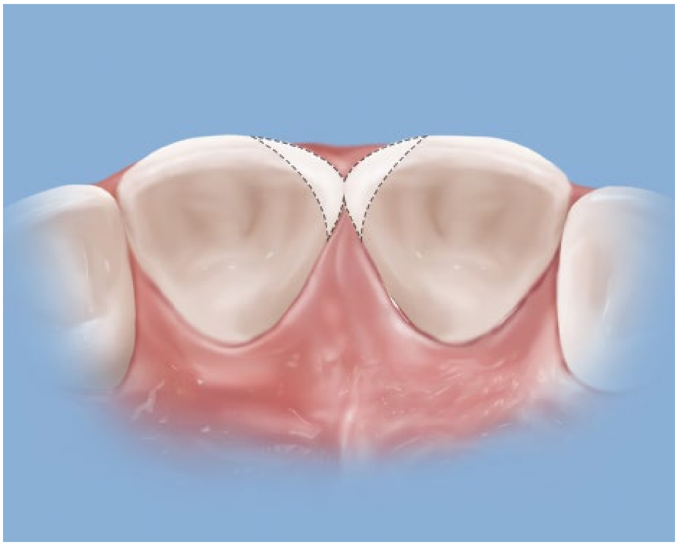

Figure 26.7 **(C)** This drawing illustrates that composite resin will be bonded to the labial, mesial, and palatal surfaces. *Source:* illustration by Zach Turner.

result. However, adding resin to only one tooth can be an acceptable strategy if it is narrower than the contralateral tooth preoperatively.

For cases involving multiple diastemata, it can be a bit more challenging and time consuming to restore with direct composite resin, and thus many clinicians resort to indirect methods. However, the guidelines and restorative protocol remain the same as with a single diastema, but the treatment requires more time and patience. Among common decision factors to be considered in restoring multiple diastemata distal to the midline involves whether to add only to the proximal surface of one tooth or include the proximal surface of the adjacent tooth as well. Obviously the interproximal contour and size of the teeth in question as well as size of the space to be closed must be taken into account. It is important, however, to keep in mind that the maxillary central incisors should be nearly mirror images of each other in terms of size, contour, and color and should "dominate" the smile. A slight variance in size, contour, and position of lateral incisors is, however, acceptable in many cases and can even result in a more natural appearance. Figure 26.9A–C demonstrates how composite resin can be utilized to restore multiple diastemata following orthodontic care and restore the smile to a very pleasing and esthetic appearance. Composite resin was chosen as the restorative material based on the patient's age, desire for conservative treatment, and finances.

Cases where a diastema exists but the teeth currently have a pleasing proportion, or such that the application of composite

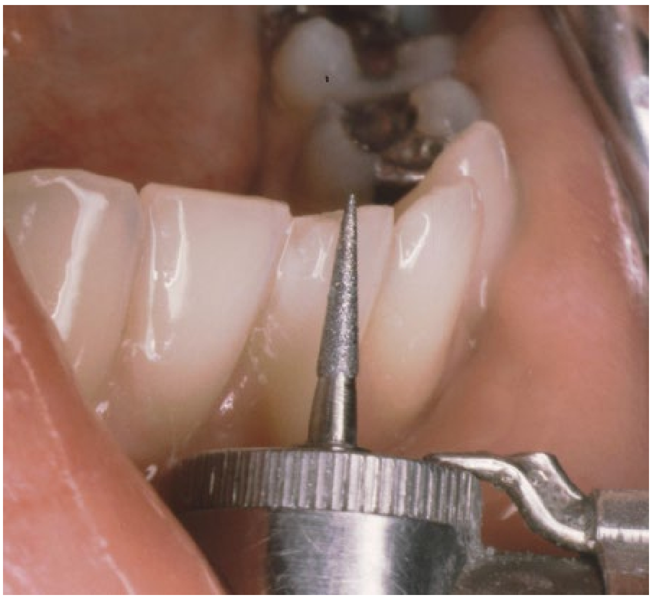

Figure 26.7 **(B)** Many times, it will be necessary to adjust the occlusion on the opposing arch to lessen the stress on the bonded incisors. Care should be exercised however to maintain a definitive lower incisal edge.

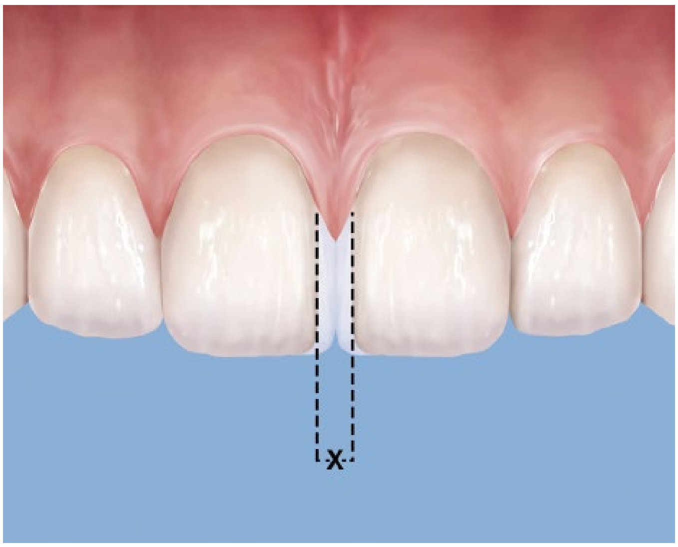

Figure 26.7 **(D)** The midline diastema is closed by measuring the size of the interdental space (*X*) and adding composite in equal amounts (*X*/2) to each tooth (assuming teeth are of equal width preoperatively). *Source:* illustration by Zach Turner.

Figure 26.7 **(E)** The space is now closed. Note how invisible a properly contoured and well-blended restoration can be.

Figure 26.7 **(F)** The post-treatment view confirms what the patient said, "that even a small diastema can distract from one's smile."

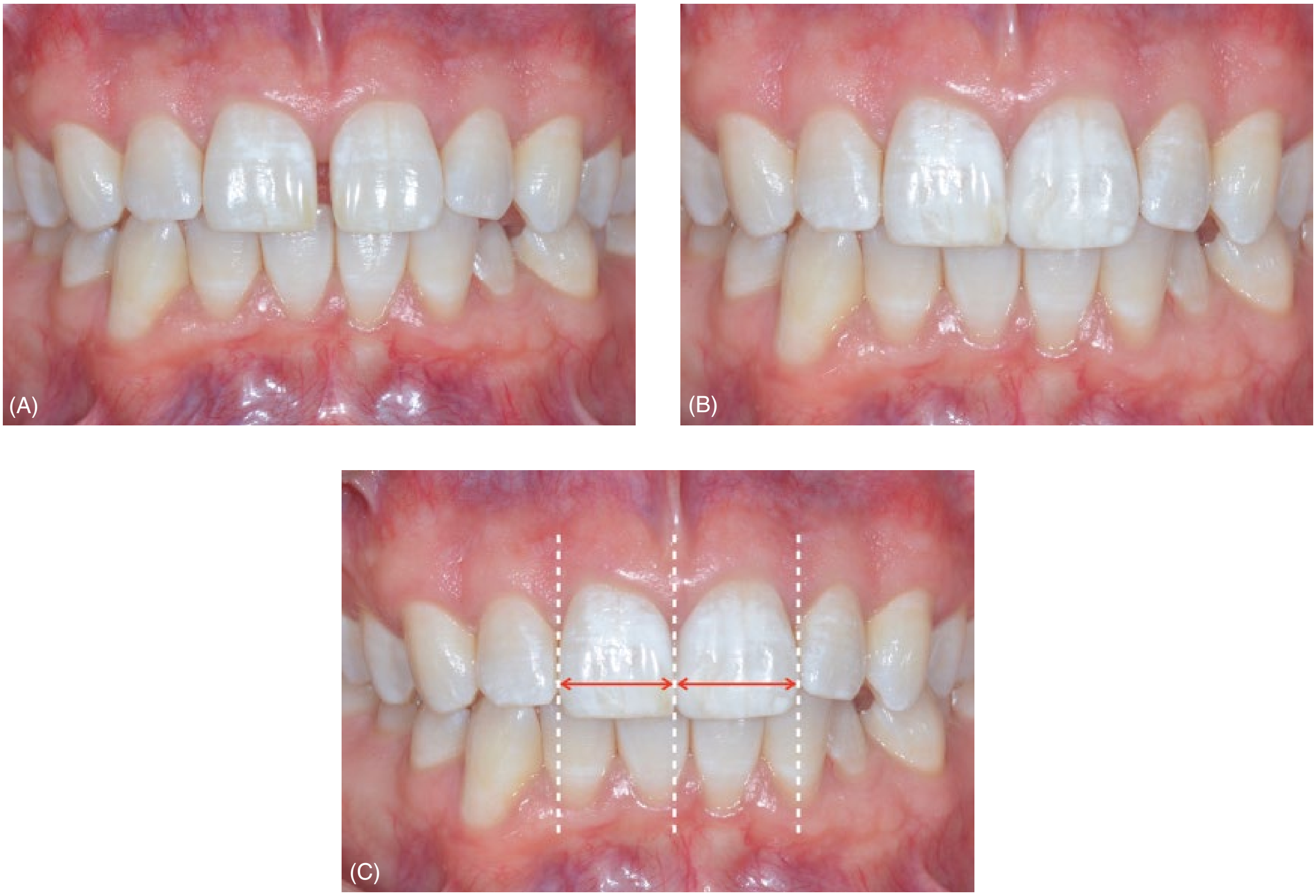

Figure 26.8 **(A–C)** Notice how the addition of composite resin to one central incisor (#9), in an attempt to close a midline diastema, results in uneven widths of the incisors and a less than desirable esthetic result.

resin to close the space would result in teeth that appear excessively wide, present more of a diagnostic challenge. An alternative to bonding to the central incisors, for example, may be to orthodontically approximate the teeth, followed by application of composite resin to the adjacent teeth as long as it does not make the lateral incisors appear too wide and cause them to compete for dominance with the central incisors. Clinical case 26.1 illustrates this technique.

An often misdiagnosed etiology of diastemata is related to tooth shape. Narrow teeth can present challenges to achieving the ideal 75–80% width-to-length ratio and may exhibit long interproximal contacts (accompanied by a lack of ideal interproximal soft tissue contours) that are not esthetically pleasing. Understanding not only how tooth size but also tooth shape plays a role in the development of pleasing esthetics is important to the overall outcome in diastema closure. Clinical case 26.3 describes how composite resin bonding was utilized to close residual post-orthodontic spaces due to tooth shape inadequacies and create an overall esthetically pleasing and hygienic result. Although this case may not be considered to be an example of simple diastema closure treatment, it does demonstrate how appropriate diagnosis, including a pretreatment diagnostic wax-up, when needed, and subsequent well-planned orthodontic treatment allow similar cases to be finished in an expedient and pleasing manner. These types of interdisciplinary care must involve frequent and clear communication between the restorative dentist and specialist.

Localized spacing due to missing teeth may require a combination of orthodontic and restorative treatment. Minor tooth movement to correct uneven mesial or distal drifting of spaced teeth can improve the esthetic result of corrective restorations by creating symmetric interdental spaces for individual restorations, or through the formation of normal-sized edentulous spaces for prosthetic restorations. Although orthodontic repositioning may offer the most noninvasive or conservative method for diastema correction, this approach may be impractical, unaffordable, or unacceptable to some patients and may not even result in permanent closure of the diastemata. In these situations, restorations are used as a means of closing a diastema rather than orthodontics, or to splint teeth following tooth repositioning[55] to minimize any potential for relapse. The size and number of the diastemata, functional and esthetic requirements of the patient, and pretreatment condition of the affected teeth influence the choice of restoration and restorative material. Composite resin bonding can often be used to complete the final esthetic correction of remaining interdental spaces or serve as interim restorations until more definitive care can be rendered. It is important to remember that the end result of diastema closure should conform to the esthetic ideals of smile design.[21,56] Esthetic parameters for pleasing tooth proportions in terms of width-to-length ratios and tooth-to-tooth relationships should be followed wherever possible for the most esthetically pleasing result.

Figure 26.9 **(A)** This patient was unhappy with the appearance of her smile due to the spaces and small size of her teeth. These residual spaces were intentionally left by the orthodontist to allow for future bonding. *Source:* Reproduced with permission of Jim Peyton.

Closing multiple diastemas

As mentioned previously, treating a case of multiple diastemas (diastemata) presents a greater challenge. Often a "mock-up" or "esthetic preview" using a bis-acryl-type material in a polyvinyl siloxane matrix (made from a diagnostic wax-up) can be very helpful in evaluating the anticipated results prior to definitive treatment. Pretreatment clinical assessments including incisal edge position, tooth shape and width-to-length ratios, periodontal–esthetic relationships, restoration influence on speech, etc. can be evaluated prior to initiating treatment and alterations made as needed. Clinical case 26.4 depicts the closure of multiple interdental spaces using direct composite resin.

(B) (C)

Figure 26.9 **(B, C)** The patient's concerns were addressed and corrected through meticulous bonding with composite resin. Note that not only were the spaces closed but also the teeth are now more appropriately proportioned. *Source:* Reproduced with permission of Jim Peyton.

Clinical case 26.1

Problem

This 23-year-old man stated as his chief complaint that the space between his two front teeth had returned after having been restored several years before with full porcelain crowns to correct the diastema (Figure 26.10A). It was believed that the teeth had drifted apart because of an existing periodontal condition that was further complicated by an occlusal problem.

Treatment

The mandibular incisors were adjusted to eliminate anterior interference and traumatic occlusion, followed by initiation of periodontal therapy. Upon completion of conservative periodontal therapy, an elastic ligature was placed around the maxillary central incisors to close the diastema. After wearing the elastic for several days, the patient returned with the space closed (Figure 26.10B). To prevent future drifting of the central incisors and reformation of the diastema, the newly created space between the central and lateral incisors must be treated. Artus's shim-type articulating ribbon (Artus Corp.) was used to protect the adjacent centrals from acid etching and bonding to the lateral incisors. This extremely thin material (5/10 000th of an inch) is preferred over the much thicker Mylar or other materials to achieve the tightest contact possible. Figure 26.10C shows the shim stock in place with the lateral incisor etched and ready for application of composite resin bonding agent, followed by light curing (see Figure 26.10D). Alternatively, Teflon tape (also known as "plumber's tape") can be used for protection of adjacent teeth from acid etching (see Figure 26.10E). The addition of composite resin is next adapted to the lateral incisor to close the diastema (Figure 26.10E). This material is then polymerized from the labial and palatal surfaces. Some clinicians choose not to use any matrix during the placement of the composite resin itself (matrix removed after etch and

Figure 26.10 **(A)** This 23-year-old man presented with a new diastema formation between his previously crowned central incisors. The space had opened because of a periodontal condition complicated by traumatic occlusion.

Figure 26.10 **(B)** After conservative periodontal therapy and occlusal equilibration, a rubber elastic was placed on the central incisors to reapproximate the teeth.

Figure 26.10 **(C)** The adjacent lateral incisors were tightly bonded using Artus shim stock (5/10 000th of an inch thick) to achieve the tightest closure possible.

Figure 26.10 **(D)** As Figure 26.10C, but with the addition of composite resin to close the diastema.

Figure 26.10 **(E)** Use of Teflon tape wrapped around the adjacent teeth to prevent contact with acid etchant to follow. The tape can be removed following rinsing of the etchant to allow composite resin to be built up directly against the adjacent teeth to achieve a tight contact.

application of adhesive layer) and prefer to build the composite resin layer(s) directly against the adjacent tooth or adjacent composite resin restoration as long as it is smooth and highly polished. This approach provides exceptional interproximal contacts without the use of wedges that can cause gingival "black" triangles. Once completed, the teeth can be separated by the use of a small instrument inserted between the teeth below the contact using a gentle twist. The occlusion should be checked carefully, with the patient reclined and in a fully upright position, to ensure that excessive centric or excursive contacts are eliminated to avoid mobility and possible tooth movement which could lead to the recurrence of a diastema.

Figure 26.10 **(F)** After 24 months, the teeth continue to be held in position by the tightly bonded lateral incisors and a stabilized occlusion.

Result

Figure 26.10F shows the closed diastema, sufficiently stabilized by the lateral incisors. Regardless of whether the lateral incisors were crowned, laminated, or bonded, it is essential that the contact area be broad, so that the central incisors are held securely in place. During closure, it is recommended to stabilize the central incisors by temporarily holding them together on the lingual with composite resin (with minimal use of etchant and adhesive) until the lateral incisors can be bonded. Following completion of the final bonding process, the composite resin on the lingual of the central incisors can be easily removed.

Clinical case 26.2

Figure 26.11A shows a similar case where the patient had a midline diastema but was happy with the shape and size of her maxillary central incisors and elected orthodontic treatment to close the space between teeth #8 and #9. Diastemata remained bilaterally (due to the small lateral incisors) following completion of orthodontic care; see Figure 26.11B. The patient was pre-advised of this likelihood prior to initiating orthodontic treatment as part of informed consent. Teflon tape was used to protect the adjacent teeth from acid etchant (as in Figure 26.10D). Following etching and application of adhesive (no primer was needed as only bonding to enamel), composite resin was added to the mesial and distal of both lateral incisors. The composite resin additions were built directly in contact with the adjacent teeth without the use of any separating matrix. The final result can be seen in Figure 26.11C with a well-proportioned lateral incisor. One can also see the results of gingival grafting over the root of tooth #11 (#6 was also treated simultaneously) that was completed prior to orthodontic therapy. The patient was very pleased with the overall interdisciplinary combination of periodontal, orthodontic, and restorative care.

Figure 26.11 **(A)** This patient was unhappy with her midline diastema and tissue recession over her maxillary canines. The patient was given options for treatment and elected an interdisciplinary approach to achieve her desired result.

Figure 26.11 **(B)** Postorthodontic spaces remain mesial and distal to her lateral incisor (right side is identical) due to the small size of these teeth.

Figure 26.11 **(C)** Spaces closed by use of composite resin. Note the more appropriately sized lateral incisor following direct bonding and the nice result of root coverage following gingival grafting over the canine tooth. (The patient's right side was similarly treated.)

Large diastemata

Certain esthetic dilemmas are inherent with large diastemata that create more difficult challenges in trying to produce esthetically acceptable results. In many cases, without orthodontic intervention, some compromise in esthetics is likely. The first challenge is obviously attempting to create esthetically pleasing tooth width-to-length ratios. Along with this challenge is the need for more aggressive tooth preparations and the likely involvement of more teeth to attempt to compensate for and prevent excessively wide teeth. The second challenge is with soft tissue contours (i.e., gingival papillae). Large diastemata are usually associated with broad, flat interdental papillae. Without

Clinical case 26.3

Problem

A teenage male underwent orthodontic therapy for a Class II, Division II dental malocclusion (Figure 26.12A) requiring preliminary skeletal growth modifications and Class II correction. Pretreatment evaluation revealed that the shape of the teeth would in all likelihood require restorative therapy to improve their contours following tooth movement, and this finding was discussed with the patient and his parents (as part of informed consent) prior to orthodontic treatment. Following completion of his orthodontic therapy, residual maxillary anterior diastemas were apparent (maintained intentionally in preparation for future bonding, see Figure 26.12B) as a result of this tooth shape deficiency. Following debanding, the patient was unwilling to return to school until the spaces were closed, and thus the direct restorative procedure was carried out within 24 h of orthodontic appliance removal.

Treatment/result

The patient underwent 2 years of orthodontic therapy to correct his malocclusion and gingival levels. Following removal of appliances, the patient was instructed to return to his restorative dentist for composite resin bonding of the interproximal surfaces of the maxillary lateral and central incisors. Composite resin was added to close the diastemata, resulting in esthetically and periodontally ideal tooth contours (Figure 26.12C).

Figure 26.12 **(A)** Pretreatment orthodontic consultation for this male teen included the likelihood of posttreatment restorative care to improve tooth proportions as a result of tooth shape (slender teeth). *Source:* Reproduced with permission of Amara Abreu.

Figure 26.12 **(B)** The patient's smile and orthodontic results immediately following debanding. Note the significant enhancement in tooth alignment in both the horizontal and vertical planes. The health and appearance of the edematous lower gingival tissues were greatly improved following subsequent dental hygiene visits and improved home care. *Source:* Reproduced with permission of Amara Abreu.

Figure 26.12 **(C)** An improvement in tooth size and shape is shown following closure of the diastemata with composite resin the day after orthodontic appliances removal. *Source:* Reproduced with permission of Amara Abreu.

Clinical case 26.4

Problem

A 26-year-old female presented with desire to close the spaces between her front teeth (see Figure 26.13A–C) as well as replace the missing maxillary premolar teeth. Her dental history included previous orthodontics with extractions, and she subsequently had an acid-etch retained bridge ("Maryland bridge") placed from tooth #3 to #6 to replace the missing premolar (space was limited to a single pontic). This Maryland bridge eventually fractured and tooth #3 exhibited significant decay.

Figure 26.13 **(A–C)** A 26-year-old female presents wanting to close the spaces between her teeth. *Source:* Reproduced with permission of Robert C. Margeas.

Treatment

Esthetic analysis revealed narrow central incisors for which composite resin addition would not only close the interdental space but also improve the width-to-length ratios. The patient had been presented with the option of porcelain veneers by other dentists, but her desire was for a more conservative approach and instead chose composite resin bonding as both an economic and immediate solution.

Prior to acid etching, shade selection was accomplished by trial addition of composite resin to simulate the desired result. A polyvinyl siloxane putty matrix (Template, Clinician's Choice Dental Products, Inc., New Milford, CT) was fabricated on the cast of the diagnostic wax-up and used as a template intraorally to establish incisal length and midline position (Figure 26.13D). Use of such a matrix removes the guesswork as the proportions have been predetermined via the diagnostic wax-up. The bonding process was carried out starting first with the central incisors in order to ensure tooth width symmetry (Figure 26.13E). Teflon tape was utilized to protect adjacent teeth from etchant and adhesive. Following completion of the central incisors, the lateral incisors were similarly treated. The putty matrix was again utilized as support for the lingual (palatal) increment or "shelf" of composite resin (Figure 26.13F). The remaining facial increments of composite resin were freehand sculpted to complete the buildup. A clear Mylar strip was inserted between the central and lateral incisors and a "pull through" technique was used to draw the composite resin into the interproximal space as the Mylar strip was slowly pulled from a facial to palatal direction. This technique can be used to develop interproximal contacts directly against the adjacent teeth without the use of wedges, which can cause bleeding, undercontoured axial surfaces, and often result in unsightly "black triangles."

The restorations were then shaped and polished using Sof-Lex discs (3M ESPE, St. Paul, MN) and ET diamonds (Brasseler USA, Savannah, GA) followed by rubber FlexiCups and FlexiPoints (Cosmedent, Chicago, IL), Jiffy composite polishing brushes (Ultradent Products, Inc., South Jordan, UT), and finally polished with Enamelize Polishing Paste on a FlexiBuff felt-coated disc (Cosmedent) (Figure 26.13G–I). Interproximal polishing was accomplished by use of very thin polishing Epitex strips (GC America, Alsip, IL) (Figure 26.13J). Tooth #3 was then prepared to receive a monolithic zirconia crown and cantilever pontic #4. Tooth #13 was replaced by the direct bonding of a composite resin pontic to the mesial of #14 (see "Immediate closure of posterior diastema" section).

Result

The end result shows a beautiful, well-proportioned smile that met the patient's objectives of using a conservative technique to close the anterior diastemata (Figure 26.13K–N). The conservative nature of the treatment performed allows the patient the opportunity to have porcelain veneers placed at a later date should she so choose.

Figure 26.13 **(D–F)** Illustration of the use of a polyvinyl siloxane putty matrix to aid in composite addition to close the interdental spaces as predetermined from the diagnostic wax-up. *Source:* Reproduced with permission of Robert C. Margeas.

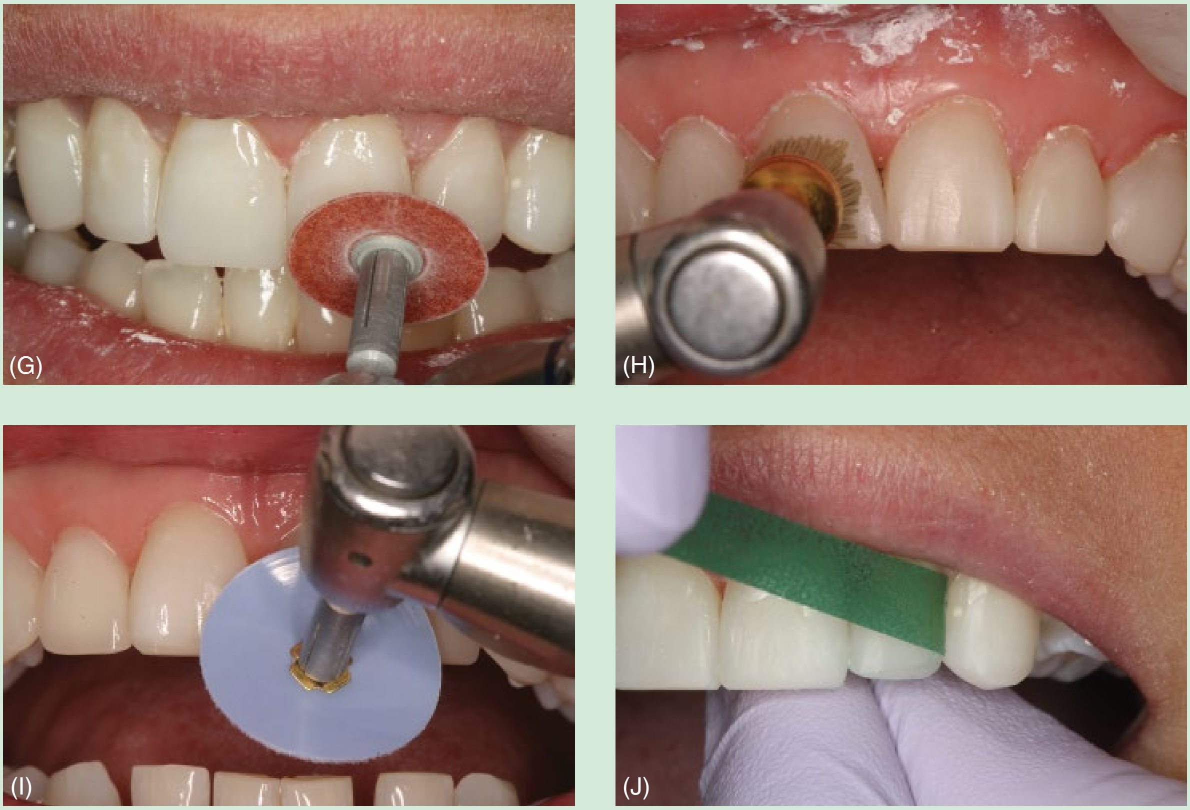

Figure 26.13 **(G to J)** Multiple steps are used to contour, finish, and polish the restorations to achieve the esthetic result desired. *Source:* Reproduced with permission of Robert C. Margeas.

Figure 26.13 **(K to N)** Final result, showing a well-proportioned smile and improvement of tooth-to-tooth proportions. *Source:* Reproduced with permission of Robert C. Margeas.

Clinical case 26.5

Problem

A 60-year-old airline travel agent presented with a large diastema between the maxillary central incisors (see Figure 26.14A–E). Advanced cervical erosion was also evident on her maxillary anterior teeth, especially on her right side.

Treatment

The teeth were slightly reproportioned by stripping and disking the distal surfaces of the central incisors (Figure 26.14B). The key to successful restorative diastema closure is creating the illusion of a believable "natural" tooth width in the central and lateral incisors. Figure 26.14C shows a narrower width of the central incisors after the distal surfaces have been sufficiently reduced and prepared for full-veneer bonding to close the central incisor diastema and restore the cervical defects. The definitive bonded composite resin restorations can be seen in Figure 26.14D.

Result

Figure 26.14 F shows an entirely new smile with better proportioned teeth rather than two oversized teeth. Note that the cervical erosion on the maxillary right side has been simultaneously restored with composite resin bonding (occlusion should be meticulously checked and adjusted to minimize any occlusal etiology to these types of noncarious cervical lesions). The mandibular anterior incisors were also cosmetically contoured to give them a level plane of occlusion. Comparing the before and after smiles (see Figure 26.14E and F) specifically illustrates how the patient's mid-upper lip naturally drops rather low, forming a classic "cupid's bow" contour. This lowered lip line tends to mask the extra width of the central incisors, which also contributes to the illusion.

A schematic drawing of how this case was restored can be seen in Figure 26.15A and B. *X* denotes the distal surface of the central and lateral incisors, which were reduced to compensate for the

Figure 26.14 **(A)** This 60-year-old woman presented with a large diastema between her central incisors and cervical erosion on her maxillary anterior teeth.

Figure 26.14 **(B)** Stripping and disking of the distal surfaces of the central incisors were done to slightly reproportion the teeth.

Figure 26.14 **(C)** The narrowed width of the central incisors (from disking of the distal surfaces) will allow for addition of composite to the mesial surfaces to close the diastema while attempting to avoid excessively wide teeth.

Figure 26.14 **(D)** The final full-veneer bonding closed the diastema and restored the cervical defects.

addition of composite resin to the mesial surface of the teeth. This reduction of the distal surface helps to keep the mesially bonded aspects (*Y*) of the central incisors in proper proportion. Residual spacing between the canines and lateral incisors can then be subsequently closed as well by the addition of composite resin. Any subgingival bonded areas must be meticulously contoured and finished so that the patient can maintain good dental hygiene and tissue health with the use of dental floss (Figure 26.15C).

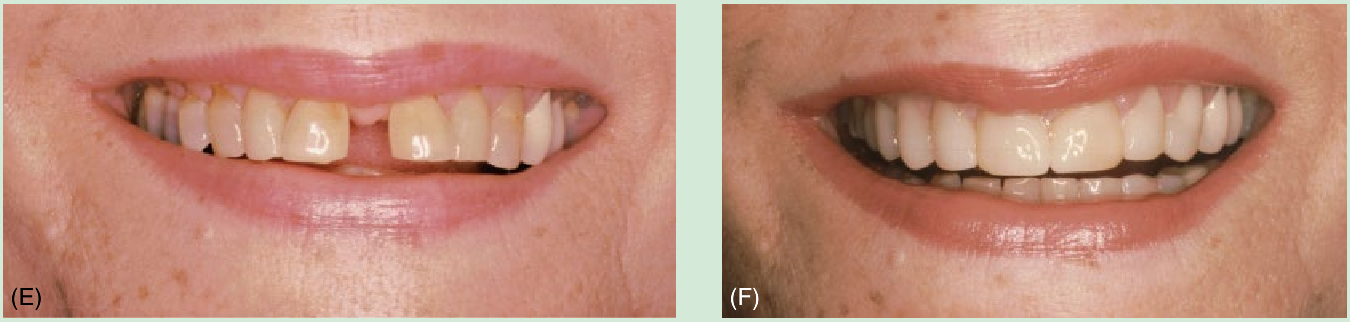

Figure 26.14 **(E, F)** Comparison of the before and after smiles shows an entirely new smile that is better proportioned by treating four anterior teeth. If only the central incisors had been bonded, two oversized central incisors would have resulted.

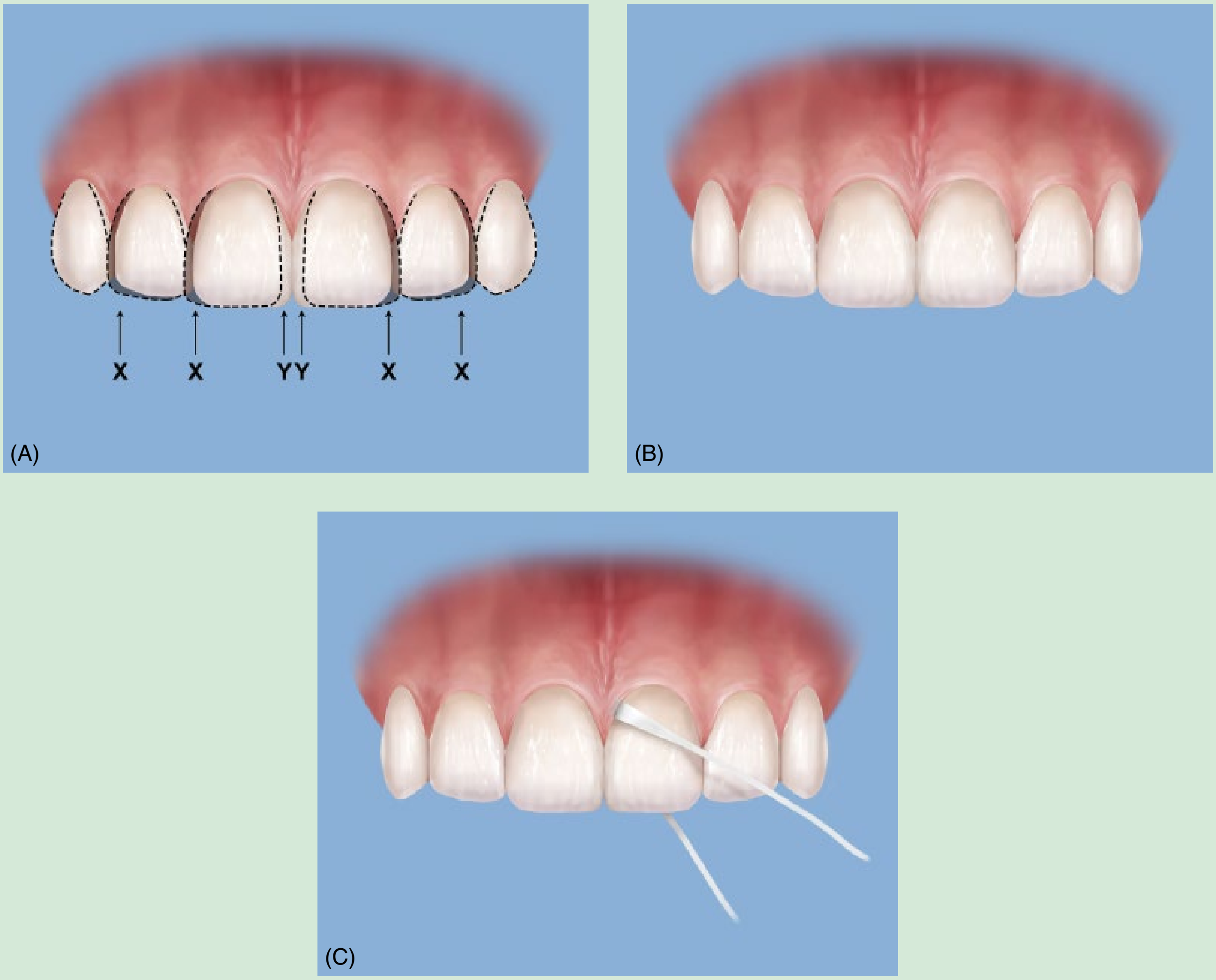

Figure 26.15 **(A, B)** These drawings illustrate how the teeth of the patient in Figure 26.14 were restored. Additional tooth reduction was performed on the distal surfaces of the central and lateral incisors ("X") to allow for the addition of composite resin to the mesial surfaces ("Y") (Note: composite resin was added to the mesial surfaces of central and lateral incisors and canines), resulting in more ideal width to length ratios and a better proportioned smile as can be seen in Figure B (see text for more details). (C) The shape of the bonding should be conducive to easy flossing to maintain periodontal health. *Source:* illustrations by Zach Turner.

orthodontic treatment to approximate the tooth roots closer together, restorative treatment of the teeth in the cervical interproximal areas can only minimally alter this type of soft tissue contour. In the ideal situation, the interdental tissue should occupy approximately 40% of the incisogingival length of the incisors. Papillae heights, as shown by Chu et al., were determined on average to be 40% of the clinical crown length as measured from gingival zenith to incisal edge.[57]

Two design options are possible with composite resin to close a diastema: full labial veneer versus proximal addition with labiolingual overlap. The following are factors that influence the choice:

- Full labial veneering offers the advantages of concealing the restoration margins by moving them further into the interproximal zone and covering any other imperfections of the facial surface. Hidden restoration margins are useful for disguising slight shade mismatches with tooth structure and to minimize the visibility of stain accumulation that may eventually occur at the margins.
- A full veneer restoration offers the advantage of increased retention, which is essential when tooth lengthening is desired in addition to interproximal space closure. Tooth lengthening is often needed to maintain an esthetic proportion of width to length for teeth when proximal additions are made to close spaces.
- If only one diastema is to be closed, composite resin is typically added to the proximal surface of one or both adjacent teeth (dependent on the size of the diastema and current width of approximating teeth) extending to the facial and lingual proximal line angles unless previous existing restorations dictate otherwise. Thus, when only the proximal surfaces require addition of composite resin, there is less indication for a complete labial veneer. This amount of coverage generally provides adequate retention and allows a sufficient amount of material to be removed by polishing if future staining occurs. Thoroughly polishing the tooth surfaces to be bonded to remove accumulated plaque and acquired pellicle prior to acid etching will help reduce future staining at the tooth resin interface. If composite resin bonding is required on both proximal surfaces of the same tooth, and especially if it extends significantly beyond the facial proximal line angles or if the incisal length needs to be increased, then full composite resin veneer coverage may be better suited for enhanced retention and esthetics. Proximal composite resin restorations that extend significantly past the facial line angles place the tooth resin interfaces more in the zone of direct vision of observers. Subsequently, staining that may occur at this interface would be more readily visible and require more frequent maintenance to polish and "renew" the restoration.
- Extremely translucent incisal edges on the teeth to be bonded may be a contraindication to using a complete labial veneer of composite resin. In this situation, confining the bonding material to the proximal surfaces will maintain the translucency of the incisal edges. When the incisal edge must be included as part of the restoration, composite resin with varying degrees of translucency or opacity can be selected to match the optical qualities of the existing incisal edge.

Historically, the choice of composite resin was influenced by the size of the space being closed in addition to the functional and esthetic requirements of the restoration.[58] If the space was small (≤1.5 mm), a microfilled composite resin material was used alone to close the diastema. However, it should be noted that deep overbites or heavy functional contacts may contribute to excessive wear or fracture of microfilled composite resins. Currently, for these situations or in the case of a larger diastema (>1.5 mm), modern, microhybrids or nanofilled resins can be used, which offer the combination of improved strength with greater fracture resistance (compared with microfills) and good polishability.[59,60] If so desired, however, a microfilled material can be veneered over the labial surface to provide the highest degree of luster and esthetics (Figure 26.16A–C).

Figure 26.16 **(A)** When a diastema of this size or larger is to be closed using composite resin bonding, a micro- or nanohybrid material should be applied to the lingual surface for strength. *Source:* Reproduced with permission of Robert C. Margeas.

Figure 25.16 **(B)** To obtain a maximum "glaze" or polish to match existing enamel, a microfilled composite resin can be used on the labial surface. *Source:* Reproduced with permission of Robert C. Margeas.

Figure 26.16 **(C)** Note the glazed appearance of the microfilled, highly polished labial enamel composite resin layer. *Source:* Reproduced with permission of Robert C. Margeas.

Immediate closure of posterior diastema

For a small posterior interdental space, a direct resin-bonded pontic could be considered as an option to improve the esthetic continuity from anterior to posterior. The patient, as described in Figure 26.13, was unhappy with the remaining space following orthodontic treatment (and accompanying extractions). As described previously, the space on the upper right was restored with a full-coverage ceramic crown and cantilevered pontic. However, the remaining space on the upper left quadrant was not of sufficient size to consider a dental implant and the adjacent teeth did not need any type of full- or partial-coverage restoration. Placing a full-coverage restoration on the first molar was discussed as an option but the patient was not willing to have an elective restoration placed in order to retain the pontic. Thus, the decision was made to close the space with a small, composite resin pontic directly bonded to the adjacent molar (tooth #14). The only preparation to the molar was to lightly roughen the mesial surface with a fine diamond bur to remove the fluoride-rich, aprismatic enamel for better etching. The connector size was kept as large as possible to decrease risk of fracture of the pontic from the adjacent molar (Figure 26.17E). Again, occlusion was carefully checked and adjusted to minimize excessive occlusal forces on the pontic or any lateral interferences in excursive movements. The final result can be seen in Figure 26.17 F and G. The patient was very happy with the overall outcome of resin bonding to solve her esthetic dilemma, both anteriorly and posteriorly.

Fortunately, posterior diastemata are not typically considered as much of an esthetic concern as those in the anterior region, and more often than not they are just a nuisance as a result of food entrapment. For larger diastemata, and especially in patients who demonstrate destructive habits such as clenching or bruxing, the prognosis of using direct resin materials should be considered guarded. As mentioned previously, use of resins with improved strength would be preferred over a microfilled

Clinical case 26.6

Problem

A 26-year-old female had undergone orthognathic surgery for her Class III protrusive malocclusion, which left a small diastema between the mandibular right cuspid and first bicuspid. The patient was very self-conscious of this space and adamantly declined other needed dental treatment until the space was closed (Figure 26.17A and B).

Treatment

Because a lack of sufficient space prevented the construction of a two- or three-unit fixed partial denture that would look symmetrical and attractive, an alternative treatment approach was needed. The option of a second orthodontic treatment was deemed impractical as surgical orthodontics had already been employed as long-term treatment. A direct placement

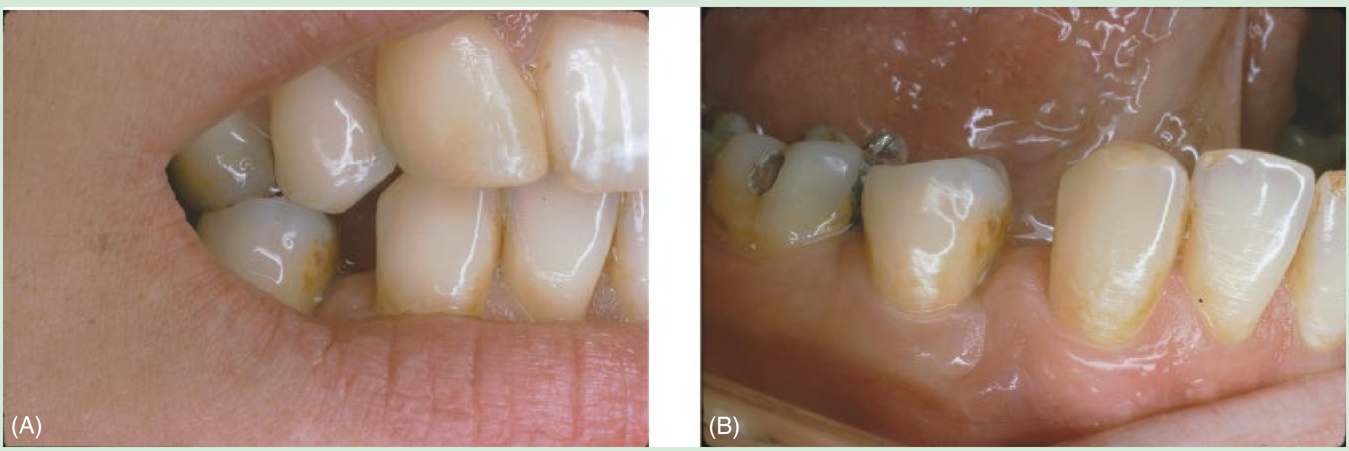

Figure 26.17 **(A, B)** This 26-year-old female was unhappy with the large diastema between the mandibular right cuspid and bicuspid following orthognathic surgery.

Figure 26.17 **(C)** Composite resin was added to the adjacent proximal surfaces.

composite resin technique was chosen as both an immediate and economical solution. In the case of a larger diastema, it will usually be necessary to add restorative material to both teeth to maintain better proportionality and minimize the overcontouring of any one tooth. In this case, the distal surface of the cuspid and the mesial surface of the first bicuspid were etched and restored with composite resin to close the diastema (Figure 26.17C). Because esthetics was the patient's chief concern, it was not imperative to completely close the space or obtain tight contact between these teeth. As each tooth was minimally bonded, neither appeared from a distance to be overly contoured or too large.

Figure 26.17 **(D)** The teeth remained acceptably closed after 5 years.

Result

The 5-year follow-up result can be seen in Figure 26.17D. It is important to inform the patient that no dental restoration is truly "permanent" and that composite resin closure of a diastema may require refinishing, repair, or replacement every few years as discoloration, wear, and fractures may occur. Appropriate case selection, delivery of care, and pre- and posttreatment preventive measures (such as occlusal evaluation and adjustment as needed, elimination of noxious habits, occlusal guard, etc.) can improve the odds for long-term success.

composite resin due to added strength, and thus a reduced risk for fracture. Attempting to establish broad contacts occlusogingivally would be advantageous to improve the strength of the marginal ridge and reduce the size of the gingival embrasure as a food trap. Occlusion must be carefully checked and adjusted, perhaps even to the opposing cusp as well, and especially in cases where a plunger cusp exists, to minimize risk of excessive wear or fracture of the restoration. An occlusal guard should be considered for those patients with parafunctional activity.

Porcelain veneers

The choice of porcelain veneers for diastema closure offers superb esthetics as the major indication for their use. Ceramics have the capacity to replicate the esthetically pleasing characteristics and vitality of natural teeth.[61] In addition, indirectly fabricated restorations are considered easier for many dentists as most of the contouring, shading, and anatomy is created by the laboratory technician. Other advantages of incorporating all-ceramic restorations, especially for anterior teeth, include improved strength, durability, marginal integrity, color match, and wear resistance.[62] Owing to its crystalline matrix, ceramics are more resistant to attritional wear than composite resin.[63] However, owing to the brittle nature of porcelain,[63] the failures with porcelain tend to be more catastrophic in nature, especially under tensile and torsional stresses[61,64,65] and, therefore, more likely to require a remake of the restoration. Although composite resin restorations often require no or minimal mechanical tooth preparation, porcelain veneers almost always require some enamel preparation for the best results and, therefore, should not be considered to be a reversible procedure. It is possible in select

Figure 26.17 **(E)** Occlusal view of the composite resin pontic showing the large connector size (patient from Clinical case 26.4 (Figure 26.13)). *Source:* Reproduced with permission of Robert C. Margeas.

Figure 26.17 **(F, G)** The final result of closing the posterior space via a resin-bonded composite pontic was very pleasing esthetically to the patient. *Source:* Reproduced with permission of Robert C. Margeas.

cases, however, to use minimal preparation veneers that can be fabricated as thin as 0.3 mm[66–68] and provide excellent esthetics with minimal tooth preparation as seen in Clinical case 26.7.

As mentioned previously, it is important to keep in mind that most cases of porcelain veneers do require some degree of tooth preparation to sufficiently align and contour the restored teeth, reduce sharp edges (to minimize risk of internal crack propagation of the overlying ceramic material), and to allow for proper gingival health. The amount of preparation is case dependent, and the practitioner should advise the patient that conservative preparation does not always mean insignificant tooth reduction, but rather reduction of the least amount of tooth structure possible to achieve the goals of the case. The final desired position, color, and shape of the restoration(s) should be the main determinants for the amount of tooth preparation. Just as the amount of reduction is specific to each case, the design of veneer preparations must also be case specific and not be generalized as a single protocol for use in every situation.[68]

Clinical case 26.7

Problem

This patient was unhappy with the appearance of his smile (Figure 26.18A and B) and was getting married in 8 weeks; thus, orthodontic treatment was not an option. The patient's goals included closing the spaces, straightening his teeth to make them show more evenly in his smile, and brightening them.

Treatment

The teeth were minimally prepared to round and soften sharp corners, remove any undercuts to the path of insertion, and to develop a very slight chamfer finish line (for gingival health) and to minimize staining at restoration–resin cement–tooth interface (Figure 26.18C). Lithium disilicate veneers were

Figure 26.18 **(A, B)** This adult male patient desired to improve the evenness and color of his smile and close the spaces. Owing to time restrictions, orthodontic care was not an option. *Source:* Reproduced with permission of James Fondriest.

Figure 26.18 **(C)** Minimal preparations were performed to allow for porcelain veneers that would fulfill the patient's desires. *Source:* Reproduced with permission of James Fondriest.

chosen because of their strength at minimal thicknesses. A shade was chosen that would brighten his smile and give him the look he was seeking.

Result

The patient's goals for treatment were successfully met without significant sacrifice of healthy tooth structure. In addition, occlusal function was improved and anterior guidance was restored. The before and after final results can be seen in Figure 26.18D and E. The patient was very happy with the results obtained and advised of necessary home care techniques and need for follow-up recall visits.

Figure 26.18 **(D, E)** The final results show that, in properly selected cases, minimal prep veneers can be very esthetic, preserve tooth structure for improved bond strength, and provide for acceptable cervical contours to maintain periodontal health. *Source:* Reproduced with permission of James Fondriest.

The normal proximal finish line employed for a traditional porcelain veneer preparation is typically a chamfer prepared labial to the interproximal contact when there are no interdental spaces present. However, when attempting to close diastemata or modify interproximal tooth contours, the lingual margin in most cases should be carried through the embrasure to the linguoproximal line angle, but without extending onto the lingual surface, thereby creating a potential path-of-draw issue (Figure 26.19A and B). The finish line for a porcelain veneer that is being used to close a diastema may approach a featheredge at the linguoproximal line angle, although a chamfer provides more edge strength.[69] A lingually positioned proximal finish line on the diastema side of the tooth avoids preparation undercuts with the linguoincisal extension and also allows for a thicker interproximal increment of porcelain to reduce translucency. In addition, it allows the laboratory technician to begin the interproximal emergence profile from the linguoproximal line angle, creating broader and more gradual contours for enhanced esthetics and patient hygiene.

Consultation with one's ceramist is important in treating diastema patients with indirect restorations. Additionally, the radiographic location of the osseous crest and periodontal pocket depths should be evaluated as interproximal subgingival margins are often needed to achieve a natural-looking diastema closure.

Closing single midline diastema with porcelain

In most cases of a single midline diastema where the teeth have normal proportion and the size of the diastema is not too large, the clinician will likely choose to close it with composite resin (given the advantages discussed previously). The results are

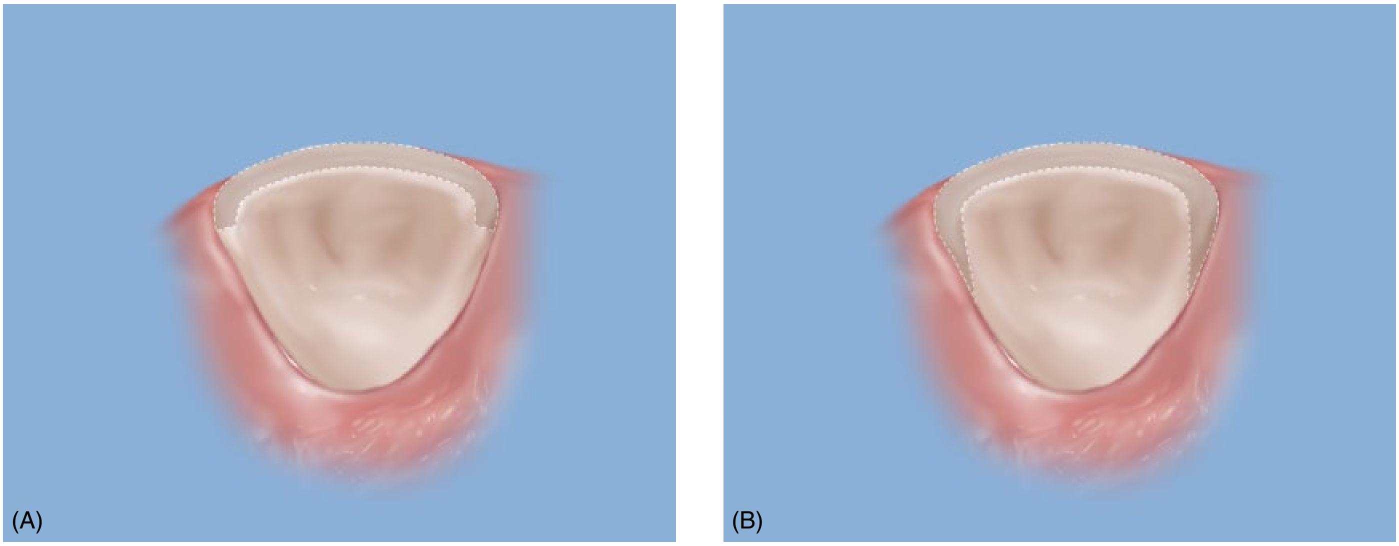

Figure 26.19 **(A)** The conventional preparation for a porcelain laminate, when there is no space to close, usually extends one-third to midway into the proximal surface. **(B)** This revised preparation extending to the linguoproximal line angle is indicated when closing interdental spaces. *Source:* illustrations by Zach Turner.

immediate and can be long lasting with proper maintenance. For those occasions when the dentist and patient prefer to close a diastema using porcelain (e.g., enhanced esthetics, larger diastema, personal preference) and the facial surfaces of the abutment teeth are unrestored and esthetic, an alternative approach may include the use of porcelain sectional veneers, or so-called "porcelain pieces." Sectional veneers enable the diastema to be closed with minimal or no tooth preparation other than creating a path of draw and rounding any sharp line angles. The disadvantages of this option are that it involves an additional appointment, the porcelain pieces can be more difficult to handle (i.e., fragile) and stabilize during the bonding procedure, and it requires exceptional laboratory support, and thus an accompanying laboratory fee. However, with good laboratory support and proper case selection, the results can be exceptional, as shown in Clinical case 26.8.

Closing multiple diastemata with porcelain veneers

When several restorations will be required (multiple diastemata), laboratory-fabricated restorations can allow the dentist to achieve more ideal results in terms of proportioning multiple teeth (assuming the teeth are relatively evenly spaced) and provide for better symmetry. Clinical case 26.9 describes use of porcelain veneers to accomplish this objective.

For the more discriminating patient who seeks results over tooth preservation, in most instances additional preparation will be required. In any case, however, it should always be the goal of the practitioner to preserve as much tooth structure, and specifically enamel, as possible to improve the bond strength and maintain the overall flexural strength of the

Clinical case 26.8

Problem

A female patient was unhappy with the space between her front teeth and the chipped edge of the right incisor and wanted to know the options for treatment, but was otherwise satisfied with the appearance of her smile (see Figure 26.20A and B). She was not interested in orthodontics to close the space, and she wanted to preserve her natural tooth structure and have the most esthetic, longest lasting result possible.

Treatment

The patient elected to have the diastema closed and incisal edge of tooth #8 repaired with ceramic. The interproximal surfaces were disked to ensure smoothly contoured surfaces, but no other preparation was made. Porcelain pieces were fabricated from feldspathic porcelain with clear porcelain added to the facial margins to create a "contact lens effect" (Figure 26.20C) and bonded using the etch-and-rinse technique and clear light-cured composite resin cement. Prior to the adhesive bonding step, the sectional veneers were carefully inserted in order to evaluate the fit, esthetics, and ultimate path of insertion needed (Figure 26.20D). After bonding to place, the excess porcelain was carefully reduced with a fine diamond bur followed by final contouring and polishing of the teeth and ceramic.

Result

The final result was very esthetic, with the patient being extremely satisfied with the outcome (see Figure 26.20E and F). The exquisite detail to emergence profile and hygienic contours, and the artistic ability of the master ceramist were paramount to the ultimate success of this case.

Figure 26.20 **(A, B)** This female patient was unhappy with the space between her front teeth and wanted the most esthetic option available for closing it while remaining as conservative as possible. *Source:* Figure B from Chiche et al.[45(p53)] Reproduced with permission of Quintessence Publishing.

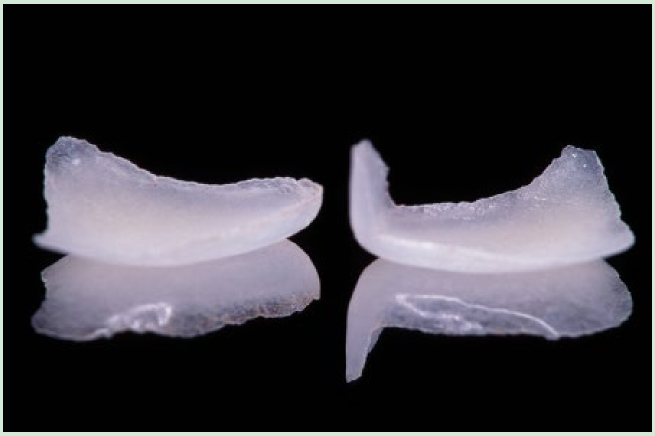

Figure 26.20 **(C)** Feldspathic sectional veneers (porcelain pieces) were fabricated that would be bonded with resin cement. *Source:* Chiche et al.[45(p45)] Reproduced with permission of Quintessence Publishing.

Figure 26.20 **(D)** Sectional veneers are shown being inserted during the try-in phase in order to evaluate fit and path of placement required for the final bonding process.

Figure 26.20 **(E, F)** The final result shows the conservative nature of this diastema closure and the extreme attention to detail in the laboratory phase and bonding technique (to ensure correct alignment of these porcelain sectional veneers). *Source:* Figure E from Chiche et al.[45(p53)] Reproduced with permission of Quintessence Publishing.

tooth as it has been shown that bonding ceramic to the tooth recovers strength that is lost as an inherent part of tooth preparation for restorative procedures.[70] In fact, bonded ceramic veneers are capable of restoring the fracture strength of teeth to values of intact teeth.[40,71,72] Clinical case 26.10 depicts a more typical porcelain veneer preparation utilized to close multiple diastemata.

Combination crowns/veneers

One of dentistry's goals is to be as conservative as possible while accomplishing the best functional and esthetic result. However, at times it becomes necessary to combine full-coverage restorations with veneers in closing diastemata. Figure 26.23A illustrates the principle of space reallocation, through specific preparation

Clinical case 26.9

Problem

Figure 26.21 shows a 21-year-old male model who hesitated to smile because of his diastemata (see Figure 26.21A, D, and F). The patient was also concerned about the appearance of his inflamed gingiva adjacent to the left central incisor, and subsequent examination showed an overextension of existing composite resin bonding. A main requirement of this patient was immediate esthetic treatment since he was leaving the country the following week. A second requirement was that no additional tooth be reduced, including the opposing teeth.

Figure 26.21 **(A)** This 21-year-old male model performed both runway and photography modeling without smiling because he disliked the spaces between his teeth.

Treatment

In order to maximize longevity and esthetics, porcelain laminates were chosen as the most conservative treatment. Figure 26.21B shows the occlusal view, indicating just how much the left central incisor protruded before restoration. Four porcelain laminates were used to create a symmetric arch with proper spacing (see Figure 26.21C). The improvement by the final result can be seen by comparing the before and after smiles (see Figure 26.21D–G). Note how the increased tooth size is well proportioned to the face. As mentioned previously, altering tooth size and controlling interproximal contours for diastema cases requires extending the lingual finish line of the veneer preparations close to the lingual–proximal line angles. By extending the finish line to the lingual, it enables the laboratory technician more flexibility in controlling the final esthetics of the case.

Result

Frequently, orthodontic treatment is required to reposition teeth together to avoid the overly contoured appearance of restored teeth. Although this treatment could have been employed and allowed for more ideal tooth proportions, the patient chose immediate esthetic correction over lengthy orthodontic treatment and was accepting of slight compromises to ideal esthetics for the sake of tooth conservation and expedience.

Figure 26.21 **(B)** This before occlusal view shows how much the left central incisor protruded prior to treatment. (Note: image is reversed).

Figure 26.21 **(C)** Only four porcelain laminate veneers were necessary to eliminate the dark spaces between his teeth. Also note that tooth #9 was brought back into arch alignment.

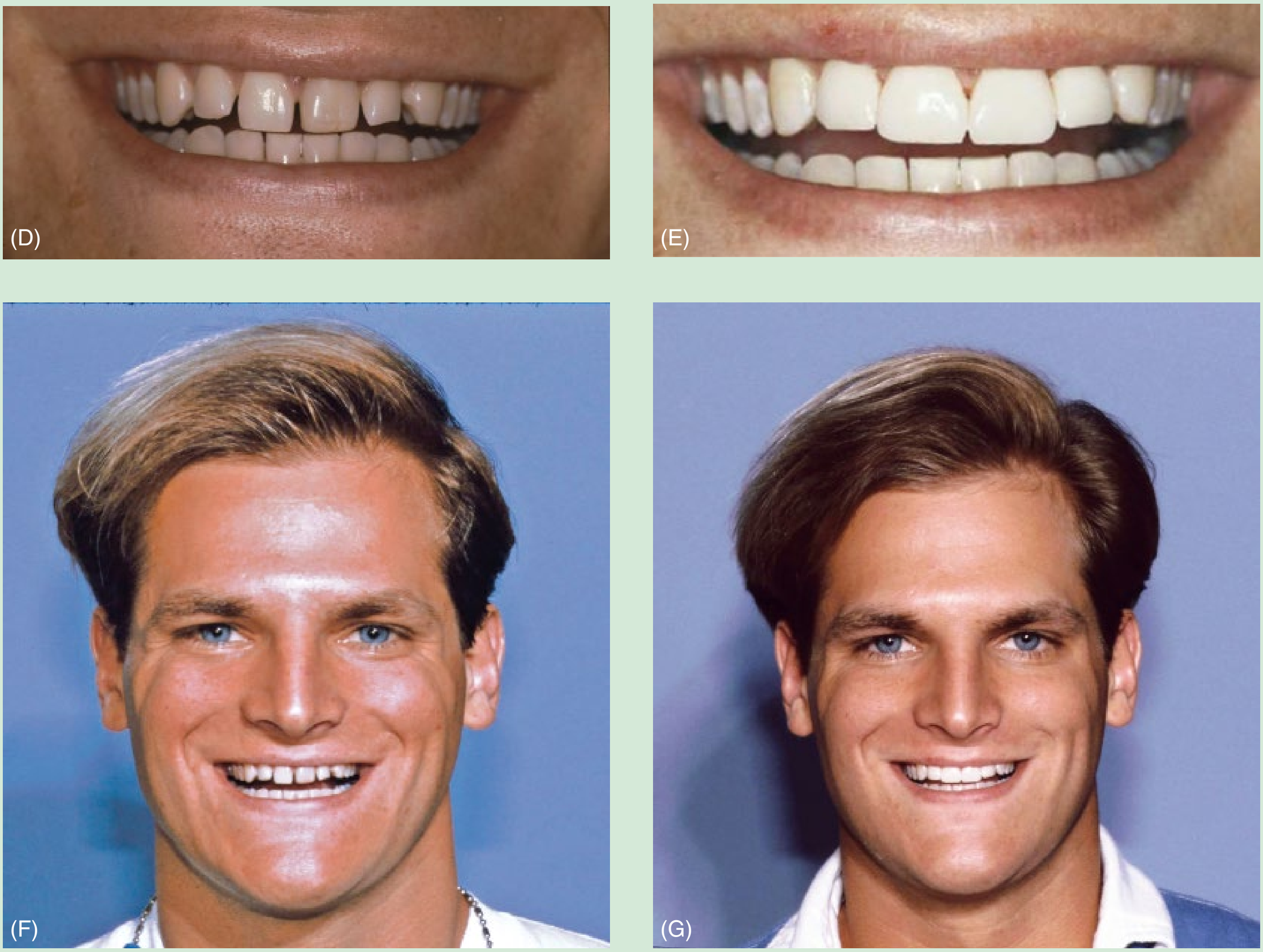

Figure 26.21 **(D–G)** These before and after pictures show how much better proportioned the larger teeth appear in the full face view.

guidelines, to allow for better proportioned teeth as if often required when closing diastemata. Tooth preparation needs to be carefully planned and carried out by means of tooth reduction guides (fabricated from accurate diagnostic wax-ups), keeping in mind that lateral incisors should not be made too wide, thereby competing for central incisor dominance. Adequate tooth reduction is paramount in providing the ceramist with appropriate space in which to create a beautiful and well-proportioned smile (Figure 26.23B–F).

Summary

The esthetic significance of a diastema and the decision to close it is predominantly the choice of the patient. The dentist must possess a full appreciation of the factors contributing to diastemata and the various options available to treat them. Once the etiology of a diastema is identified, the patient should be informed of treatment alternatives, therapeutic time commitments, prognoses, and costs. Consideration of etiologic factors, appropriate treatment planning of the dental patient as an individual, and mutually agreed-upon expectations for outcomes of treatment are essential in the successful management of anterior diastemata and other modalities of esthetic care.

Selecting the proper treatment involves the usual challenges of addressing the needs and expectations of the patient and determining what degree of accommodation is necessary to achieve the desired result. An integrated orthodontic restorative or totally restorative approach may enhance the esthetic result only when a pure orthodontic therapy solution is not feasible or

Clinical case 26.10

Problem

This patient desired to close the spaces between her teeth but did not wish to undergo orthodontic treatment. The teeth were determined to need additional width to improve the proportions, and thus it was decided to treat her case restoratively. In addition, she wanted to have brighter teeth while maintaining a natural appearance. The pretreatment photo can be seen in Figure 26.22A.

Treatment

Following diagnostic wax-up and surgical guide fabrication, the gingival margins of teeth #7 and #8 were altered via osseous reduction for tooth #7 and very slight soft tissue modification over #8 to match the height and gingival zenith position with that of #9. Following adequate healing, teeth #6–#11 were prepared as conservatively as possible for ceramic veneers (see Figure 26.22B). The canines were included for better proportion of her smile, especially with respect to achieving pleasing widths and proportions of the incisors while maintaining central incisor dominance. Tooth preparations involved the proximal surfaces and were extended slightly subgingivally to allow the laboratory technician to have better control of the emergence profile and interproximal contours. Feldspathic veneers were fabricated following the guidelines of the diagnostic wax-up and approved provisional restorations.

Result

As seen in Figure 26.22C and D, the patient's goals of space closure and additional brightness were accomplished very successfully. The teeth are well proportioned, and the gingival architecture developed through minor periodontal surgery balanced out the soft tissue profile to give a very pleasing and esthetic result.

Figure 26.22 **(A)** This patient desired to improve her smile nonorthodontically as well as brighten her teeth. *Source:* Chiche et al.[45(p53)] Reproduced with permission of Quintessence Publishing.

Figure 26.22 **(B)** The six maxillary anterior teeth were prepared for feldspathic porcelain veneers. The canines were included to prevent excessively wide lateral incisors. *Source:* Chiche et al.[45(p53)] Reproduced with permission of Quintessence Publishing.

Figure 26.22 **(C, D)** The final result shows a very pleasing and natural smile that met the patient's goals. *Source:* Figure C from Chiche et al.[45(p53)] Reproduced with permission of Quintessence Publishing.

practical. For larger diastemata where teeth will appear excessively wide when restored, periodontal therapy should be considered to improve tooth proportionality and bring better balance to the overall smile.

Regardless of the choice of treatment, the objective is to improve esthetics while preserving as much healthy tooth structure as possible. For the highly esthetic-driven patient, however, the ultimate esthetic result may come at the price of greater tooth reduction, and the patient must be made aware of this trade-off and its inherent risks. Good occlusion and maintenance of the supporting tissues are equally important to prevent diastema reformation and failure of corrective therapies. The ability of the dentist to successfully manage diastemata is the mark of a clinician who practices esthetic dentistry according to sound, interdisciplinary, evidence-based principles.

Figure 26.23 **(A)** This drawing illustrates the principle of additional reduction on the distal surfaces of the central incisors to prevent excessively wide centrals when closing a midline diastema in cases where the teeth are currently correctly proportioned. Additional porcelain or composite resin will be subsequently added to the mesial of the lateral incisors to close the space created by this preparation design. *Source:* Illustrations by Zach Turner

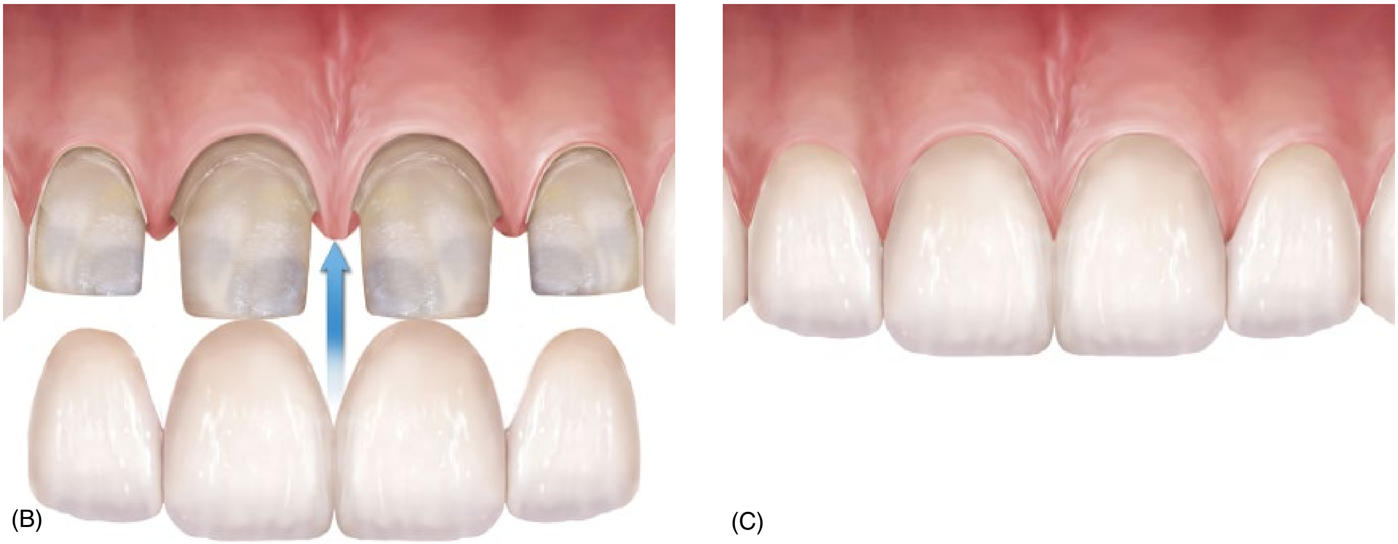

Figure 26.23 **(B, C)** These illustrations show the preparation design as drawn in Figure 26.23A and the definitive restorations (full-coverage crowns on central incisors and porcelain veneers on lateral incisors) created to close the midline diastema and maintain proportionality between the central and lateral incisors.

Figure 26.23 **(D)** This patient wanted to close his maxillary diastema plus improve his smile with brighter and better looking teeth. **(E)** The left central crown was removed and the right central was prepared for full crown, and the canines and lateral incisors prepared for porcelain veneers. **(F)** The final result corrects the patient's previous reverse smile line and illustrates using both porcelain veneers and crowns to provide a more attractive smile.

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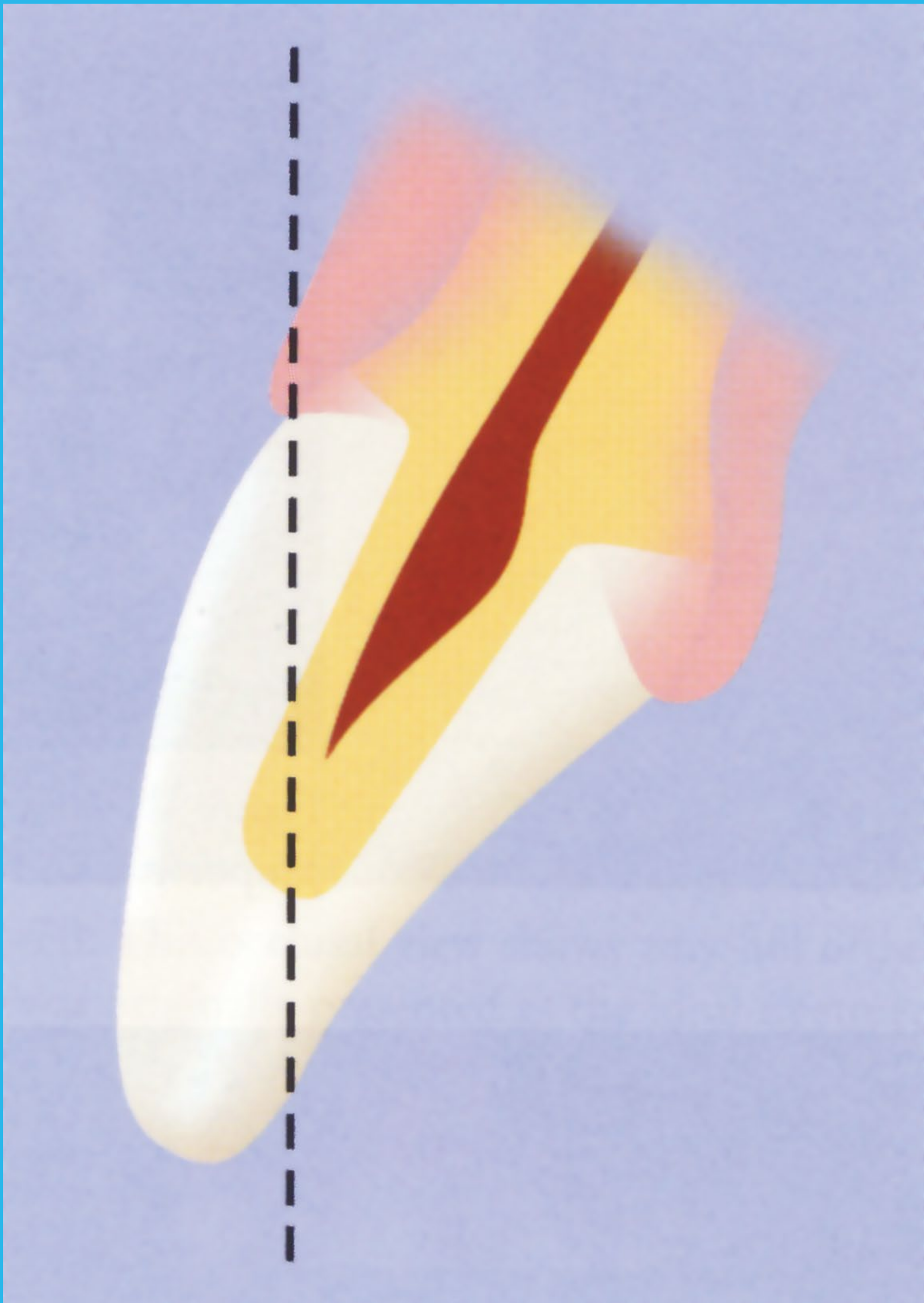

Chapter 27 Restorative Treatment of Crowded Teeth

Ronald E. Goldstein, DDS, Geoffrey W. Sheen, DDS, MS, and Steven T. Hackman, DDS

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Orthodontics should be the first consideration when the patient presents with crowded teeth.[1–4] If a patient is unable to accept orthodontic solutions, the general practitioner must determine whether the patient can be treated with minor tooth movement, restorations, or extraction, or a combination of these procedures.

To analyze the treatment of crowded teeth, this chapter has been organized into the following sections: treatment considerations, treatment strategy, treatment options, and unusual or rare clinical presentations.

Treatment considerations

Many patients have slightly crowded or overlapping anterior teeth that are not an esthetic problem. However, when an individual feels their crowded teeth are unesthetic and seeks treatment, it may present a challenge for the dentist. Choosing the correct approach is the most important aspect of the treatment.[5]

Before properly developing a plan of treatment, consider a number of preoperative conditions. A thorough evaluation of

Ronald E. Goldstein's Esthetics in Dentistry, Third Edition. Edited by Ronald E. Goldstein, Stephen J. Chu, Ernesto A. Lee, and Christian F.J. Stappert.

the patient will establish the basis for potential treatment options.[6] The areas to be evaluated include arch space, gingival architecture, influence of root proximity, smile line, emergence profile, occlusion, and oral hygiene.

Arch space

The most significant factor in the treatment of crowded teeth is the available arch space, and how that space is occupied by the dentition. Locating space deficiencies and their degree will determine which teeth will require modification (Figure 27.1A–D).

Berliner presented a classic formulation and clinical rule in his text that helps to make treatment of crowding more predictable. He stated:[7]

> When the sum of the mesiodistal widths (at contact-point level from distal of right lateral to distal of left lateral) in any given segment measures more than the available arch space, when measured between the two points (obtained by dropping perpendicular lines from the mesial contact-point levels of the right and the left cuspids to the gingival line), the central and the lateral teeth will be buckled (displaced labially or lingually) or overlapped; conversely, when the sum of the combined mesiodistal widths of the central and the lateral teeth measure less than the available arch space (as indicated above), the involved teeth present diastemas.

This formula can aid in the correction of crowded or spaced teeth by measuring the amount to be added or subtracted for the desired objective (Figure 27.2A–C).

Gingival architecture

An often overlooked component of an esthetic smile is the gingival architecture. When there is crowding in the anterior region, certain teeth will be forced facially or lingually. In a Class II, Division 2 occlusion, for example, the maxillary lateral incisors may be positioned labially, and the gingival tissue will be forced more apically. This creates a discontinuity in the overall smile of

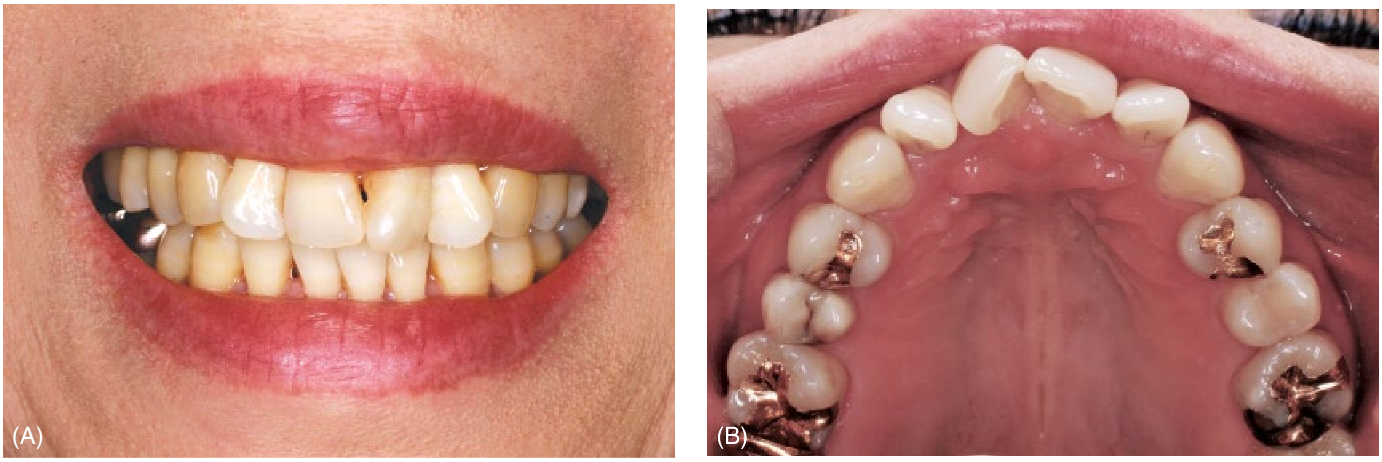

Figure 27.1 **(A, B)** This dental assistant wanted to change her smile without orthodontics or crowning. After measuring her arch space, reviewing her radiographs, plus doing mock contouring and bonding on the diagnostic casts, it was decided that direct bonding with composite resin could be a compromise solution.

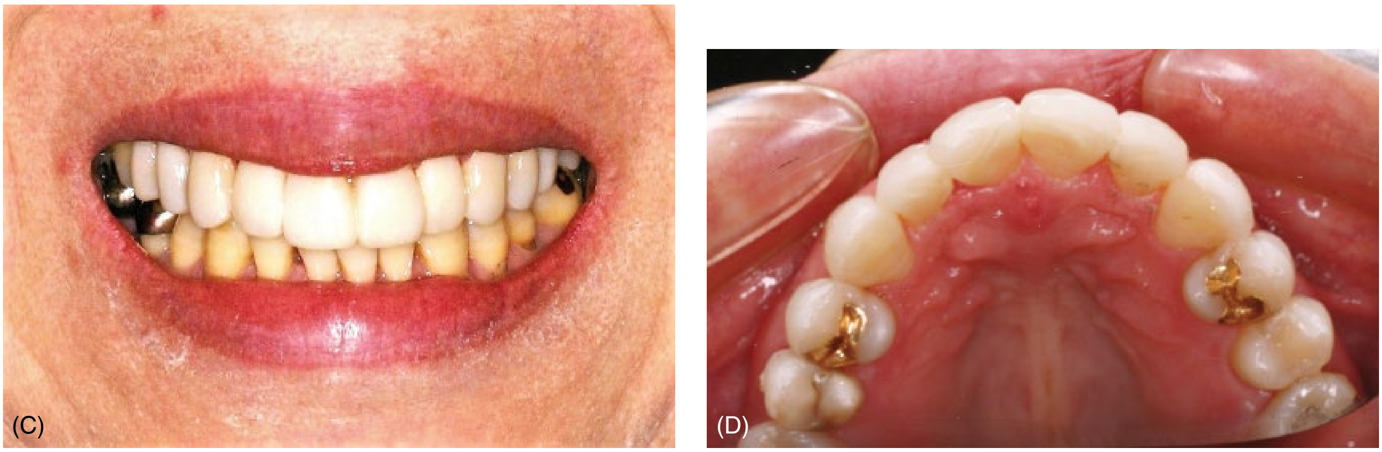

Figure 27.1 **(C, D)** The final result shows proportionate-sized teeth and a much improved smile were accomplished in a 1-day appointment. (The step-by-step procedures for this patient can be seen at http://www.dentalxp.com/video/contouring-mock-bonding-using-diagnostic-99131.aspx?locale.)

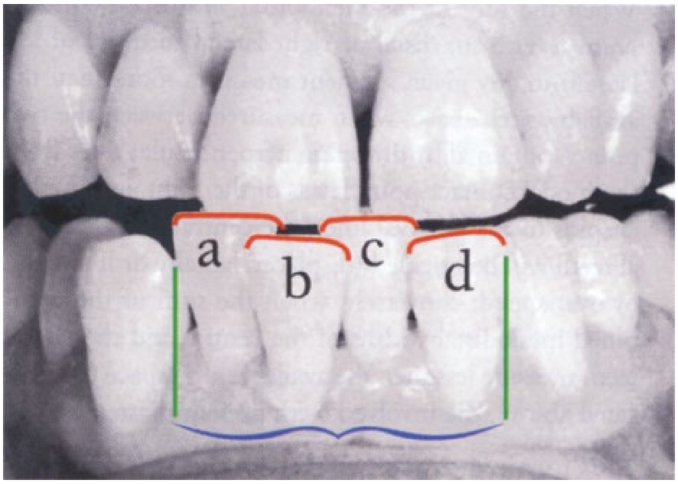

Figure 27.2 **(A)** Preoperative view: note the relationship of the combined widths of the lower central and lateral teeth (a, b, c, d) to the extent of available arch space. Sum of combined tooth widths is greater than available arch space, resulting in buckling.

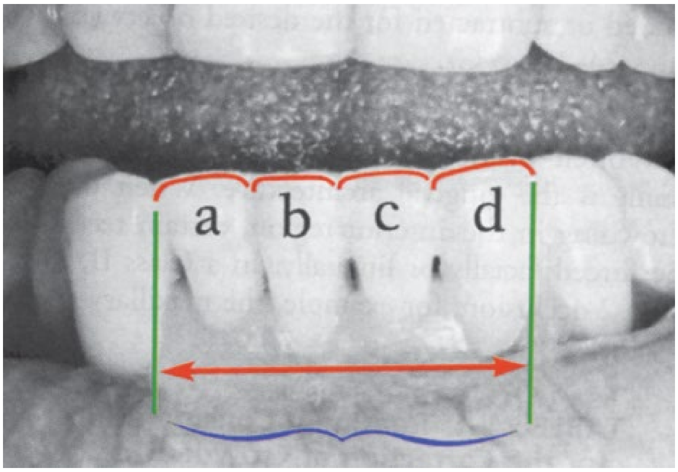

Figure 27.2 **(B)** Postoperative measurement, after remodeling of the lower central and lateral incisor teeth: the combined tooth widths equal the available arch space, and repositioning of the teeth became a feasible clinical procedure.

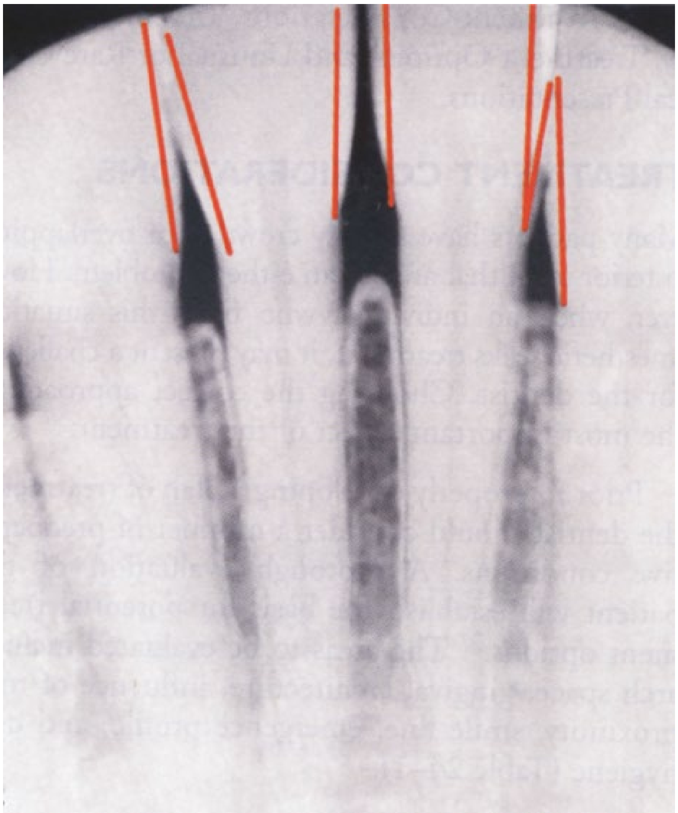

Figure 27.2 **(C)** The proximal thickness of the enamel "caps" of the teeth on a lower anterior segment of the dental arch is indicated in outline. *Source:* Reproduced with permission from Berliner.[7(p65)]

the patient. Treatment considerations in this situation may require slight modification to the gingival architecture around the central incisors to create a more harmonious smile. If the patient's lip line hides the gingival discrepancy, then surgical intervention may not be necessary (Figure 27.3A–F).

Likewise, crowding in the mandibular anterior incisors often results in the rotation or lingualization of the central or lateral incisors. Therefore, the gingival tissue will be positioned more incisally. It may be necessary to perform a crown-lengthening procedure prior to esthetic restoration of these teeth.[8,9]

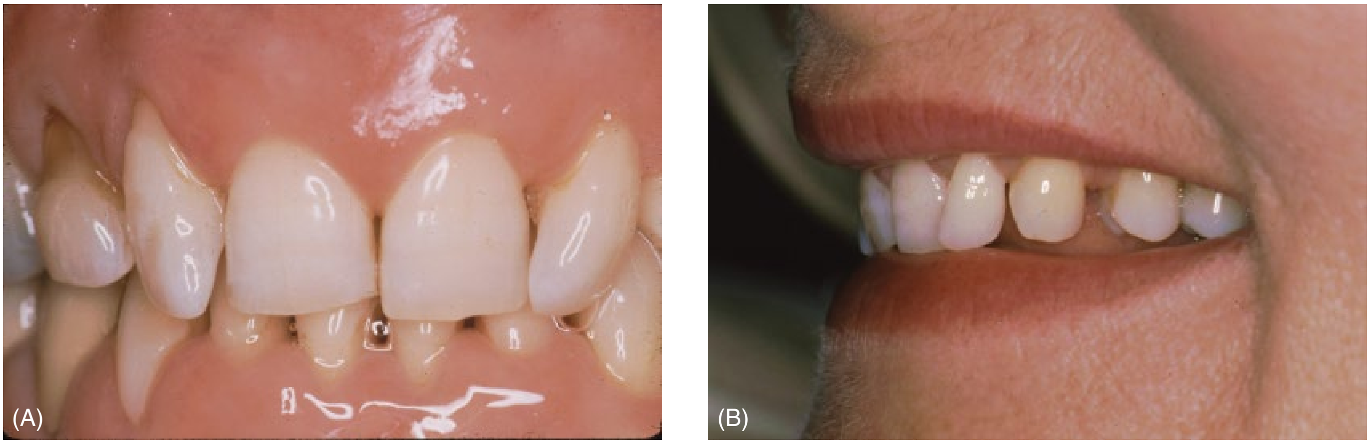

Figure 27.3 **(A, B)** This patient was dissatisfied with her crowded anterior teeth. Note how the gingival height differs between the central and lateral incisors and the maxillary right cuspid was a retained deciduous tooth.

Figure 27.3 **(C)** The dissimilar gingival heights did not bother the patient because her natural smile line concealed these irregularities.

Figure 27.3 **(D, E)** After cosmetic contouring of the six anterior teeth, direct composite bonding was completed. The final result shows improved proportion in tooth size and form.

Figure 27.3 **(F)** Sixteen years later, the composite bonding is still in place and there is just slight staining.

Influence of root proximity

Root proximity may complicate the restoration of crowded mandibular anterior teeth. Root structures may be so close to one another that a separation is not possible. This creates gingival impingement that can be almost impossible to treat.

It may be necessary to extract one of the crowded teeth, leaving three incisors in place of four.[10] The decision should be based on radiographs and a study of the periodontium to determine the amount of bone present. If bone loss exists due to crowding, then extraction and repositioning are generally the treatment of choice. This can be successful when the teeth are properly proportioned. It is seldom noticeable to the patient. The tooth is extracted, and the remaining anterior teeth are repositioned, providing additional bone support. When small diastemas remain, the teeth can be bonded with composite resin or splinted to prevent further tooth movement.

In almost every case, some form of retainer is necessary. The patient should be informed that they can reduce the wearing time of the retainer only if it does not fit too tightly each time it is placed. A tight fit might indicate some relapse, and the retainer should continue to be worn each night. The patient can also return for possible further treatment either to surgically relax retentive gingival fibers or to adjust the occlusion to help equilibrate the stressful occlusal forces. But failure to wear the retainer can result in relapse.

Smile line

It is important to study the patient's smile line. The extent to which incisogingival tooth structure will show in the widest smile and in other expressions should be noted. If the patients cervical margins show during the widest smiles, the treatment of choice should be an all-ceramic crown with shoulder or deep chamfer margins. If there are occlusal demands for the strongest restoration possible, choose a zirconia crown. If occlusion is not a problem, a lesser strength all-ceramic crown or other esthetic restoration, such as bonding or porcelain veneer, should be considered.[11]

Emergence profile and oral hygiene

Many of the nonorthodontic treatment options discussed in this chapter are meant to "camouflage" malposed or malaligned teeth. Consideration must be given to the contours that will be created by the restorative process.[12–14] Often, these contours are unnatural and create areas around the teeth that the patient will find difficult to maintain with good oral hygiene. If these esthetic restorations are to survive, consider the final contours being created, and the patient must be given the necessary instructions to maintain them.

Treatment strategy

Development of an appropriate treatment plan for the correction of crowded teeth should follow a strategy. First, it is necessary to identify what type of correction and how much correction of tooth contours are required to achieve the desired esthetic results.[4,15] Then, it becomes necessary to evaluate the dentition, identify clinical limitations to treatment, and select appropriate restorative options that will accomplish the desired esthetic outcome.

Identifying the degree of esthetic correction required

Following a process of evaluation and development of a problem list, utilize this information to determine the degree of corrections required. Esthetic computer imaging can assist both you and the patient to visualize the proposed treatment.[16,17] The development of a diagnostic wax-up is a necessary procedure and may be used to confirm the viability of the proposed treatment developed by computer imaging. It will also enable you to perform a trial smile so the patient can see your proposed treatment plan.

Two sets of diagnostic casts should be made. One set will serve as a historical record of the patient's preoperative condition and should never be modified. The second set of casts should be used for the diagnostic wax-up.

Developing a diagnostic wax-up involves both the addition of wax to deficient areas of the dentition and the removal of stone as necessary to achieve the desired esthetic results. The diagnostic wax-up should be accomplished with attention to detail. Line angles, embrasure spaces, incisal lengths, and gingival contours must represent the desired results if this effort is to be an effective tool in the esthetic treatment plan.[18] Through this process, arch space deficiencies can be worked out, and specific modifications to each tooth involved can be identified.

Once completed, the diagnostic wax-up is used to develop additional clinical aids for the accurate and successful completion of the esthetic treatment plan. Polyvinyl siloxane material is applied to the palate, lingual surface, and incisal edge of the wax-up to form a simple reduction guide. After the material has set, the matrix is carefully trimmed just to the facioincisal line angle. During preparation, the matrix is placed against the lingual surfaces of the teeth (the palatal coverage stabilizes the matrix). The desired incisal length and position of the facial surface (as developed in the diagnostic wax-up) can be identified, and adequate tooth reduction can be determined.

A provisional matrix can also be fabricated by using the same materials and technique. In addition to the palate, lingual surfaces, and incisal edges, the interocclusal record material also covers the facial surfaces and extends several millimeters onto the gingival tissue. The matrix formed will accurately duplicate the subtleties of the diagnostic wax-up. With proper embrasure form and gingival contours accurately duplicated in the provisional restorations, chairside adjustment will be significantly reduced.

A well-planned and executed diagnostic wax-up is an essential communication tool for both the patient and the laboratory.[19–21] Dental esthetics is truly in the eyes of the beholder. Everyone has a certain concept of how the teeth should look. Since provisional restorations are closely fabricated to the contours of the diagnostic wax-up,[22] the patient will have a chance to observe and identify any changes in contour and function they may desire. If necessary, changes can be made in the provisional restorations, and an impression of these newly contoured restorations can be made. The new cast will serve as a clinically evaluated diagnostic tool used to communicate this vital information to the laboratory.

In summary, a diagnostic wax-up will identify to what degree corrective contours must be made to idealize a crowded dentition. With knowledge of the specific modifications required for each tooth, you can begin to select the proper treatment options.[23] This process should be undertaken whether the treatment is minor cosmetic contouring or as comprehensive as a complete restoration of the anterior region with full-coverage crowns.

Identifying the type of restoration required

There are many treatment options available for correcting crowded teeth,[24–27] including cosmetic contouring, bonding, porcelain veneers, and crowns (Table 27.1). The condition of the existing dentition is a factor in determining which restorative option is ideal.

Teeth without any restorations or caries should be treated as conservatively as possible. If only minor modifications to tooth contours are required to achieve the desired esthetic result, cosmetic contouring and bonding provide the least invasive treatment options. Small existing restorations are easily incorporated into other restorative treatments.

If caries in the teeth to be treated are too large for composite resin, then more extensive restorations, such as porcelain veneers or crowns, need to be considered. The size and location of the caries may dictate the design of these restorations.

The presence of an endodontically treated tooth,[28] with or without a post and core, may or may not require a crown. In the crowded tooth scenario, a full crown may be beneficial to create a more esthetic arrangement in the anterior region. Care must be taken, however, not to overextend or overcontour the final restoration, which would result in possible gingival irritation.

In summary, conservative treatments such as esthetic contouring,[29] disking combined with minor tooth movement, and bonding are available for minor corrections of crowded teeth.

Table 27.1 Treatment Options and Indications for the Correction of Crowded Teeth

Procedure	Indications	Contraindications	Sequence	Criteria
Disking and orthodontics	Usually the first and best option for redistribution of significantly crowded teeth in the anterior region Disking used to slightly modify the width of specific teeth to reposition them into the dental arch	Inadequate supporting structures–bone, tooth roots, or gingival tissue When immediate solutions are demanded by the patient	Study model analysis of available arch space and tooth size Orthodontic consult to reposition teeth into desired final position	
Cosmetic contouring	Modification of line angles, incisal edges, or defects to create illusions of proper tooth size, shape, or position Minimal alteration of tooth position	If contouring would expose dentin If contouring would eliminate desirable occlusal or functional contacts	Following determination of the desired results by diagnostic wax-up	<0.5 mm of facial reduction <1.0 mm of incisal reduction
Bonding	Addition of composite resin to modify apparent height and width of natural tooth by alteration of the shape and location of line angles Diastema closure Incisal edge modification of sound tooth structure	Inadequate enamel or supporting tooth structure Severe occlusal loads placed on composite restoration Severe tooth discoloration	Following color modification (bleaching, etc.) of natural tooth structure Following diagnostic wax-up to determine need for preoperative cosmetic contouring	<1.0 mm addition of composite resin
Porcelain veneers	Indicated for esthetic rehabilitation of entire anterior segments Individual teeth must be structurally sound Changes can be additive, subtractive, or both Shape/size, alignment, and color of the teeth may be modified	Weak supporting tooth structure Multiple, large existing restorations Minimal bondable tooth structure Bruxism	Following diagnostic wax-up to determine need for preoperative esthetic contouring	0.5 mm of reduction possible within enamel <25% exposed dentin 2 mm maximum thickness of porcelain
All-ceramic crowns	Indicated for structurally weak teeth with large multiple restorations or when a more conservative restoration is contraindicated A favorable occlusal scheme should exist (canine guidance) Compatible opposing dentition or restorations	Unfavorable occlusal scheme Significant vertical overlap with minimal occlusal clearance When a more conservative restoration is indicated to achieve desired esthetic results	Following diagnostic wax-up to clearly define esthetic and functional objectives Following proper buildup procedures	1.0 mm marginal reduction Uniform, circumferential 90° shoulder margin 2 mm incisal reduction

When corrections that are more substantial are required, porcelain veneers and crowns become the treatment of choice.[12]

Treatment options

Cosmetic contouring

Certainly, the most economic and simplest of treatments to improve crowded teeth is through cosmetic contouring. This one appointment procedure can make a dramatic difference to the smile in most patients who may not have the funds for either the more time consuming procedure such as orthodontic treatment or either bonding or porcelain veneers (see Chapter 11).

Although cosmetic contouring by itself can make a major difference (Figure 27.4A and B), it can also help make the difference between ordinary and extraordinary results when other restorative procedures are included. Thus, this chapter will include results featuring bonding, veneering, and crowning with help from cosmetic contouring techniques.

Correction by disking

If the evaluation of arch space, as previously described by Berliner,[7] shows that the combined addition of a, b, c, and d in the lower arch equals 21 mm (see Figure 27.2A) but the available space is 20 mm, the amount of crowding is 1 mm. Therefore, if minor movement or repositioning is attempted to realign the teeth, 1 mm of combined mesiodistal width can be sacrificed through disking. However, not all of the tooth surface will have to be lost from the central and lateral incisors. The mesial surfaces of the cuspids are also available and, under certain rare conditions, the distal surfaces of cuspids as well.

One limitation on reducing tooth structure through disking is the thickness of enamel on the teeth. Radiographs must be accurate enough to measure the available enamel. A measurement can be made of the proximal surfaces on each of the anterior teeth to predict the maximum reduction possible without perforating the dentin.

For example, if 0.25 mm is found to be the amount that can be reduced per proximal surface, then 0.5 mm can be reduced per tooth. Therefore, 3.0 mm could theoretically be reduced from the six anterior teeth by disking to increase the available arch space. In applying this to the earlier example of 1 mm crowding, there should be no repositioning problem.

The procedure for applying the aforementioned principle is as follows:

1. Measure the mesiodistal width of the individual teeth and the available arch space with a dental dial caliper (Erskine).
2. Measure the enamel thickness by studying the radiographs of the involved anterior teeth (see Figure 27.2C). Peck and Peck caution that accessing enamel thickness from radiographs alone is subject to possible distortion.[30] Instead, they offer an arbitrary, but safe, guideline of 50% of the mesiodistal enamel thickness as the maximum limit of reproximation.
3. After determining that the amount of space necessary to realign the teeth is attainable without perforating dentin, disk the teeth accordingly. This can be done at one time, if the space is minimal, or over a period of time, depending on the conditions present. The patient can be instructed to return weekly or biweekly for stripping. Diamond separating strips should be used. If the teeth are extremely tight, use a diamond separator disk or mini strip first for ease in initial disking. If considerable space is necessary, consider using coarser strips which have a diamond abrasive on each side or an ET3, ET4, or 30 μm diamond bur (Brasseler, USA).
4. Repositioning can now be accomplished by any of several different methods shown in Chapter 28.

Correction by bonding

The success of composite resin bonding has made immediate restorative correction of crowded teeth possible.[31,32] In most cases, it will be necessary to combine the treatments of composite resin bonding with esthetic contouring (see Chapter 11) to

Figure 27.4 **(A)** This patient wanted to improve her smile as economically as possible, so cosmetic contouring was selected as the treatment of choice.

Figure 27.4 **(B)** A 1 hour appointment was all it took to please the patient with her new improved smile.

produce the greatest effect. As with all bonding techniques, the patient must be apprised of not only the esthetic life expectancy and limitations of the bonded restoration, but also an estimate of how much maintenance may be required.

In cases of severe crowding, it is always best to take diagnostic models and actually perform the proposed procedure before telling the patient you think you can do it. This way you can also show the patient what the "after" will look like.

The combination of cosmetic contouring and composite resin bonding is one of the most economical treatments to transform the smile in a single appointment (Figure 27.5A–G). However, when space is a problem, you do need to let your patient see how much narrower each tooth will be and how it may change their perception of what is envisioned. One major advantage of first doing direct bonding is that the patient can see a dramatic change. Later, the patient can always opt for a ceramic alternative.

Correction by porcelain veneers

The advantage in selecting porcelain veneers to correct crowded teeth is the ability for the laboratory to properly proportion the new restorations. This permits a conservative solution to be used that will need less maintenance.[12,33]

Figure 27.5 **(A)** This woman presented with severe crowding of both maxillary and mandibular arches, but refused orthodontic treatment, even with Invisalign. Diagnostic casts were made and the proposed treatment was performed on the models to see if the patient could be pleased with the result.

Figure 27.5 **(B–D)** After the patient approved the treatment plan consisting of cosmetic contouring and composite resin bonding, the teeth were marked with an alcohol marker and contoured using a 30 μm diamond (ET6, Brasseler USA).

Figure 27.5 **(E)** Next, the left and right maxillary lateral incisors and lower central and laterals were bonded with a microfill composite resin using an extra-thin nonstick bonding instrument (TNCIGFT3, Hu-Friedy).

Figure 27.5 **(F)** Next, the final contour was done using a 30 blade carbide (ET6UF, Brasseler USA).

Figure 27.5 **(G)** The patient was happy with a much improved smile.

When selecting porcelain veneers, determine arch space deficiencies on each side. Both lateral incisors may be rotated in a similar fashion, resulting in an equal amount of space on both sides of the arch. However, if one lateral is overlapped more than the other, the available space may be asymmetric. Correction may require shifting of line angles in the final restorations to create an illusion of equal dimension in the final restorations.

After reproportioning the anterior space, if the total space will result in teeth that would look much too narrow, building out the teeth in a slight labioversion should be considered. The more the buccal surface is positioned anteriorly, the wider the teeth will become. The added thickness will go unnoticed if it occurs throughout the restored teeth and results in an entire arc that is positioned labially from bicuspid to bicuspid. A curve that will look good from an occlusal and a labial view should be selected. It is usually possible to compromise by building out the other teeth slightly and lingualizing the most labially positioned teeth. How much and where the existing teeth will need reducing during the preparation of the teeth should be determined. This is easily accomplished by using a reduction matrix fabricated from a diagnostic wax-up.

Usually, the most severe reduction would resemble a similar amount of dentin loss as in a full crown. Even if a tooth will have to be severely prepared for a veneer, the total tooth structure removed would be much less with a veneer preparation than for a crown preparation. The worst scenario would be to require endodontic therapy by doing a vital extirpation of the pulp. If you are considering building out the teeth you must consider any possible effect this action will have on the smile line. Will this result make the patient too “toothy”? Also consider any possible change in tooth shade the patient may want. A lighter tooth tends to make the teeth appear to stand out even more. Of major importance is to always let the patient see and understand how their tooth sizes will change with your treatment plan.

The following sections give examples of the use of porcelain veneers to correct crowding in the anterior region.

Cosmetic contouring and porcelain veneers to eliminate crowding

Case study 27.1

Problem

Figure shows a 58-year-old housewife with concerns about her eroded, crowded, and stained front teeth. Measurement with a dental dial caliper (Erskine) helped to accurately determine available space for reproportioning tooth size. Although orthodontics was mentioned as a first step to an ideal solution, the patient preferred to accept a compromise treatment of porcelain veneers and cosmetic contouring. Although crowding was less of a concern to the patient, she nevertheless decided to have straighter-looking teeth through a compromise treatment of porcelain veneers that would also esthetically correct the erosion and discoloration.

Treatment

Figure 27.6D shows the areas that will be esthetically contoured. Following contouring to reproportion spaces, Figure 27.6E demonstrates the gingival chamfer margin being placed with a two-grit LVS diamond bur (Brasseler USA). The occlusal view (Figure 27.6C) reveals just how much overlapping existed. Figure 27.6 F shows the teeth after esthetic contouring and tooth preparation have occurred, and also how defective amalgam restorations were removed and glass ionomer bases were placed. Figure 27.6G shows finished veneers in place. Note the newly proportioned, straighter, and lighter-looking teeth. The final occlusal view also shows a new arch created by the veneers, building out teeth #9 and #10 and the new posterior veneer onlays on the upper right side.

Result

Before and after smiles can be seen by comparing Figure 27.6A and H. Cosmetic contouring has also improved the alignment of the lower anteriors. Constructing the porcelain veneers indirectly allows the laboratory to better proportion the tooth size.

Figure 27.6 **(A)** This 58-year-old woman was dissatisfied with her crowded, eroded, and discolored teeth.

Figure 27.6 **(B)** The teeth are first esthetically contoured to begin creating the illusion of straighter teeth.

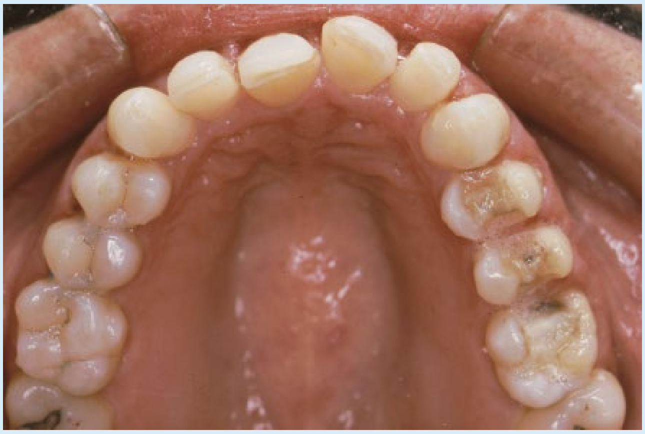

Figure 27.6 **(C)** This occlusal view shows the final tooth contouring. Note the patient's right posterior quadrant. The teeth were prepared for combination laminate/onlays.

Figure 27.6 **(D)** Next, the anterior teeth are prepared for porcelain veneers. A special two-grit diamond bur (LVS2, Brasseler USA) helps prepare both the body and margin of the tooth.

Figure 27.6 **(E)** The occlusal view shows the extent of overlapping in the central incisors.

Figure 27.6 **(F)** Porcelain veneers were cemented from the right cuspid to the left second bicuspid; the laminate onlays were inserted on the maxillary right bicuspids and first molar.

Figure 27.6 **(G)** Preoperative smile view.

Figure 27.6 **(H)** Postoperative view of improved smile created by use of porcelain veneers and cosmetic contouring.

Correction by crowning

As in bonding, the first problem in restoring crowded teeth by crowning is tooth size. Each tooth needs to be or appear to be proportional. The more teeth that are crowned, the less distortion there is.[34–36] This means that if only one or two teeth are crowned, there may be a noticeable difference between the crowned teeth (which would be smaller) and the natural ones, depending on the space involved. However, it is possible to accomplish this by carefully shaping both the tooth to be crowned and the adjacent teeth to appear harmonious in size.

An alternative solution is to reshape the existing teeth.[37] For example, in a maxillary anterior crowded condition, instead of merely crowning two central incisors, the lateral incisors can be reshaped by reducing the mesial surface slightly, so that the adjacent central incisors can be enlarged. This same principle can be applied to other areas of the mouth. The teeth adjacent to crowns are always reduced to recover some of the space lost because of crowding. The more the adjacent teeth are reduced, the less noticeable is the distortion. An example of crowning six incisors to eliminate the crowding of anteriors follows.

Crowning to eliminate crowding

Case study 27.2

Problem

Figure 27.7A and B shows a 38-year-old store owner who presented with crowded and discolored maxillary and mandibular teeth. Although orthodontic treatment was suggested as ideal treatment, he elected a compromise that consisted of bonding the mandibular and crowning the maxillary teeth.

Treatment

When teeth are as crowded as this, it is sometimes necessary to do a vital pulp extirpation to prepare the teeth for adequate porcelain thickness. Thus, tooth preparation and diagnostic wax-up were first completed on the study casts (Figure 27.7C and D). The patient was fully informed of the possibility of endodontic therapy. The actual tooth preparation can be seen in Figure 27.7E and F. Fortunately, the pulp had receded, so extirpation was not necessary. Electrosurgery was completed prior to impressions to improve access to the preparation margins. Six full porcelain crowns restored the esthetics of the maxillary arch (Figure 27.7G), whereas composite resin bonding helped restore mandibular esthetics. A maxillary occlusal night appliance was constructed for the patient to wear since the patient had a history of clenching while sleeping.

Result

The resulting smile with straighter and lighter teeth (Figure 24.7H and I) was most appreciated by the patient. In fact, at the next postoperative appointment I noticed he had shaved off his facial hair. When I asked why, he told me he felt he did not have to hide his "crooked tooth smile" any longer.

Figure 27.7 **(A)** This 38-year-old man wanted to improve his crowded maxillary and mandibular teeth.

Figure 27.7 **(B)** This occlusal view shows why full orthodontic treatment was originally presented as the ideal treatment. The patient insisted on a "quick fix" solution.

Figure 27.7 **(C)** The occlusal view shows the patient ready for impressions after electrosurgery for effective tissue displacement.

Figure 27.7 **(D)** The final six crowns show improved proportion and symmetry in the arch.

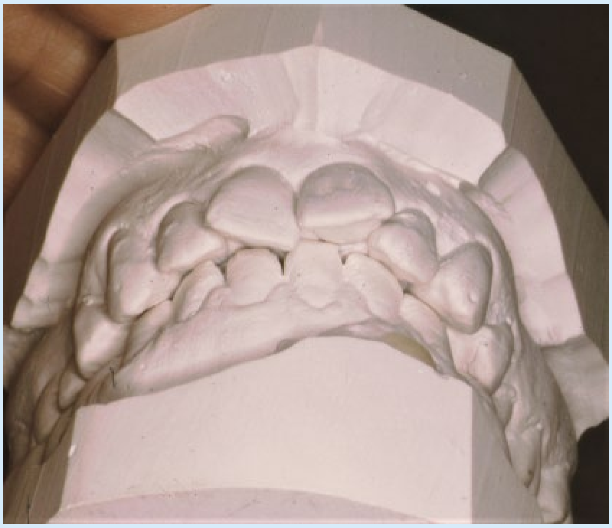

Figure 27.7 **(E)** Diagnostic casts show the extent of crowding in the maxillary anterior teeth.

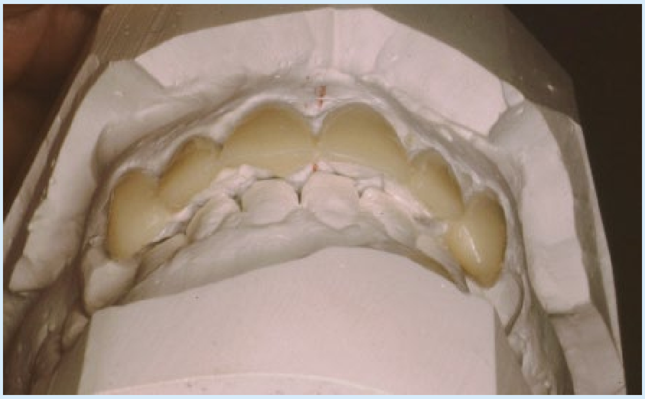

Figure 27.7 **(F)** A wax-up was completed to demonstrate to the patient and dental team how crowns could be used to accomplish the esthetic goal.

Figure 27.7 **(G)** Although the patient was warned that endodontic therapy might be necessary on the maxillary incisors, the teeth were prepared without pulpal exposures.

Figure 27.7 **(H)** Pretreatment smile.

Figure 27.7 **(I)** Posttreatment smile with six maxillary full porcelain crowns and four mandibular incisors with bonded composite resins.

Figure 27.7 **(J)** At the next postoperative appointment I noticed the patient had shaved off his facial hair because he felt he did not need to hide his "crooked tooth smile" now.

If crowded teeth are to be corrected with bonding, veneering, or full crowns, the central incisors must be proportioned correctly. This can be accomplished by either disking the mesial surfaces of adjacent uninvolved teeth or reducing the size of adjacent crowned teeth. For final esthetics, contouring of adjacent teeth should be considered.

The decision whether to veneer or crown should be made primarily on the position of the overlapping (protruding) teeth. To restore the arch on or near the labial-most position of the teeth, porcelain veneers can be used. However, if the choice is to use maximum position (including vital pulp extirpation), then crowns will probably be the best choice.

Crowning and repositioning of mandibular anteriors

Although crowding can occur in both arches, it is more common in the mandibular anterior teeth. Treatment for these teeth is usually repositioning. There may be occasions when the orthodontist will choose not to reposition, and the patient may want these teeth bonded, veneered, or crowned. For teeth that are badly broken down or have significant gingival recession that has made them unattractive, bonding, veneering, or crowning can accomplish two things: it can restore and straighten each tooth to its proper form. How much correction can be achieved by repositioning is governed partially by root structure and crown inclination. If the axial alignments of the teeth are divergent, there is a limit to how much they can be straightened. If one of the teeth is in extreme labioversion, it is difficult to do much straightening without building the adjacent tooth somewhat thicker. This may create a gingival impingement on the tooth that is being overcontoured. Excessive labial reduction could cause pulp damage, so some compromise has to be reached. For this reason, repositioning is generally the better solution. Sometimes, a combination approach is the best solution. If the teeth are broken down and discolored, and have unattractive, large restorations, partial repositioning can be attempted, and crowning may take care of the remainder of the problem. This way, the patient might not mind wearing an appliance for a short while. One of the main objections that patients have to orthodontic treatment is the length of time the appliances have to be worn. However, if Invisalign or lingual brackets can be utilized, then patients have much less objection to orthodontic therapy.

Unusual or rare clinical presentations

Occasionally, you are presented with unusual dental problems associated with crowded dentitions, such as severely malposed and misaligned teeth, a protruding tooth, a retruded tooth, or the "lingually locked" tooth.[38–43]

Malposed and misaligned teeth

The method of choice for correcting malposition or misalignment of a tooth or teeth is orthodontics. For adults, consideration should be given to the easiest and less noticeable method if the patient has any fear of others knowing the treatment is taking place. We have had tremendous success with suggesting Invisalign whenever it is possible to obtain the desired result. If the patient is not concerned with appearance, then removable appliances, ceramic brackets, or even lingual braces are options.

An effective technique for repositioning crowded lower incisors is the use of the provisional splint with small hooks. A composite resin stop that is mechanically bonded to the teeth helps keep the elastic from slipping. Some disking in the interproximal surfaces of the anterior teeth is necessary to create space for the incisors to move lingually. Finally, it is vital to plan some sort of retention—if the typical removable retainer is not acceptable to the patient, then either an A-splint or direct bonding with a composite resin splint can be used. Auxiliary products such as tooth-colored reinforced fibers, such as Ribbond and Dentapreg, have been quite useful. Adult patients may think that they are too old for orthodontic therapy. You will have to judge the importance of immediate facial esthetics to the patient. If repositioning is the best solution to the esthetic problem, then the patient should be motivated to accept this therapy. Obviously if you have staff or other patients who do not mind showing your patient how pleased they are with the treatment in their own mouths this can be quite effective in motivating the patient to accept treatment. Generally, fear of the unknown can be cured by personal contact with those who may have had the same fear but are so happy with their ongoing treatment.

If the patient will accept only those procedures that offer an immediate solution, then bonding, veneering, or crowning may be the only feasible compromises. Cosmetic contouring should also be considered. Rather than no treatment, cosmetic contouring may provide some compromise benefit.

The protruding tooth

In restoring a crowded labially positioned incisor, careful preparation can make the protruding tooth appear to be in a more lingual position. Care must be taken to avoid a short preparation. The labial surface is reduced as far as possible without damaging the pulp; very little tooth structure is removed from the linguoincisal surface (Figure 27.8A and B). It is extremely important not to reduce the incisogingival height until the preparation is essentially complete. This will help avoid a short preparation. If the labial protrusion is so extreme that the pulp may become involved, explain to the patient that vital pulp extirpation may be necessary.[7] Such aggressive procedures should be undertaken only when appearance is extremely important and the patient is completely aware of the possible consequences and has signed an informed consent for treatment.

The retruded tooth

This esthetic problem is similar to that of the protruded tooth. However, realignment of the tooth in linguoversion frequently necessitates reduction and recontouring of the opposing teeth to allow for clearance of the newly crowned, bonded, or veneered tooth. To achieve the desired result, a large amount of the tooth structure may have to be removed from the linguoincisal surface of the opposing tooth. Esthetic results can then be achieved by crowning or veneering. If a full crown is desired, then the lingual side can be covered with a thin layer of porcelain and perhaps an all-zirconia crown could be utilized. The labial porcelain may be built out to correct alignment. Veneering can be especially useful since virtually no enamel needs to be reduced on the labial surface, with only linguoincisal enamel being reshaped to mask the amount of retrusion present. One potential problem may be the amount of impingement on the labial gingival tissue, so consultation with a periodontist could be beneficial.

The lingually locked tooth

If a lingually locked tooth is fully erupted, it can be restored to correct position by pulp extirpation and placement of an off-center endodontic post and porcelain crown. However, if the tooth is too short and in moderate linguoversion, this treatment may be impractical. A porcelain shoulder is prepared on the labial, and the porcelain is built up butted against the labial gingiva. The patient must be warned that oral hygiene must be scrupulous. It is far better to try to convince the patient of the

Figure 27.8 **(A)** The crowded labially positioned incisor requires a careful preparation to make it appear to be in a more lingual position.

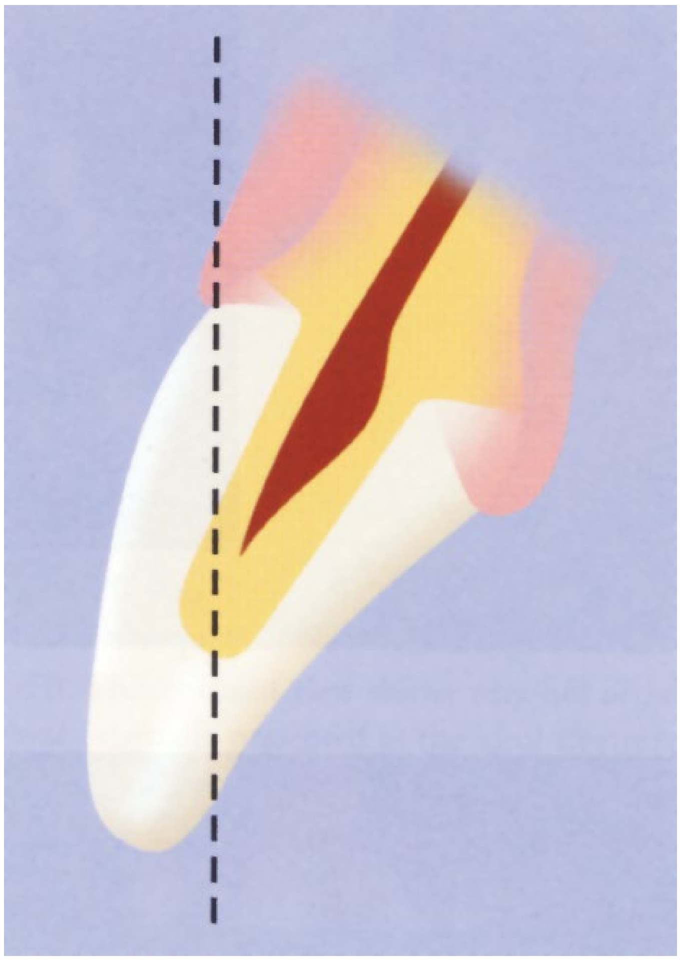

Figure 27.8 **(B)** The labial surface is reduced as far as possible without damaging the pulp. It is extremely important not to reduce the incisogingival height until the preparation is essentially complete.

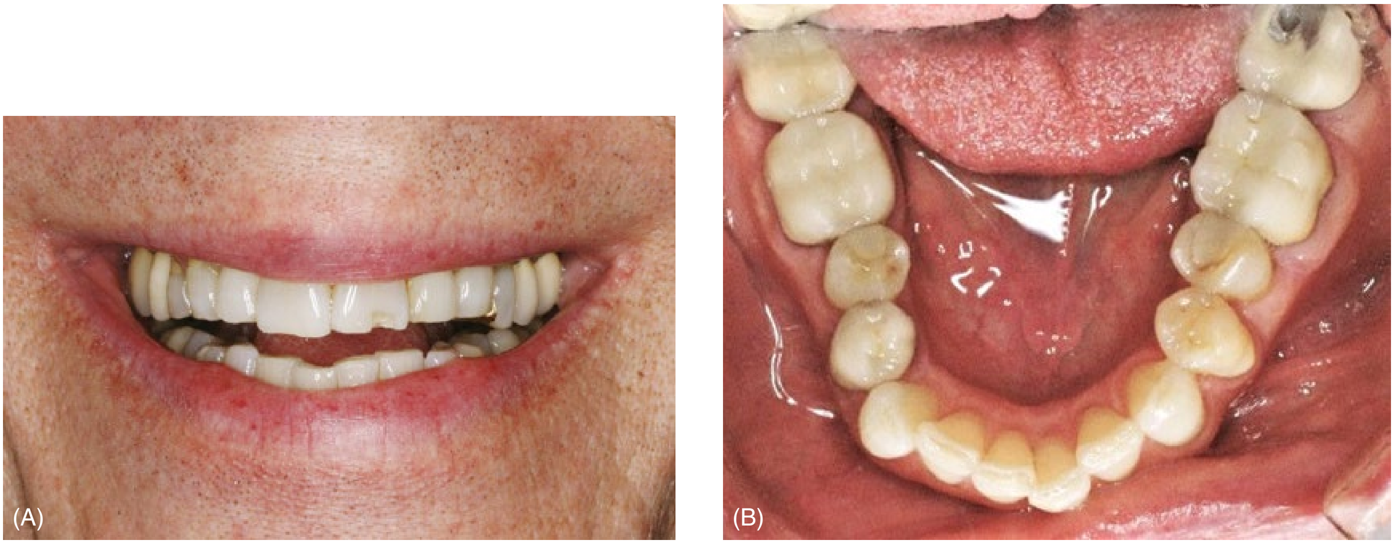

Figure 27.9 **(A, B)** This man wanted to improve his smile both esthetically and functionally.

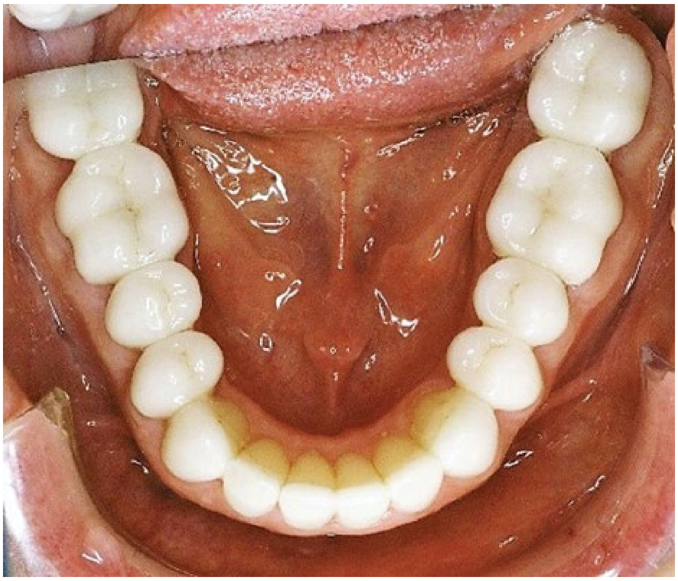

Figure 27.9 **(C)** The patient was accepting of conventional orthodontics for a short period that would improve the crowding on the lower arch for a better eventual result.

Figure 27.9 **(D, E)** The final result is a combination of orthodontics, all-ceramic crowns, and porcelain veneers, which pleased the patient.

advantages of repositioning the lingually locked tooth than to try to restore it in place. In severe situations, a third choice involving extraction and moving the remaining teeth together with bonded brackets may be indicated.

To bond, veneer, or crown?

The following questions should be considered:

- What is the size of the crowded tooth? Will bonding make the tooth too bulky? Bonded lower anteriors are more susceptible to this problem.
- How much enamel is left for bonding? Are there very large existing restorations that, once removed, will lessen the retention for a new bonded restoration? Also, if the patient normally has a tendency to build plaque and calculus on the lingual surfaces of lower anteriors, bonding may not be the best choice.
- What is the appearance of the enamel? Is it badly stained or discolored so that a large amount of opaquer plus several layers of composite resin will be required to mask the defects? If so, then veneering or crowning is the better choice.
- Does the patient have a bad habit that may stain a bonded restoration? Heavy smokers or coffee/tea drinkers may choose veneering or crowning to lessen the amount of postoperative discoloration.
- Is there an economic problem? Frequently, patients may wish to have their teeth veneered or crowned, but finances enter into the decision since bonding with composite resin is less expensive than either crowning or veneering with porcelain.
- How long does the patient expect the restoration to last? Chances are that both veneering and crowning can provide much longer life than direct bonding with composite resin.

In the final analysis, most patients could benefit from a combination of orthodontics and restorative dentistry (Figure 27.9A–E). Those patients who select a more conservative option should also be informed whether later on it will be possible to proceed with a more ideal or optimal treatment plan. In this regard, so many of my earlier bonding patients have opted to change from composite resin to porcelain veneers or even all-ceramic crowns. Others even decided to undergo some orthodontic therapy before their final restoration option. Thus, it is always appropriate to present both an ideal and compromised treatment plan as well as a long-term option. Patients who may need a quick smile transformation but are restricted by financial considerations may be in a much better financial situation in later years.

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Chapter 28 Esthetics in Adult Orthodontics

Eladio DeLeon Jr, DMD, MS

Chapter Outline

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In honor and memory of Dr Marvin C. Goldstein.

Over the past few decades, the focus of dentistry has undergone a significant paradigm shift. The increasing esthetic awareness of the adult patient has expanded the therapeutic realm of dental practitioners from solely controlling dental disease to optimizing smile esthetics.

Although orthodontic treatment is primarily perceived as based on achieving "straight teeth" and ideal occlusal relationships, greater attention is increasingly directed toward enhancing the smile, the face, and the ability to masticate. The scope of "adult orthodontics" simply includes the alignment of teeth and jaws of those persons who are beyond the normal growth phase. These are typically individuals over the age of 16. Given the expanded and often prolonged dental history of this patient population, an interdisciplinary approach is often required to maximize the esthetic result.

There are positive and negative aspects of treating adult patients. The advantages are threefold: enhanced motivation, increased pain tolerance, and autonomous fiscal responsibility. The adult patient is obviously reluctant to be seen wearing the "braces" that are usually associated with adolescent and preadolescent therapy. The advent of esthetic removable and fixed appliances, coupled with the prospects of improved esthetics and function, is generally sufficient to overcome this hesitation. The limited ability of the orthodontist to channel the facial growth of the child to improve facial esthetics is a luxury that is unavailable to the adult orthodontic patient. In those adults who require skeletal movement to enhance esthetics, surgical intervention may be required.

There are two basic reasons that adults seek orthodontic treatment: to improve appearance and/or to improve chewing or speaking function. Obviously, the former comprises the majority of the motivation in the adult seeking treatment. It is therefore valuable to distinguish between esthetic and cosmetic services. Esthetic treatment involves an effort to improve appearance by providing permanent structural changes. Cosmetic treatment generally involves obscuring or covering unsightly imperfections.

Ronald E. Goldstein's Esthetics in Dentistry, Third Edition. Edited by Ronald E. Goldstein, Stephen J. Chu, Ernesto A. Lee, and Christian F.J. Stappert.

The intent is to enhance certain facial features with temporary applications. However, the field of cosmetics has expanded to mildly invasive procedures such as injections of botulinum toxin type A (Botox) and/or injectable fillers to eliminate age-related facial wrinkles and furrows. Treatment with Botox now includes the treatment of wrinkles lateral to the eyes ("crow's feet") and to treat the gummy smile. Other cosmetic procedures include soft tissue revisions, such as blepharoplasties and rhinoplasties, and extensive dental prosthetic procedures, which are extensively explored in other chapters of this volume.

Cosmetic dentistry likewise seeks to merely camouflage the underlying defects (Figure 28.1). In contrast, esthetic dentistry seeks to correct the underlying problems, such as improper dental, skeletal, and functional relationships, and those involved in arch coordination and symmetry. Only when these goals have been achieved, can subsequent esthetic restorative procedures create a truly esthetic smile. Faced with this growing demand, the responsibility of the dental practitioner is to first and foremost educate the patient that the foundation of an esthetic smile lies in controlling disease as well as the achievement of proper orthodontic form and function. When educating the patient about treatment options, it is essential to differentiate between cosmetic dentistry and esthetic dentistry. Attempting to achieve esthetic results without the realization of these goals can only lead to a compromised treatment outcome. Thorough patient education of the discriminating, self-motivated adult patient is essential to generate an informed treatment decision tailored to the patient's goals and economic resources.

This chapter will illustrate tooth movement to relieve tooth crowding, spacing, and to provide simple alignment. Chapter 29 will avail the reader of a comprehensive review of the diagnosis, treatment planning, and appliance selection with treatment of complex orthodontic and facial abnormalities that negatively impact facial and dental esthetics.

Although the contemporary identity of the profession is orthodontics and dentofacial orthopedics, the expanded domain requires a team approach involving oral and maxillofacial surgeons, periodontists, and restorative dentists, all collaborating to enhance the smiles of patients of all ages.

Impact of orthodontic treatment on facial esthetics

Facial esthetics is a blend of the health, symmetry, and proportionality of facial and dental hard and soft tissues and, accordingly, a comprehensive evaluation of all factors must be evaluated in order determine the most effective and efficient treatment plan for the adult orthodontics patient. The following factors all play a role in treatment planning orthodontics in the adult patient and ultimately determine whether or not the treatment was successful: preexisting dental conditions, preexisting

Figure 28.1 Camouflaging defects: orthodontics, implants to replace congenitally missing maxillary laterals.

facial features, and preexisting temporomandibular conditions, based upon comprehensive facial, dental skeletal analyses, patient finances, and patient intangibles.

Historically, some adults have sought orthodontic care for their children before seeking it themselves, but recently that paradigm has begun to shift. According to the American Association of Orthodontists (AAO), adults now make up 20%[1] of all orthodontic patients seen by AAO members. Traditionally, orthodontists have treated almost exclusively patients under the age of 18, with the majority of them having healthy, intact dentitions. Adults can pose added complexity to treating their facial, skeletal, and dental problems successfully, as Dr Vincent Kokich[2] points out: "Adults may have old and failing restorations, edentulous spaces, abraded teeth, periodontal bone defects, gingival level discrepancies, and teeth beyond any sustained useful purpose…that could compromise the orthodontic result."

To fully understand the needs of adult patients, a lengthy medical and dental history is needed and extensive clinical records to include extra-/intraoral exams and photographs, lateral cephalogram, panoramic radiograph, full periodontal charting, and a recent full mouth series of radiographs. In the present stage of digital images, there is simply no excuse for poor quality of images, and staff should be trained properly and be expected to deliver the best diagnostic records that current technology has to offer (Figures 28.2, 28.3, and 28.4).

One of the first analyses that should be conducted, both in person and with the aid of high-quality digital images, is a smile analysis. According to Dr David Sarver,[3] "smile and facial animation…should be of great interest to orthodontist." As Sarver writes, orthodontists typically evaluate the "posed smile" even with the knowledge that there are two different types of smiles: the posed and the spontaneous smile. The posed smile is evaluated due to its reproducibility and predictability with two major characteristics being scrutinized: the amount of incisor and gingival display and the transverse dimension of the smile. The posed smile and the spontaneous smile must be acceptable to the patient to prevent a self-conscious or affected smile (Figure 28.5).

The amount of incisor and gingival display for the maximum esthetic result has been found to not always be congruent, according to orthodontists and laypeople alike. Truly, beauty is in the eye of the beholder and is supported by the following studies. In 2008, Gul-e-Erum and Fida[4] asked 12 laypeople who were orthodontic patients to evaluate 46 frontal full-face pictures of a man and woman with digitally altered characteristics of buccal corridors, incisal show/lip line, and smile arc, among others. Results showed that "zero gingival display with zero incisal coverage was preferred in the photograph of the man, incisal display with 2 mm gingival display preferred in the photograph of the woman." In similar studies by Hulsey,[5] Hunt et al.,[6] and Kokich et al.,[7] upper lip height at the gingival margin of the upper incisor, tolerance of −2 to +2 mm from gingival margin, and gingival display threshold of 3.0 mm were the preferences of their respective studies.

This deviation in study results holds true for preferences on buccal corridors, gingival zeniths, smile arcs, and midline deviations.[8] Although there seems to be agreement as to what is

Figure 28.2 Photographic montage, close-up smile, periodontal charting.

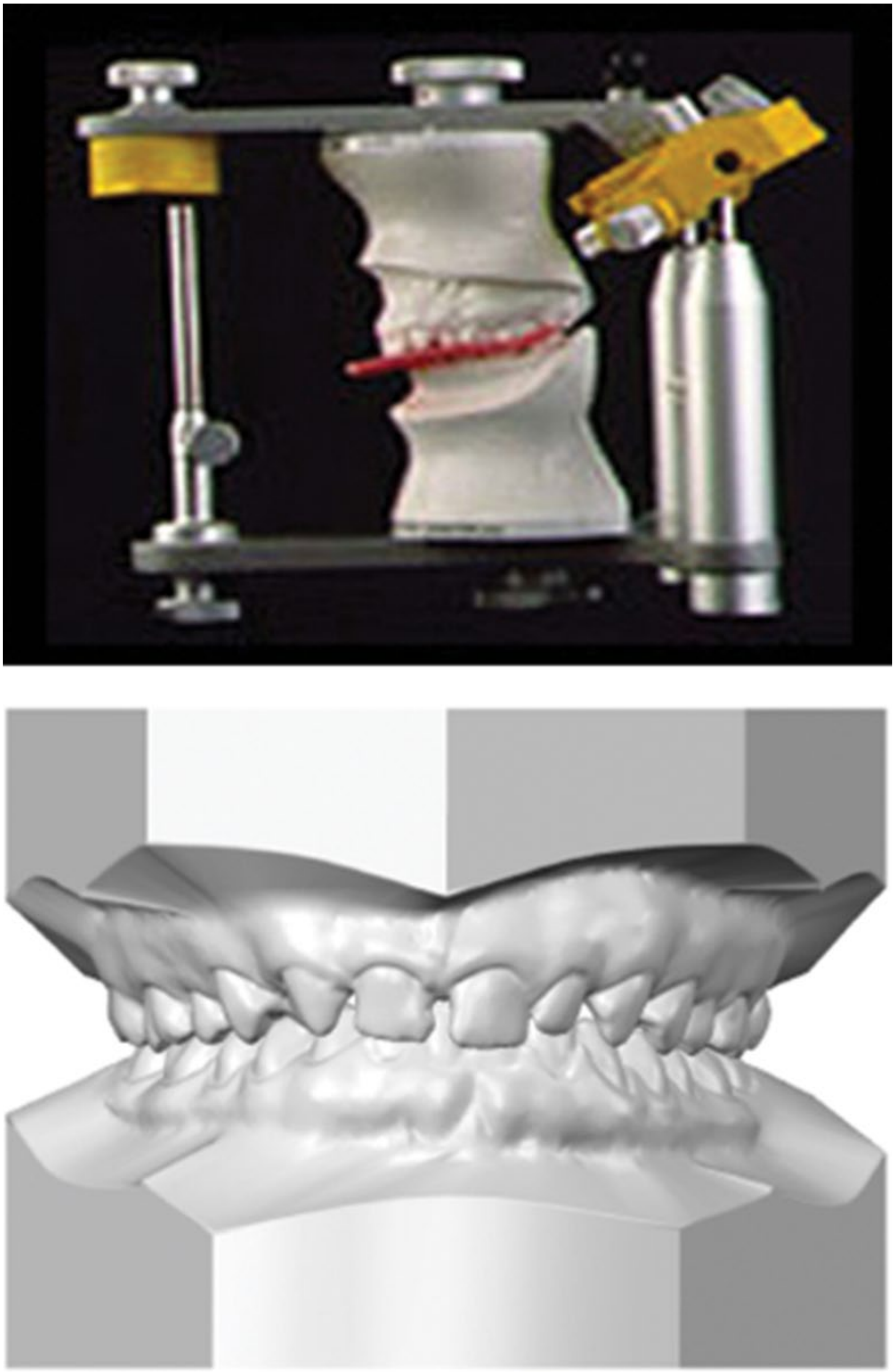

Figure 28.3 Mounted models and American Board of Orthodontists (ABO) dental models.

"not esthetic," there is a slight variation among dental professionals and laypeople as to what consists of maximum esthetics (Figures 28.6, 28.7, and 28.8).

As a part of smile and facial analysis, the orthodontist must also evaluate for proper dental and facial proportions, and also display and length of teeth. With the incorporation of high-quality digital images into the treatment planning of orthodontics, it is very important to scrutinize facial symmetry in all three planes of space: height, width, and depth. According to Sarver,[9] when determining proportionality in the horizontal plane, the face is divided into three equal planes, with the distances measured between the chin to the bottom of the nose,

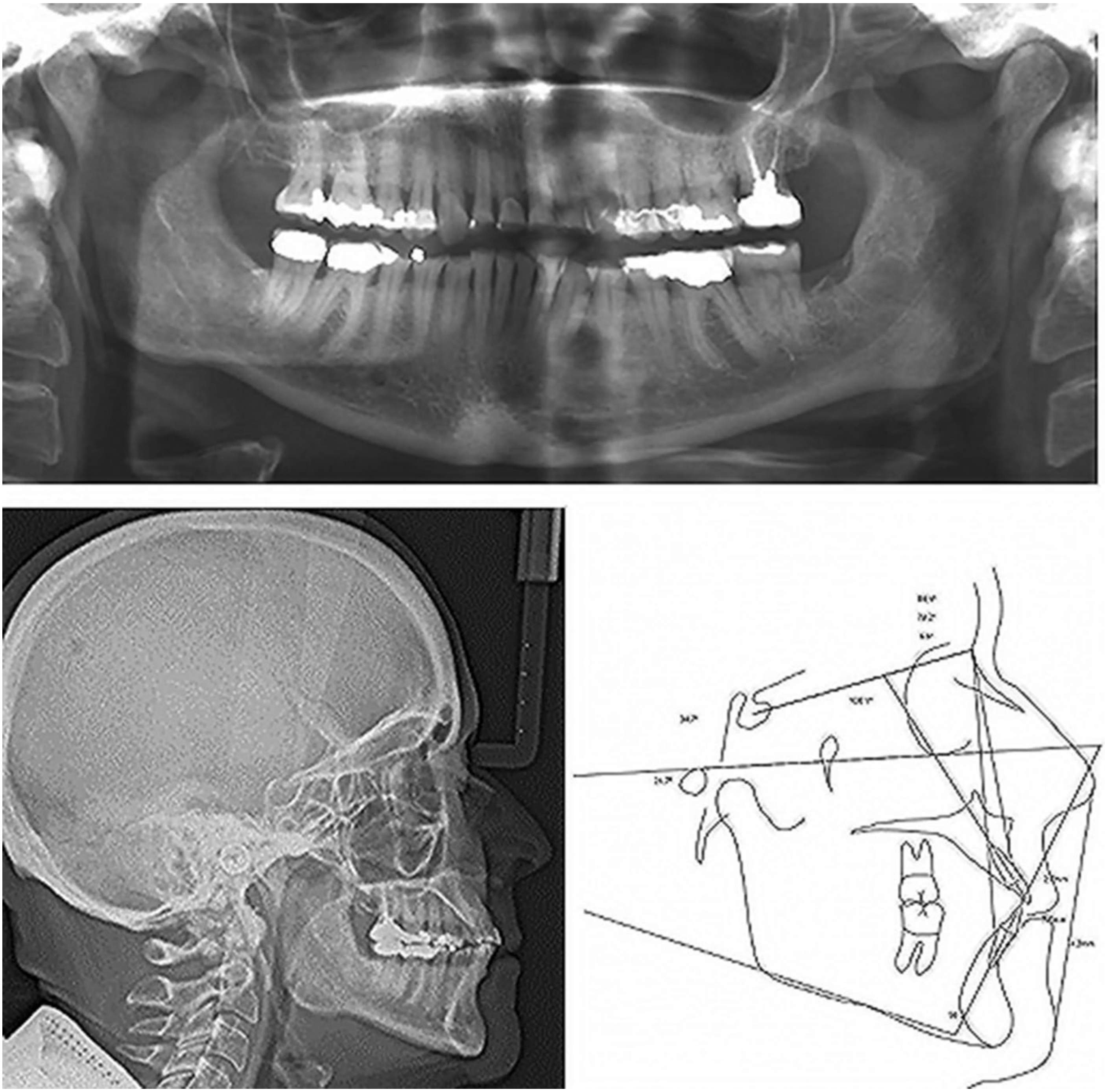

Figure 28.4 Panoramic and cephalometric radiographs and cephalometric analysis.

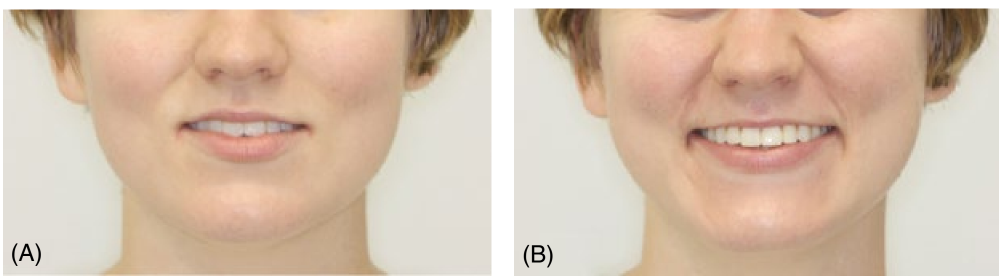

Figure 28.5 **(A)** Posed smile. **(B)** Spontaneous smile.

Figure 28.6 Excessive buccal corridors.

Figure 28.7 Reverse smile line.

Figure 28.8 Midline deviation, black triangle, and gingival recession with significant crowding

from the bottom of the nose to the brow, and from the brow to the hairline being of equal value (the rule of thirds). Of distinct importance to orthodontists are the proportions of the lower face, because that is where the orthodontic impact is the greatest. The upper lip to the nose should represent a third, while the lower lip to chin should equal two-thirds. If these proportions are not correct prior to treatment, they should be noted in the findings section and can figure into the objectives of treatment if the orthodontist so chooses. Vertically, the face should follow the rule of fifths, with one-fifth equaling the width of an individual's eye. The boundaries in which there should be equal fifths are

Figure 28.9 The rule of thirds.

from the lateral portion of the ear to the lateral portion of the eye to medial aspect of the eye, with the distances being congruent and symmetric on the right and left sides of a person's face (Figures 28.9 and 28.10).

Symmetric and proportional facial components are an absolute for maximum orthodontic esthetics, but orthodontists face an uphill battle without proper dental proportions that include display of teeth. When treating adults, those who venture into esthetic and functional reconstruction should be fully aware of the potential compromising factors so clearly outlined by Dr Kokich. He listed and expanded on key compromising factors of adult treatment: attrition of teeth, iatrogenic width/height changes with permanent dental restorations, and periodontal considerations. Simplified, the greater the attrition of teeth, the greater the width compared with the height. Dentists also restore teeth to the best of their abilities, but often times change the anatomic width/height ratios with restorative treatment.

Periodontal disease affects the proportionality of teeth because the receding gums reveal greater amounts of tooth structure, which alters the natural width/height ratios. In addition to single tooth width/height ratios, one of the longest standing ratios was proposed to relate to dentistry: the golden proportion. When used in dentistry, the golden proportion of 1.618 to 1 has been shown to relate to the perceived width of the maxillary teeth starting at the midline and working distally, but only when the onlooker is positioned directly in front of the subject being examined. Using the lateral incisor as the value "1," the most esthetic width of the central would be 1.618 and the width of the canine would be 0.618.[10,11] However, according to references on

Figure 28.10 The rule of fifths.

tooth size, there is no correlation of the golden proportion with the actual dimensions of incisors.[12]

The actual width of maxillary lateral incisor to maxillary central incisor proportionally is better estimated at 77.5%, with a range of 71–82%. As a result, the use of the golden proportion to determine tooth size or space appropriation for replacement or restoration of missing or anomalous crown would not be appropriate.[13]

To determine proper width-to-height ratio, we again rely upon the research of Dr Sarver,[14] who states that although there is some variability in the data of width-to-height ratios of maxillary central incisors, which varies between 66% and 80%, he and Dr G. Gurel,[15] in a published study on the art of laminate veneers, believe the most esthetic width-to-height ratio is 0.8. While well stated, this is a guideline and not an absolute rule, since natural teeth undergo attrition during their lifetime and it may be difficult to determine what the preattrition ratio was. In all of esthetics, proper ratio amounts and symmetry appear to be the most important factors (Figures 28.11, 28.12, and 28.13).

Beyond the world of diagnosing and treatment planning in three dimensions, orthodontists continue to rely upon two-dimensional radiography, especially panoramic and cephalometric radiographs. Prior to cone beam computed tomography (CBCT) being available on the market for reasonable prices, these two radiographs were two of the most important pieces of the treatment planning puzzle (Figure 28.4). Today, cephalograms and panoramic radiographs are used adjunctively with three-dimensional radiographs. It has always been imperative that orthodontists do not take normal values created with population statistics from cephalograms as absolute treatment values

Figure 28.11 Severe attrition.

Figure 28.12 Orthodontic–restorative preparation in establishing the proper ratio and symmetry.

Figure 28.13 Ideal tooth size proportions.

for their patients in hopes of achieving “normal values.” With that said, normal values are extremely helpful in understanding where an individual deviates and possibly needs correction. In 1988, McNamara and Ellis[16] established normal cephalometric values based on their sample size of 125 untreated individuals with "ideal" occlusal and facial relationships. It was stressed in this particular study that infinite combinations of dentoskeletal relationships could lead to normal values; again, these cephalometric "norms" were not numbers to treat to, but rather "guides for the clinical assessment of the patient. The final diagnosis and treatment plan will rely on a number of other factors that cannot be obtained from a radiograph." Taking into account that different researchers and clinicians have established their own cephalometric analyses, the McNamara and Ellis study aimed to evaluate the parameters from some of the more popular analyses, including Steiner, Downs, and McNamara. The results of this study continue to substantiate the norms established by the creators of the different cephalometric analyses and further prove that there is large variation as to how an individual may reach a point of ideal facial and dental esthetics when evaluating the dentoskeletal relationships (Figures 28.14 and 28.15).

When treating adults, orthodontically, the practitioner must be keenly aware that faces change with age and that there are several very predictable facial features we should consider when doing treatment planning. In 2009, Desai et al.[17] concluded that, after looking at 221 subjects placed into five age groups, "a significant decrease of 1.5–2 mm in maxillary display at smile was found with increasing age. Similarly, upper lip thickness also decreases by 1.5 mm at rest and at smile." In addition, "no subject in the 50 and over age group had a high smile and no subject 15–19 year group had a low smile. Most subjects (78%) had average smile height." Their conclusions were that the smile gets narrower vertically and wider transversely, and this is due to the decreasing ability of a subject's facial muscles to frame a smile with increasing age. For orthodontists, this is critical evidence in determining what harmony must exist between the hard and soft tissues of the lower face. For instance, gingival height discrepancies are of less importance in an adult that shows no gingiva on full smile compared with a teenage patient who shows full incisors plus a small amount of soft tissue. Although we strive for perfection in all of our patients, the amount of reveal of the

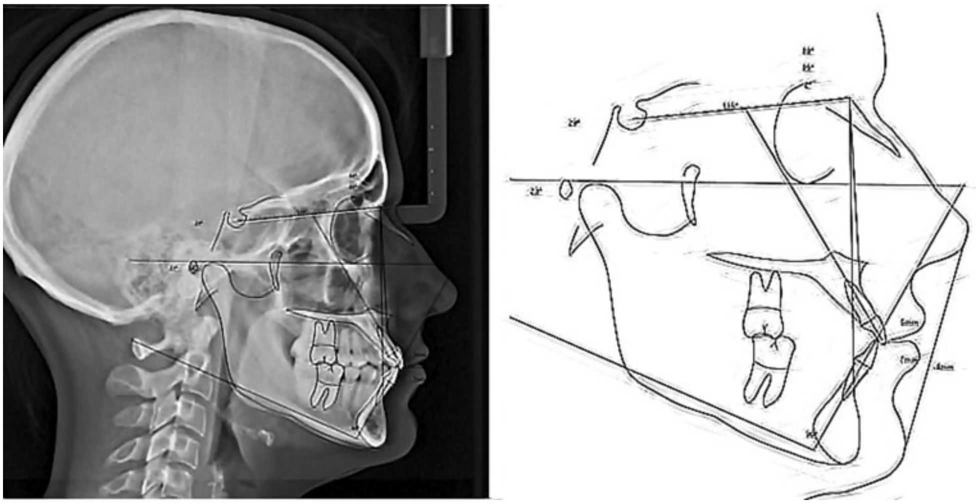

Figure 28.14 Cephalometric analyses are used to evaluate the formation of the facial skeleton, jaw relationships, axial inclination of the incisors, soft-tissue morphology, and growth patterns. Cephalometric norms for various ethnic and racial groups are available and should be used in the analysis.

Measurement Name	Norm (American white)
SNA	82°
SNB	80°
ANB	2°
$\underline{1}$- NA	4 mm
$\overline{1}$- NB	4 mm
$\underline{1}$ to $\overline{1}$	131°
GoGn - SN	32°
$\overline{1}$- MnPl	93°
$\overline{1}$- $\vert$ FH	62°
Y axis	61°

Figure 28.15 Steiner cephalometric norm measurements: sample population, white North American children and young adults.

anterior teeth in the adult smile can be a compromise in the adult patient (Figures 28.16, 28.17, and 28.18).

Within the past decade, one treatment modality that has been highly sought after in the world of plastic surgery has crept into the world of dentistry: the use of Botox. Botox has historically been used to help alleviate some of the effects of aging, namely wrinkles and frown lines. However, within the past decade, dentists have found a novel use for it in treating one of the most difficult problems in facial esthetics, the "gummy smile." The gummy smile can be attributed to being caused by several different etiologies: delayed passive eruption, vertical maxillary excess, and a hyperfunctional upper lip musculature. Traditional methods of treating these etiologies have consisted of periodontal osseous recontouring, orthognathic surgery impacting the maxilla, or simply patient restriction of their full smile. A gummy smile has been reported to truly affect one's self-esteem, making them incredibly self-conscious about smiling and embarrassed in social settings. As such, Dr Mario Polo[18] published a study in 2008 relating to the use of Botox in the correction of excessive gingival display during smiling that was of neuromuscular origin, meaning a hyperfunctioning lip. His sample of 30 patients was injected with 2.5 units of Botox on the right and left sides of their faces in several places to hopefully attenuate the activity of the upper lip. Results showed that the average lip drop 2 weeks postinjection was 5.1 mm for the 30 patients. Secondarily, what Dr Polo also found was that the Botox began to be less effective over time, but even at 24 weeks postinjection the gingival display was still less than the baseline. His prediction, based on third-order polynomial equations, was the Botox would not become 100% ineffective until 30–32 weeks postinjection. With this study and results, it is only a matter of time before dental professionals begin to prescribe this possible short-term treatment modality for their patients.

Figure 28.16 Low smile line.

Figure 28.17 Medium smile line.

Figure 28.18 High smile line.

Integrating orthodontics into the interdisciplinary treatment plan

Orthodontics alone can solve many esthetic problems of the face, jaws, and teeth, but many others require an interdisciplinary approach.[19] Such an interdisciplinary approach requires teamwork and constant communication between the restorative dentist and each specialist involved.[20] Failure of effective communication between the practitioners involved results in disjointed and uncoordinated multidisciplinary treatment of the patient rather than a stepwise integrated interdisciplinary treatment, and this lack of communication and consensus can compromise the final esthetic result.

Orthodontics can serve as an adjunct to esthetic restorative treatments in several different ways. One of the most common orthodontic–restorative treatments involves the restoration of peg laterals (Figures 28.19, 28.20, 28.21, and 28.22). Orthodontics can also facilitate restorative treatment in the esthetic zone by extruding teeth (planned for future extraction or as a result of a traumatic injury) to avoid the need for bone grafting prior to placement of an implant to replace that hopeless tooth,[21] aligning incisors to maximize restorative effect, and adjusting vertical

Figure 28.19 Close-up smile of congenitally missing right lateral and pegged left lateral.

Figure 28.20 Panorex of congenitally missing right lateral and pegged left lateral.

Figure 28.21 Orthodontic–restorative treatment of congenitally missing right lateral and pegged left lateral restored with an acid etch bonded bridge for the maxillary right lateral and veneer maxillary left lateral.

Figure 28.22 Initial and final photographs of the orthodontic–restorative treatment of congenitally missing right lateral and pegged left lateral.

position of teeth to restore symmetry of gingival heights (Figures 28.23, 28.24, 28.25, and 28.26). Kokich and Spear define a series of eight guidelines that, if followed, can help the dental team to integrate orthodontics into the restorative treatment:

1. Establishing realistic treatment objectives.
2. Creating a vision of the treatment outcome.
3. Determining the treatment sequence.
4. Building up small or malformed teeth (i.e., peg laterals).
5. Positioning the teeth in a way that facilitates the planned restorative treatments.
6. Evaluating the gingival esthetics during the orthodontic finishing.
7. Taking radiographs during the orthodontic finishing.
8. Interaction between the orthodontist and the restorative dentist.

When establishing treatment objectives for the orthodontic–restorative patient, "It is important to establish achievable/realistic, not idealistic treatment objectives."[20] Such treatment objectives must be financially realistic, occlusally realistic, and realistic for the restorative dentist. If the team does not establish financially realistic treatment objectives, the patient might be unable to continue with the restorative work following the orthodontic treatment. Because the orthodontist may be unaware of the restorative requirements, and the restorative dentist may have difficulty visualizing the possibilities of orthodontic treatment, the team should use a diagnostic wax setup to illustrate the possibilities and requirements of each stage of treatment[20] (Figures 28.27, 28.28, and 28.29).

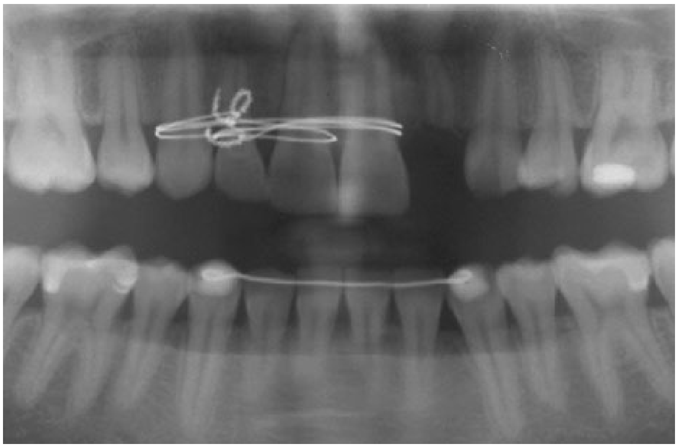

Figure 28.23 Traumatic injury of maxillary lateral. Treatment plan was to promote alveolar bone development by extruding maxillary lateral root, thus avoiding the need for bone grafting prior to implant placement.

Figure 28.24 Orthodontic lingual appliance to extrude maxillary lateral root.

After setting treatment objectives, creating a vision for treatment, and discussing the treatment plan with the patient, the team must establish a sequence for the treatment. Many orthodontic–restorative patients also require treatment from a periodontist, endodontist, and an oral surgeon. The greater the number of specialists involved, the more complex the treatment becomes. Often, the patient must undergo treatment from each specialist at multiple times during the entirety of the treatment. This necessitates that an accurate sequence of treatment be established to avoid each practitioner from operating in a vacuum and carrying out *multi*disciplinary treatment rather than *inter*disciplinary treatment. Each of the participating practitioners should have a copy of the sequence of treatment.[20]

If the patient has small or malformed teeth, such as peg lateral incisors, that are involved in the treatment plan, the issue of when to build these teeth up must be addressed in the treatment sequence. In many instances, the orthodontist will need to create space around these teeth for a proper buildup to be completed by the restoring dentist. This issue is most common in two situations: peg-shaped lateral incisors and retained primary teeth. In the instance of peg lateral incisors, sufficient space may exist prior to initiating orthodontic therapy, and a composite buildup may be completed prior to the orthodontist bonding brackets. More commonly, however, insufficient space exists adjacent to the peg lateral, and the orthodontist must open space for a proper composite buildup. Kokich and Spear raise four key

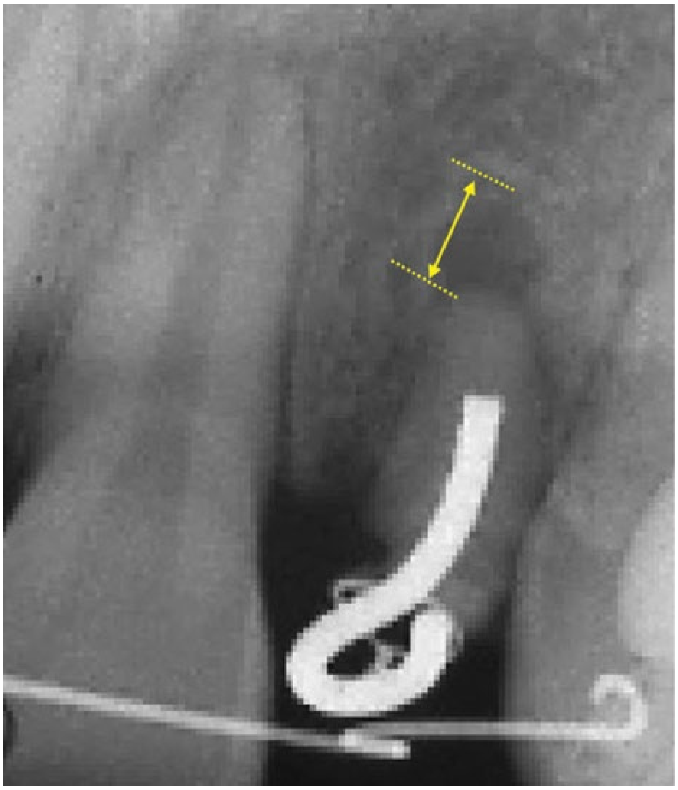

Figure 28.25 Periapical radiograph revealing extrusive movement of maxillary lateral root.

Figure 28.26 Implant/crown for replacement of the maxillary left lateral after orthodontic extrusion as an alternative to bone grafting prior to implant placement.

issues that the orthodontist and restorative dentist must discuss related to the positioning of pegged lateral incisors:

1. *How much space is needed for an adequate build-up?* Once this has been determined, the restorative dentist may find it helpful for the orthodontist to open slightly more space than is deemed necessary. This allows easier contouring and polishing of the interproximal surfaces of the buildup. The orthodontist can then close the space during finishing of the case.[20]

Figure 28.27 Traumatic injury to maxillary anteriors resulting in the need to visualize the treatment possibilities.

2. *Where should the peg lateral incisor be positioned mesiodistally relative to the central incisor and canine?* With the lateral too close to the canine, the restorative dentist must overcontour the mesial surface of the lateral. Because natural lateral incisors have a relatively flat emergence profile on their mesial surfaces and a more convex emergence profile on their distal surfaces, the peg lateral should be positioned closer to the central incisor than to the canine.[20]
3. *Where should the lateral incisor be positioned buccolingually?* The buccolingual position of the lateral depends largely on the type of planned restoration for the peg lateral incisor. If the definitive restoration will be a porcelain crown, the lateral should be positioned in the center of the ridge, with 0.50–0.75 mm of overjet. This helps to minimize unnecessary preparation of the tooth. If the definitive restoration will be a porcelain veneer, the orthodontist should position the lateral lingually so that it contacts the mandibular incisor.[20]
4. *Where should the peg lateral incisor be positioned incisogingivally?* This decision is based on the relationship of the gingival margins. The gingival margin of the peg lateral should be aligned with the contralateral lateral incisor, slightly apical to the gingival margin of the central incisors.[20]

In a patient with a retained primary tooth, the primary tooth may be replaced in the future with an implant. If this is the case, the primary tooth will need to be retained for as long as possible to maintain as much alveolar bone as possible for placement of the implant in the future. The orthodontist should open space mesial and distal to the primary tooth so that the restorative dentist can build up the primary tooth temporarily during the orthodontic treatment. A diagnostic wax-up may be necessary to determine the correct width of the composite restoration.[20]

Figure 28.28 Diagnostic setup.

Figure 28.29 Comparison of the pretreatment and final close-up smile after completing an interdisciplinary orthodontic and restorative treatment.

The orthodontist should consider the planned restorative treatment when determining the final position of teeth in the orthodontic–restorative patient. If a resin-bonded bridge is planned, it is important to position the abutment teeth with sufficient overjet and appropriate overbite. With the overbite minimized, more of the lingual surface of the abutment teeth can be covered with the bonded metal framework, increasing the retention of the resin-bonded bridge. Owing to the greater shear strength of the resin-bonded bridge, incisors should be oriented more upright to direct forces on the bridge more vertically. If a conventional anterior fixed partial denture is planned, the orthodontist should create 0.50–0.75 mm of excess overjet. This will allow for material thickness when restoring the missing tooth. In most patients with an abraded anterior dentition, the teeth have supraerupted to accommodate for the attrition, and the incisors are shorter in height than unworn teeth. In such a patient, the orthodontist should intrude the abraded teeth and reestablish the appropriate gingival heights. As the orthodontist is intruding the incisors, the restorative dentist may restore the incisal edges of these teeth.[20]

The orthodontist, restorative dentist, and a periodontist should evaluate the gingival esthetics. Kokich and Spear recommend four criteria for the orthodontist to evaluate (Figure 28.12) as follows:

1. Gingival levels of two central incisors should be at same height.
2. Gingival margin over lateral incisor should be about 0.50 mm incisal to central incisor gingival margin, and the gingival margin of the canines should be at the same height as the central incisor.
3. The labial gingival contour of each tooth should follow the contour of the cementoenamel junction.
4. The interproximal papilla should fill the space gingival to the proximal contact.

While finishing the case, the orthodontist should take radiographs to evaluate root position. While proper root position is important in all orthodontic patients, it becomes even more critical in the orthodontic–restorative patient in whom implants are planned. The orthodontist should be careful to create adequate space between the roots for proper placement of the planned implant. The orthodontists should maintain close contact with the restorative dentist during finishing in the orthodontic–restorative patient so that the restorative dentist has input on the final tooth position prior to restorations.[20]

Technological advances in orthodontics

There have been many technological advances in orthodontics that have enhanced the orthodontic treatment of patients seeking esthetic enhancement. These advances have come in ceramic brackets, self-ligating brackets, clear aligners, CBCT, digital photography, digital models, and three-dimensional photography. The advances in ceramic brackets to reduce the friction, enhance deboning protocols, and decrease the bulk of brackets have made them a more viable option for the patient concerned with the appearance of traditional braces.[22] Newer, self-ligating ceramic brackets have even been shown to have less friction than traditionally ligated metal brackets.[22] Many have claimed that the lower level of friction associated with self-ligating brackets results in faster initial alignment, shorter overall treatment time, and fewer patient visits to the orthodontist; however, more research is needed to substantiate such claims.[23,24] Along with tooth-colored brackets, tooth-colored wires have become a more viable option for use in the esthetic-minded patient. While some of these esthetic archwires have been fabricated from various silica polymers, newer esthetic archwires are metallic archwires coated with polymers such as Teflon and epoxy resin. These esthetic archwires have been shown to be rougher than their metallic counterparts, and the coatings may affect their three-point bending properties.[25]

Other, less visible orthodontic appliances have also made substantial advances. Customized lingual brackets and wires can be fabricated using computer-aided design/manufacturing technology and have been shown to be an accurate means of positioning teeth.[26] These appliances have the esthetic benefit of being virtually invisible to the patient and third parties, but have the disadvantage of being extremely expensive and sometimes difficult to manipulate. Another esthetic treatment option is a clear aligner system, commonly referred to as clear aligner therapy. While anecdotal evidence and advertising claims are strongly in favor of the treatment effects of such systems, neither the treatment indications nor the limitations of clear aligner therapy have been defined or supported with scientific evidence.[27] This leaves clinicians to rely on the experience of respected colleagues, personal clinical experience, and advertising claims when using clear aligner therapy.

Other technologies have enhanced the communication and treatment planning capabilities between specialists and the restorative dentist. CBCT three-dimensional radiographs have enhanced the ability of orthodontists and oral surgeons to locate impacted teeth[28] (Figure 28.30). Three-dimensional imaging enhances the treatment planning for patients with impacted maxillary canines, and helps the orthodontist and restorative dentist decide whether to bring an impacted canine into the arch or have it extracted and replaced with a prosthesis. Digital photographs and radiographs have made communication easier between orthodontist and the restorative dentist, with the two being able to send images to each other easily and inexpensively.[29,30] As digital models have become more widely available and affordable, accurate measurements are able to be made by multiple practitioners on a single set of models[31] (Figure 28.31). With CBCT, digital models, and three-dimensional photography[32] (Figure 28.32), a virtual patient that practitioners could use to make treatment decisions is on the horizon.

Periodontal considerations with adult orthodontic treatment

With an increasing number or adults seeking orthodontic treatment, periodontal concerns have become a major consideration for treating adult patients. In 1985–1986, a national survey of adults showed 8% of employed adults aged greater than

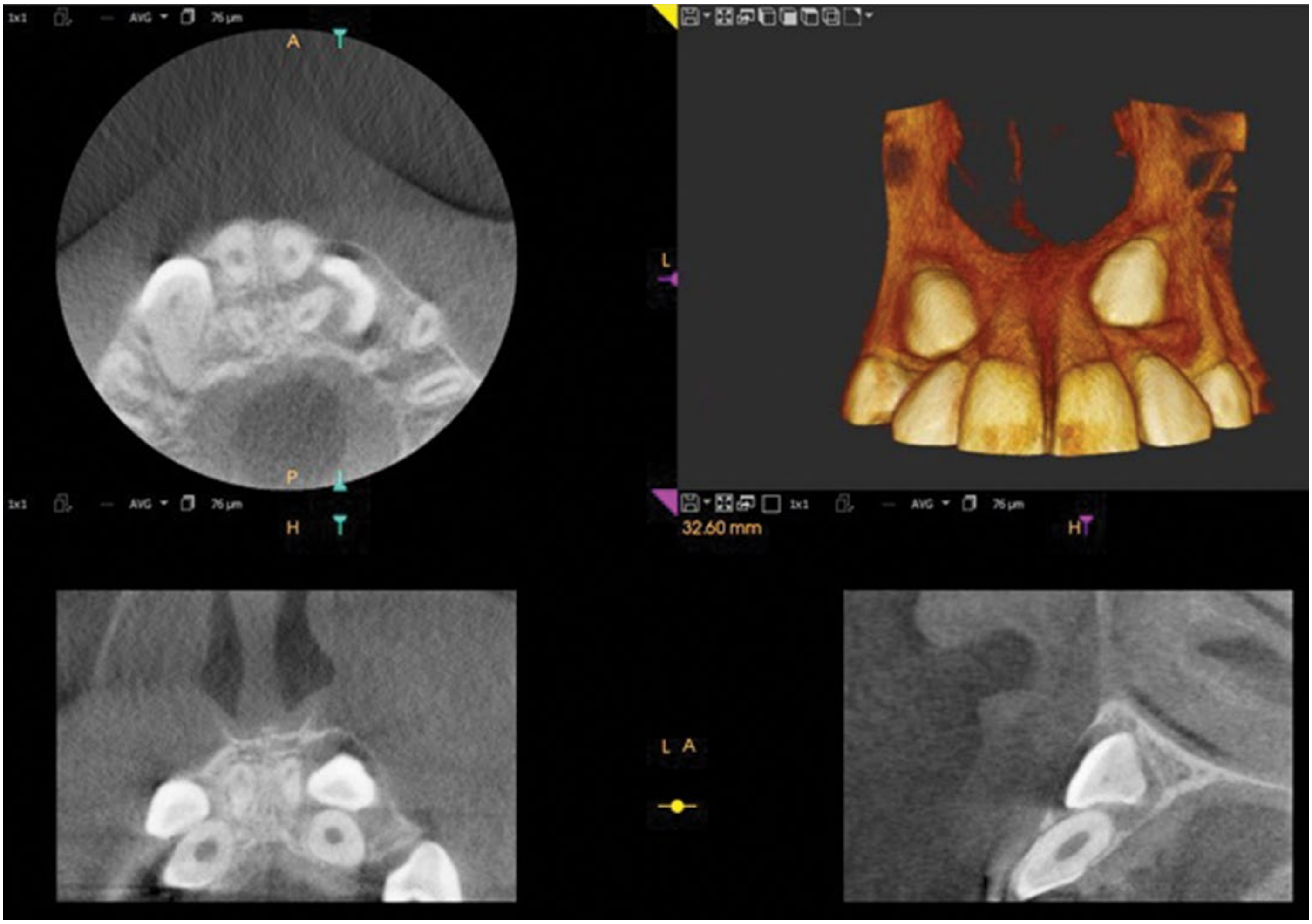

Figure 28.30 CBCT, CS 3D imaging Carestream Dental.

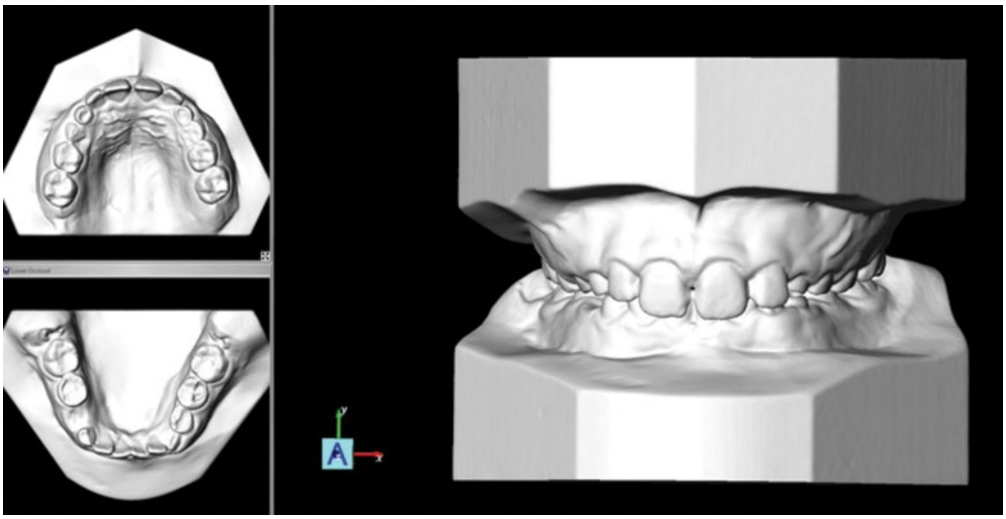

Figure 28.31 Digital models by Ortho Insight 3D™ by Motion View Software, LLC.

or equal to 18 years and 34% of retired adults aged greater than or equal to 65 years had at least one periodontal site with greater than or equal to 6 mm loss of attachment.[33] When an adult patient presents for orthodontic treatment, a clinician must first determine which patients are at risk for developing periodontal disease or have a history of periodontal disease. Despite the high prevalence of periodontal problems in adult patients, orthodontic treatment is not contraindicated as long as the disease process is under control. On the contrary, orthodontics has been shown to improve some periodontal defects and the ability to restore a

Figure 28.32 Virtual patient created in Ortho Insight 3D™ software by Motion View Software, LLC.

Figure 28.33 Orthodontics and periodontics to improve a compromised dentition.

compromised dentition[34–36] (Figure 28.33). However, considerations such as treatment schedules, tooth movement, tissue response, esthetics, and retention must all be taken into consideration during the treatment planning of adult orthodontic treatment.

Evaluating adult orthodontic patients for risk of periodontal disease during treatment is of utmost importance. Aside from pretreatment records and close communication with the patient's general dentist and periodontist, several recommendations have been made concerning adult orthodontic patients. The first involves a thorough medical and dental history. Important questions that should be answered on the patient's history include the interval at which the patient receives regular dental care, use of tobacco products, history of diabetes and other metabolic diseases, a list of their medications, and a history of past periodontal treatment. Intraoral radiographs are another important screening tool to help assess risk and disease. These radiographs should include anterior periapical radiographs and posterior bitewing radiographs. Radiographs not only allow a clinician to assess the periodontal condition of the patient, but also establish a baseline at the start of treatment. Clinical exam, including full-mouth periodontal probing, is also recommended to help assess periodontal risks and disease (Figure 28.34). Appropriate measures should be taken if a patient demonstrates periodontal disease or be at risk of developing periodontal disease.

Treatment planning patients with a history of periodontal disease must receive major attention prior to initiating orthodontic treatment. It is recommended to allow at least 2–6 months after the last periodontal therapy to ensure proper periodontal tissue remodeling.[37] Regenerative periodontal techniques are usually implemented prior to orthodontic treatment, but some studies indicate that it may be performed after treatment.[38–41]

In patients with thin attached gingiva, it is often recommended to improve the tissue width before labial orthodontic movement in an attempt to prevent the development of bony dehiscences.[42–44] Timing of preventative surgical measures ranges from several weeks to 6 months and needs to be further investigated to establish guidelines.[45] Whatever the recommended treatment prior to orthodontics, it is critical for the patient to exhibit sound oral hygiene to minimize risks and optimize treatment results.

During orthodontic treatment of adults with a history of periodontal problems, it is recommended that the patient continues regular periodontal maintenance.[37] The maintenance intervals should be determined based on the patient's risks and the planned tooth movements. If a patient fails to maintain good oral hygiene practices, treatment may be discontinued at the clinician's discretion. Procedures that are considered elective (i.e., frenectomy, esthetic recontouring, etc.) should be completed at the end of orthodontic treatment when the final positions of hard and soft tissues can be determined.[46–48] Despite proper planning and preventative periodontal treatments to help reduce anticipated problems in patients with a history of periodontal disease, the adult periodontium can respond unpredictably to forces placed on teeth.

As a result of the current ability to control orthodontic forces on teeth, force systems can be adjusted for the needs of adult patients. Adult patients may have experienced alveolar bone loss and a reduced periodontium over time, thus positioning the center of resistance more apically. As a result of a more apical center of resistance, it is more likely for a tooth to be tipped and extruded rather than bodily moved.[49,50] Therefore, it is recommended to use light forces of between 30 and 60 gf per tooth, often using segmental arch mechanics (Figures 28.35 and 28.36).[51,52] Treatment time is often prolonged due to the complexity of treatment mechanics and the age of the patient.[53]

In adult patients, tooth movement may become slower due to the lack of collagen conversion and cell mobilization.[53] Adults also form hyalinized zones more easily on the pressure side of

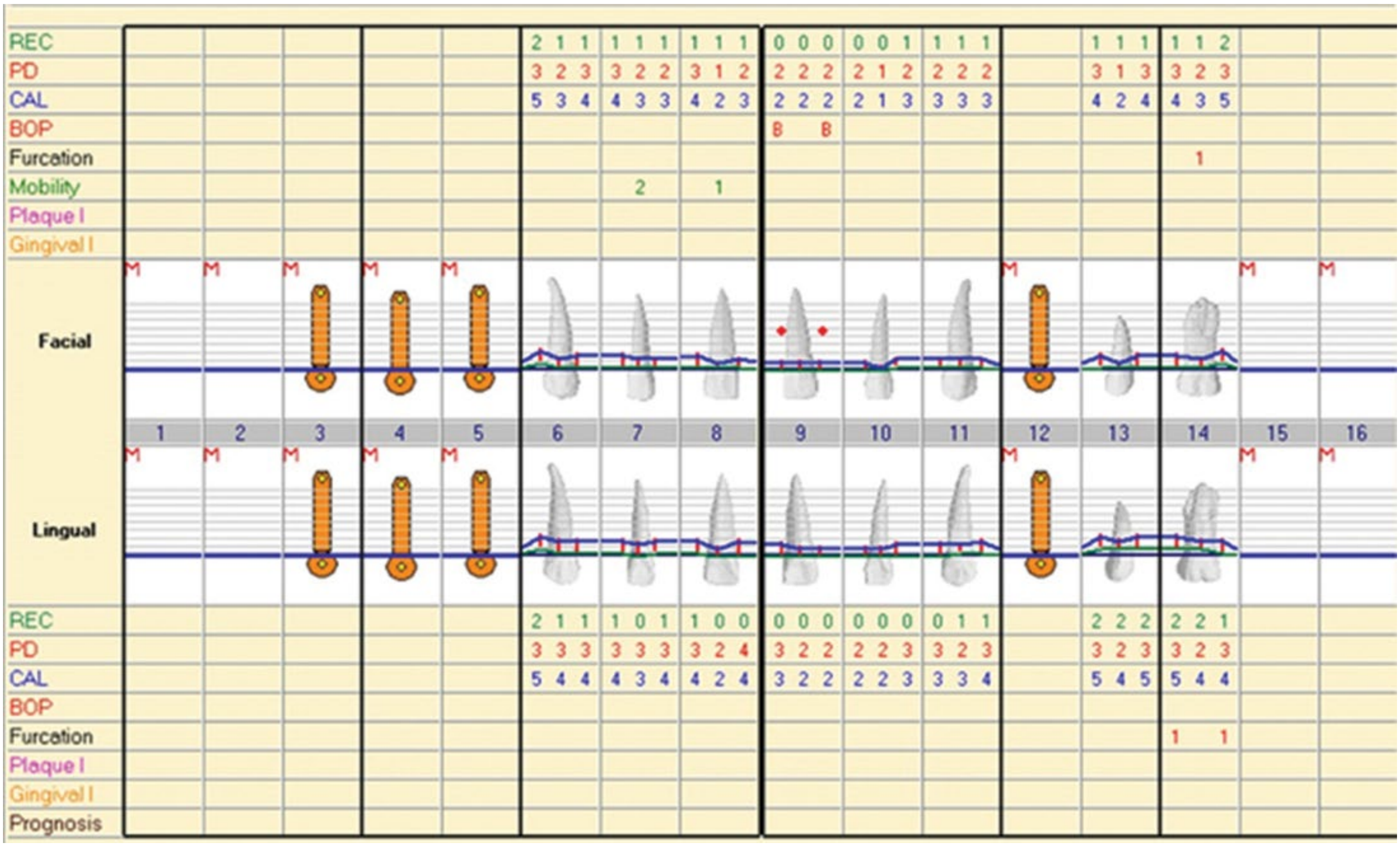

Figure 28.34 Periodontal probing.

Types of Tooth Movement	Force (grams)
Tipping	30–60
Rotation	30–60
Root Uprighting	50–100
Translation	70–120
Extrusion	30–60
Intrusion	5–20

Force requirements will vary based on the available root area (single versus multirooted). Reduced periodontal support will alter the center of resistance of a tooth. As the center of resistance moves apically, the magnitude of the tipping moment produced is equal to the force times the distance from the point of force application to the center of resistance. As the distance of force application to center of resistance increases, force levels should be lighter.

Figure 28.35 Forces systems. Reproduced with permission of Elsevier.

tooth movement, thus initially preventing the tooth from being moved to the intended position.[54] Once the hyalinized zone (acellular) is eliminated by periodontal ligament regeneration, tooth movement may continue.[55] Throughout the history of orthodontics, there have been attempts to overcome the factors that contribute to delayed tooth movement. In recent times, periodontally accelerated osteogenic orthodontics (PAOO), also known as Wilckodontics, has gained attention in the field of orthodontics.

PAOO is a treatment technique that uses full-flap periodontal surgery to improve osseous contours and mechanical injury to bone surrounding teeth to induce cell mobilization needed for tooth movement (Figures 28.37 and 28.38). To date, numerous case presentations have shown decreased treatment times in adult patients, but long-term controlled data are lacking.

Improving dental and facial esthetics has been shown to be the primary motivating factor for adult patients seeking orthodontic

Figure 28.36 Segmental mechanics.

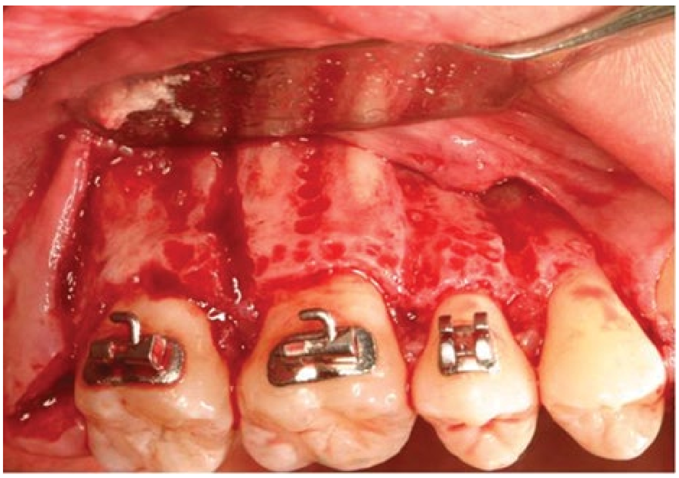

Figure 28.37 Full-flap periodontal surgery with induced mechanical injury to induce cell mobilization needed for tooth movement.

treatment.[56] Gingival tissues play an integral part in dental esthetics and should be considered during orthodontic treatment planning in adult patients. Two problems that may develop during orthodontic treatment concerning gingival tissues include gingival margin discrepancies and lack of interdental papilla, also known as "black triangles."[57]

The gingival margins are the negative space that frames the clinical crown. For optimal esthetics, it has been noted that the central incisors and canines should share the same gingival margin height. The lateral incisors should be placed slightly coronal to the gingival margins of the central incisors and canines (see

Figure 28.38 PAOO: a surgical procedure that combines selective alveolar corticotomy, particulate bone grafting, and the application of orthodontic forces.

Figure 28.51).[57] The labial margins should also mimic the contours of the cementoenamel junction. When gingival margins are less than ideal, the clinician must make one of two decisions: orthodontically attempt to reposition the gingival margin, or surgical reposition the gingival margin. It must be noted that if the gingival margins are hidden by the upper lip upon smiling, there is no need to reposition the gingival margins to an ideal position. If the gingival margins are displayed upon smiling, the next step is to determine the labial sulcus depth of the central incisors. If the shorter of the teeth has a deeper sulcus depth, gingival surgery may be indicated to lengthen the shorter tooth. If they have the same sulcular depth, gingival surgery will not correct the problem. It is also important to compare the shortest central incisor with the lateral incisors. If the shortest central incisor is longer than the lateral incisors, it may be possible to extrude the longer incisor and equilibrate the incisal edge. On the contrary, if the shortest central incisor is the same size or smaller than the lateral incisor, extruding and equilibrating the longer incisor will produce suboptimal esthetics. The next step is to determine whether the incisal edges have been abraded. If the edges are thicker than the adjacent teeth due to attrition, it may be indicated to intrude the teeth to allow for proper restoration.[57] The gingival margin is also formed by the papilla, or lack thereof.

For optimal esthetics, there should be papilla between each tooth and the tip should extend halfway between the incisal edge and labial gingival height of contour over the center of each anterior tooth. In some adult patients, the papilla may be absent, creating the appearance of "black triangles" (Figure 28.39). The lack of papilla may be due to several problems. The first problem involves divergent roots. If the roots are divergent, the brackets may be placed parallel to the long axis of the tooth or a bend may be placed in the tooth to help produce more parallel roots. Another cause may involve abnormal tooth shape. If this is the case, the tooth may be recontoured interproximally to help eliminate the space. In patients with lack of papilla due to the destruction of crestal bone, the mesial contours of the central incisors may be flattened to move the contact more distally, creating a larger contact point. Although this may not completely eliminate the negative space from the lack of papilla, it will most likely improve the esthetics significantly (Figure 28.40).[45,57] After optimal esthetics is achieved, it is important to create and maintain a stable periodontium to prevent relapse (Figure 28.41).

Gingival tissues are compressed in the direction of tooth movement, creating an increase in elasticity that is often associated with orthodontic relapse.[58] Periodontal fibers have been shown to undergo rearrangement even after a retention period of 4–6 months.[59,60]

It is recommended to allow at least 12 months of retention to provide appropriate time for remodeling of periodontal fibers.[61] Stability of periodontal tissues has shown to have been accomplished by long-term fixed retention, adjunctive periodontal surgery, orthodontic overcorrection, or a combination of the latter two (Figure 28.41).[62,63]

Orthodontically treated patients with significantly reduced periodontal support are in need of definitive retention.[64] Fixed retention as a means of permanent splinting is often preferred to removable retention due to unwanted forces exerted by insertion and removal of the removal retainer.[49] Retention may also involve prosthetic reconstruction in patients with loss of teeth, occlusal trauma, progressive mobility, or pain in function.[45,65]

Adjunctive periodontal procedures may also be advised to help improve stability in orthodontically treated patients.

Figure 28.39 Absence of papilla, resulting in "black triangle."

Figure 28.41 Long-term fixed retainer.

Base of proximal contact to Bone Crest	Presence of interdental papilla
5 mm	98%
6 mm	56%
7 mm	27%

Figure 28.40 Presence of interdental papilla. Reproduced with permission of John Wiley and Sons.

Periodontal surgery may help provide stability to an orthodontically treated dentition. The cause–effect relationship between a thick frenum with a high insertion and maxillary midline diastema is well documented.[66] Therefore, it is often advisable to perform a frenectomy after closure of a midline diastema caused by prominent frenum.[45] Other periodontal procedures, such as circumferential fiberotomy of supracrestal gingival fibers (CSF), have been effective preventing relapse of teeth that were severely rotated prior to treatment.[67,68] CSF should be done toward the finishing stages of orthodontic treatment, since studies have shown that relapse can occur as soon as 5 h after removal of orthodontic appliances.[59,69] Long-term studies have shown CSF to be more effective in alleviating pure rotational relapse than in labiolingual relapse and more effective in the maxillary anterior segment than in the mandibular anterior segment.[68]

Occlusal considerations for the adult orthodontic patient

Although a consensus exists among restorative dentists, periodontists, and orthodontists on the parameters of an "ideal" occlusion, when evaluating the occlusion of an adult orthodontic patient the occlusal goals must be determined on a patient-by-patient basis. Many adults present for orthodontic treatment with a myriad of preexisting conditions that can make achieving an "ideal" occlusion challenging and even detrimental to either the esthetics or functional integrity of the patient's occlusal health. For these adult patients, the goal should be to achieve a "compromised and sustainable" occlusion.

Such a compromised goal should be clearly understood by all parties involved that includes a signed understanding by the patient of the intended outcome.

Ideal static occlusion: an historical and contemporary perspective

One of the classic papers on evaluating static occlusion is by Lawrence F. Andrews, wherein he outlines six characteristics that were noted in a study of 120 casts of nonorthodontic patients with normal occlusion.[70]

Normal occlusion was determined by teeth which, "(1) had never had orthodontic treatment, (2) were straight and pleasing in appearance, (3) had a bite which looked generally correct, and (4) in my [Andrews'] judgment would not benefit from orthodontic treatment."[70] The six keys were also validated by studying 1150 treated orthodontic cases that were presented at national orthodontic meetings, and it was found that the lack of one of the six keys of occlusion was an error that was predictive of an incomplete end result in the treated cases.[70] Andrews' six keys of occlusion are as follows:

1. Angle Class I molar relationship and the distal surface of the distobuccal cusp of the upper first molar occluded with the mesial surface of the mesiobuccal cusp of the lower second molar.
2. Mesial inclination of the incisal aspect of the crown (toward the midline).
3. Ideal crown inclination (labiolingual or buccolingual) of maxillary and mandibular anterior teeth and lingual inclination of the crowns of maxillary and mandibular posterior teeth.
4. Teeth should be free of undesirable rotations.
5. No spacing present, with tight contact points.
6. Flat to slight curve of Spee.[70]

The current reference that many orthodontists use to evaluate whether they have achieved an ideal static occlusion is the standards set forth by the ABO.[71] The criteria that the ABO use to evaluate posttreatment results of orthodontic treatment are as follows:

1. Alignment. The incisal edges of the maxillary and mandibular anteriors are evaluated as the lingual surfaces of the maxillary anteriors and the labial–incisal surfaces of the mandibular anteriors.[71] In the maxillary posterior segments, the central groove is evaluated, whereas in the mandibular posterior segments the buccal cusps are used for evaluation.[71]
2. Marginal ridges must be leveled.
3. Buccolingual inclination. There should not be significant differences between the heights of the buccal and lingual cusps of the maxillary and mandibular molars and premolars.
4. Occlusal relationship. The mesiobuccal cusp on the maxillary first molar must align within 1 mm of the buccal groove of the mandibular first molar, and the buccal cusps of the maxillary molars, premolars, and canines must align within 1 mm of the interproximal embrasures of the mandibular posterior teeth.
5. Occlusal contact between the lingual cusps of maxillary dentition and occlusal contact of the buccal cusps of the mandibular dentition with their complementary arches' marginal ridges/fossae.
6. Proper buccal overjet in the posterior segments and proper mandibular incisal edge contact with the lingual surfaces of the maxillary anterior teeth.
7. Interproximal contact between adjacent teeth.
8. Proper angulation of the roots of teeth such that they closely parallel each other and are perpendicular to the occlusal plane, allowing sufficient interradicular bone between adjacent teeth.[71]

What is the ideal functional occlusal scheme?

Dentists and orthodontists alike both seek to find the ideal functional occlusal scheme for their patients that will provide them with the best opportunity to function in the short and long term in an efficient, sustainable, symptom-free manner. This search has led to many different viewpoints as to which functional occlusal scheme truly is "ideal." Popular functional occlusal schemes include the following:

1. Canine protected occlusion (CPO). Only the canines contact on the working side during eccentric lateral mandibular movements with no nonworking contacts.

2. Group function. Multiple posterior teeth contact on the working side during eccentric lateral mandibular movements with no nonworking contacts.
3. Balanced occlusion. Multiple posterior teeth contact on the working and nonworking sides during eccentric lateral mandibular movements. CPO and group function are the two theories that predominate current thinking, with certain individuals believing that one occlusal scheme is superior to the other.

In order to determine which, if any, functional occlusal scheme is superior, we must look at the relevant literature to practice evidence-based decision making, which is the standard of care. Rinchuse et al. performed an exhaustive and comprehensive review of the literature (172 different books/articles) concerning functional occlusion and found the following:[72]

1. A single type of functional occlusion has not been demonstrated to predominate in nature.
2. CPO as the optimal type of functional occlusion to establish in orthodontic patients is equivocal and unsupported by the evidence-based literature.
3. CPO might be merely one of several possible optimal functional occlusion types toward which to direct orthodontic patients' treatments.
4. Group function occlusion and balanced occlusion (with no interferences) appear to be acceptable functional occlusion schemes, depending on the patient's characteristics.
5. The stability and longevity of CPO is questionable (i.e., as the cusp tip of the canine wears over a patient's life, CPO can change to group function).

Achieving a "realistically ideal" occlusion in adult orthodontic patients

Certain conditions prevalent in some adults may prevent practitioners from achieving the aforementioned criteria that are used to define an ideal static and functional occlusion. These conditions can include skeletal discrepancies, missing/extracted teeth, existing prosthetic appliances (such as dental implants), an altered vertical dimension of occlusion (VDO), and previous or existing periodontal disease.[73] These conditions, along with the patient's level of motivation for treatment, must be taken into account when the pretreatment occlusal goals are set. Thus, determining the occlusal scheme that is "realistically ideal" for each individual patient, based upon their pretreatment condition and motivation for treatment, is vital to developing a treatment plan that can be successfully achieved (Figures 28.42, 28.43, 28.44, 28.45, and 28.46).[73]

In adult patients with significant skeletal discrepancies, growth modification to help correct these discrepancies is not a treatment option. Therefore, the practitioner and the patient are left with two options to help correct the discrepancy: orthognathic surgery or dental compensation. The patient needs to be informed in cases in which the dental camouflage that must be made to compensate for the skeletal discrepancy will result in

Figure 28.42 Malocclusion requiring realistic treatment plan and occlusal scheme.

Figure 28.43 Malocclusion/occlusal scheme right.

Figure 28.44 Malocclusion/occlusal scheme left.

Figure 28.45 Maxillary occlusal malocclusion.

Figure 28.46 Mandibular occlusal malocclusion.

the patient having a less than ideal outcome esthetically and/or functionally so that they can make an educated decision as to which treatment option to pursue (Figure 28.47).

Some adult patients present for orthodontic treatment with multiple missing teeth. There are a very large number of scenarios and treatment options that can present themselves in these situations. The decision on whether to replace or not replace missing teeth will have an effect on the occlusal scheme that the patient will have at the end of treatment, and this must be taken into account during diagnosis and treatment planning to ensure a favorable posttreatment outcome.[20] If missing teeth are to be replaced prosthetically, it is vitally important that the orthodontist is allowed to treat the patient before the placement of the prosthesis to ensure that the prosthesis functions with the patient's postorthodontic occlusion correctly.[20] It is also important for the orthodontist to know the restorative dentist's prosthetic plan so that the most ideal occlusal relationship can be created.[20]

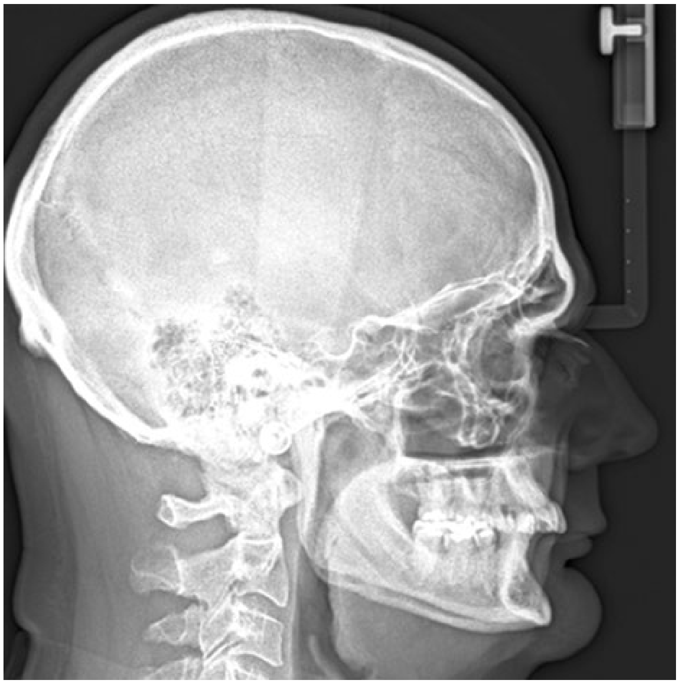

Figure 28.47 Adult Class II skeletal malocclusion. Treatment options: orthognathic surgery or dental compensation.

Many types of dental restorations are more prone to failure during excursive, nonaxial loading. This should be taken into account when the ideal functional occlusal scheme is chosen for the patient (Figures 28.48, 28.49, 28.50, 28.51, and 28.52).

Many adult patients are presented for orthodontic treatment with preexisting prosthetic restorations, such as fixed partial dentures, dental implants, fixed prosthetic crowns, removable partial dentures, full dentures, and so forth. These preexisting restorations/prostheses may necessitate removal and/or replacement to achieve a more ideal occlusal result. However, the

Figure 28.48 Initial intraoral photographs.

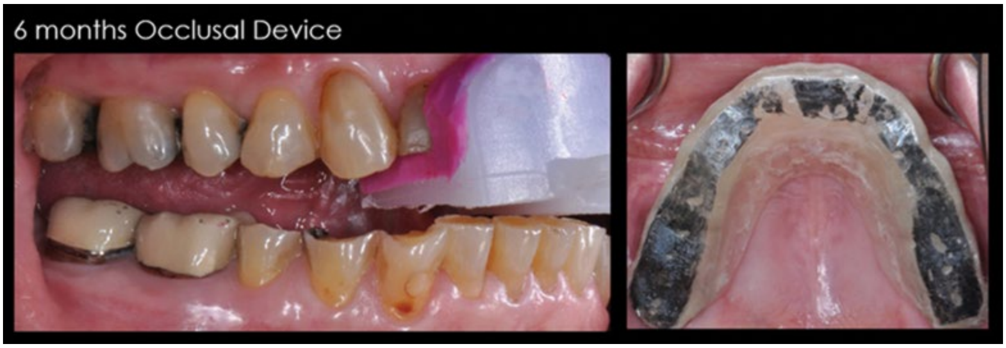

Figure 28.49 Occlusal splint to establish occlusal positioning and treatment goals.

Figure 28.50 Orthodontic treatment progress.

Figure 28.51 Final extra- and intraoral images.

Figure 28.52 Initial and final close-up smile.

Figure 28.53 Adult with altered VDO, severe attrition, and 100% overbite.

benefits of achieving this result must be weighed against the cost that the patient must go through to have these restorations removed and/or replaced. It is our duty as orthodontic practitioners to educate our patients on these issues so that the patient can make an informed decision about which treatment option they would like to pursue.

Adult patients may also present with an increased or decreased VDO. An altered VDO is typically seen due to multiple missing teeth, severe attrition, or an existing dental prosthesis made at an incorrect VDO. In patients that appear to have an altered vertical dimension, a thorough clinic examination with documentation and mounted models is needed. Establishing a patient at the correct vertical dimension or maintaining the vertical dimension if it is correct is of the utmost importance in establishing an ideal occlusal scheme (Figures 28.53 and 28.54).

Periodontal status also must be taken into account when developing the occlusal scheme for adult orthodontic patients.[74] For example, lack of periodontal support around the maxillary and mandibular canines may be an indication to make the patient's functional occlusal scheme group function instead of CPO. Another example would be avoiding a deep overbite with heavy anterior guidance on a patient with significantly compromised periodontal support in the maxillary and mandibular incisors.[74] Also, in adult patients that have had a combination of bone loss and uneven attrition of the posterior dentition, leveling the marginal ridges to meet ABO standards should not take precedence over achieving interproximal bone levels free of vertical defects.[74,75] Therefore, the occlusal relationship that may be achieved postorthodontically may be less than "ideal" when evaluated by board standards to achieve a more favorable periodontal situation.[74,75] For all these reasons, a comprehensive periodontal evaluation complete with vertical bite wings should be performed before establishing the occlusal goals for an orthodontic patient.[75,76]

Tooth size–arch length discrepancies in the adult patient

As one ages, there are notable changes that occur to both the craniofacial complex and the dental arches. Cephalometric studies by Behrents demonstrate that craniofacial growth continues

Figure 28.54 Altered VDO, severe attrition, and 100% overbite treated with an interdisciplinary treatment approach combining orthodontics and restorative.

into adulthood.[77,78] Although the curve of Spee, overjet, and overbite may appear to remain stable throughout adulthood, studies[79–83[84] have found statistically significant decreases in arch width, depth, and perimeter over the course of one's life. Carter and McNamara's results found that these decreases were no more than 3 mm in any one dimension.[79] The etiology for these decrements is unclear; however, the changes appear not to occur independently of each other and are not statistically associated with any one factor.[82] Dr Begg's study of Stone Age human dentition demonstrates excessive occlusal and interproximal wear that contributed to the reduction in arch perimeter.[85] He attributed the excessive wear to the primitive diet of early humans. One may speculate that that a light consistent force from one's musculature or function may cause these arch changes, but Proffit[86] notes that tongue pressure is greater than lip pressure during swallowing and at rest. If tooth position was determined solely by muscular forces from the tongue and lip alone, one would expect an increase in arch dimensions rather than a decrease.

Decreases in arch width, depth, and perimeter all contribute to potential arch length discrepancies that result in crowding, especially in the mandibular anterior region. There are several other hypotheses that attempt to explain the reason behind late mandibular crowding. Some studies have attributed third molars to anterior malalignment, claiming that they exert forces that direct the dentition mesially.[84,87–89] However, later studies showed no correlation between the two.[90–93] Other researchers have suggested that skeletal growth changes can lead to lower crowding,[94–96] but a study by Levin found no significant association between jaw growth and late mandibular incisor malalignment.[97] Tooth morphology and tooth size are other variables that have been studied. Fastlicht[91] concluded that the larger the mesiodistal width of the mandibular incisors, the greater the crowding, but others have shown that the size and the shape of mandibular incisors do not significantly contribute to their alignment.[97,98]

Regardless of etiology, lower, and to a lesser extent upper, malalignment increases with age. The Third National Health and Nutrition Examination Survey (NHANESIII) study used the irregularity index to quantify incisor crowding among subjects. The irregularity index is the sum of the distance (in millimeters) from the intended contact point of one incisor to the adjacent contact point of the neighboring incisor. Data taken from NHANESIII show that 55% of children from age 8 to 11 have well-aligned incisors, while this percentage decreases during adolescence (44%) and further decreases in adults. Only 34% of adults have well-aligned incisors. As one ages, there appears to be about a 50% chance of increased crowding in the maxillary arch, and an 85% chance of increased crowding in the mandibular arch.[86] Furthermore, McNamara and Carter found that males displayed more incisor irregularity than females. However, the change in irregularity throughout adulthood was the same in both sexes.[79]

When evaluating an adult for orthodontic treatment, one must consider four factors involving the total tooth size–arch length discrepancy: (1) arch length/perimeter; (2) curve of Spee; (3) incisor protrusion; and (4) tooth size discrepancies.

Arch length/perimeter

Arch perimeter is defined as the distance between the mesial of the first molars, measuring with the line traveling over the contact points of the posterior teeth and the incisal edges of the anterior teeth. Carter and McNamara found a statistically

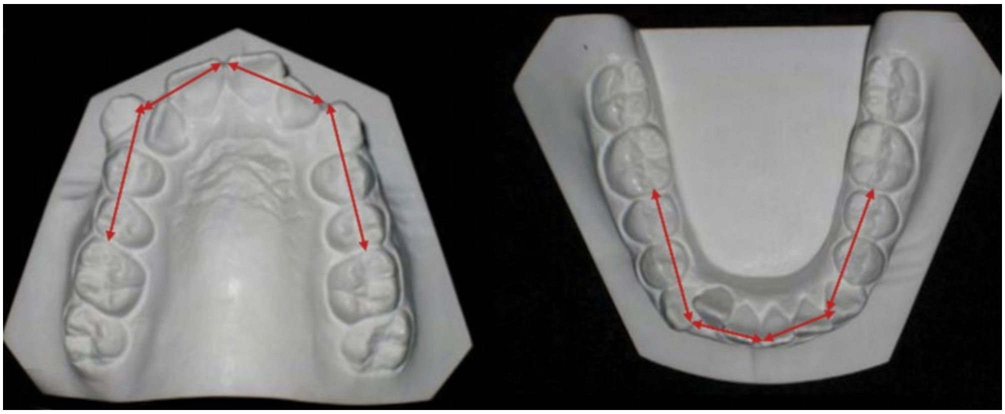

Figure 28.55 Calculating arch perimeter.

Figure 28.56 Curve of Spee.

significant decrease in maxillary perimeter is similar over time for males (1.8 ± 1.2 mm) and females (2.0 ± 1.2 mm); however, mandibular arch perimeter in males decreased significantly more from 17 to 48 years of age (2.4 ± 1.2 mm) than the same perimeter in females (1.7 ± 1.3 mm).[79] Arch perimeter can be estimated by analyzing a patient's dental casts. This is done by dividing the casts into four straight-line segments: the posterior segments are measured from the mesial of the first molars to the mesial of the canines, and the anterior segments are measured from the mesial of the canines to the mesial of central incisors (Figure 28.55). The sum of these four segments is considered as the space available. To calculate the space required, sharpened calipers are used to measure mesiodistal of each tooth mesial of the first molars. Subtracting space available from space required will estimate the amount of crowding or spacing that is present. It is important to realize that this measurement is only one of four factors that helps predict a tooth size–arch length discrepancy. This measurement would only be accurate if the arches had ideal protrusion, minimal curve of Spee, and no apparent tooth size discrepancy, which is seldom the case. Molar distalization is one way to provide space for maxillary crowding.

With the use of miniplates as anchorage, it has been demonstrated that an entire arch can be distalized.[99] Miniplates allow the roots of teeth to be moved more predictably through the alveolar bone without interference of screws. If a greater amount is necessary, extractions of second molars can allow more space for posterior segment distalization, or extraction of premolars so that only the anterior segment has to be moved.

Curve of Spee

The curve of Spee was described by F. Graf von Spee in 1890. He used skulls with abraded teeth to define the line of occlusion as the line on a cylinder tangent to the anterior border of the condyle, the occlusal surface of the second molar, and the incisal edges of the mandibular incisors. Studies show that, as one ages, the curve of Spee remains relatively stable.[79]

A significant curve of Spee is often evident in malocclusions with deep overbites. This curve is frequently leveled as part of overbite reduction and represents a routine procedure in orthodontic practice (Figure 28.56). Clinicians have been concerned for some time with the degree of reduction in arch circumference that accompanies leveling of the curve of Spee because they believe that this leads to incisor protrusion.[100]

One popular rule of thumb for estimating the resulting loss of arch circumference is that 1 mm of arch circumference is needed for each millimeter of curve of Spee depth present.[101] Baldridge[100] and Garcia[101] found the ratio to be more accurately expressed by the formulas $Y = 0.488X - 0.51$ and $Y = 0.657X + 1.34$ respectively, where Y is the arch length differential in millimeters and X is the sum of right and left side maximum depths of the curve of Spee in millimeters. In a mathematical model, Germane et al.[102] determined the relationship to be nonlinear and the arch circumference differential less than a one-to-one ratio for curves of Spee having a depth of 9 mm or less. Woods[103] showed that incisor flaring may be primarily related to the mechanics of leveling the curve of Spee, not necessarily due to the differential in arch circumference. He stated that the reduction of the curve may be achieved through anterior teeth intrusion and/or tip-back mechanics without flaring the incisors.

Incisor protrusion

When incisors protrude they align on a large arc with a greater circumference, creating space to minimize crowding. On the other hand, retroclined incisors, a much rarer occurrence,

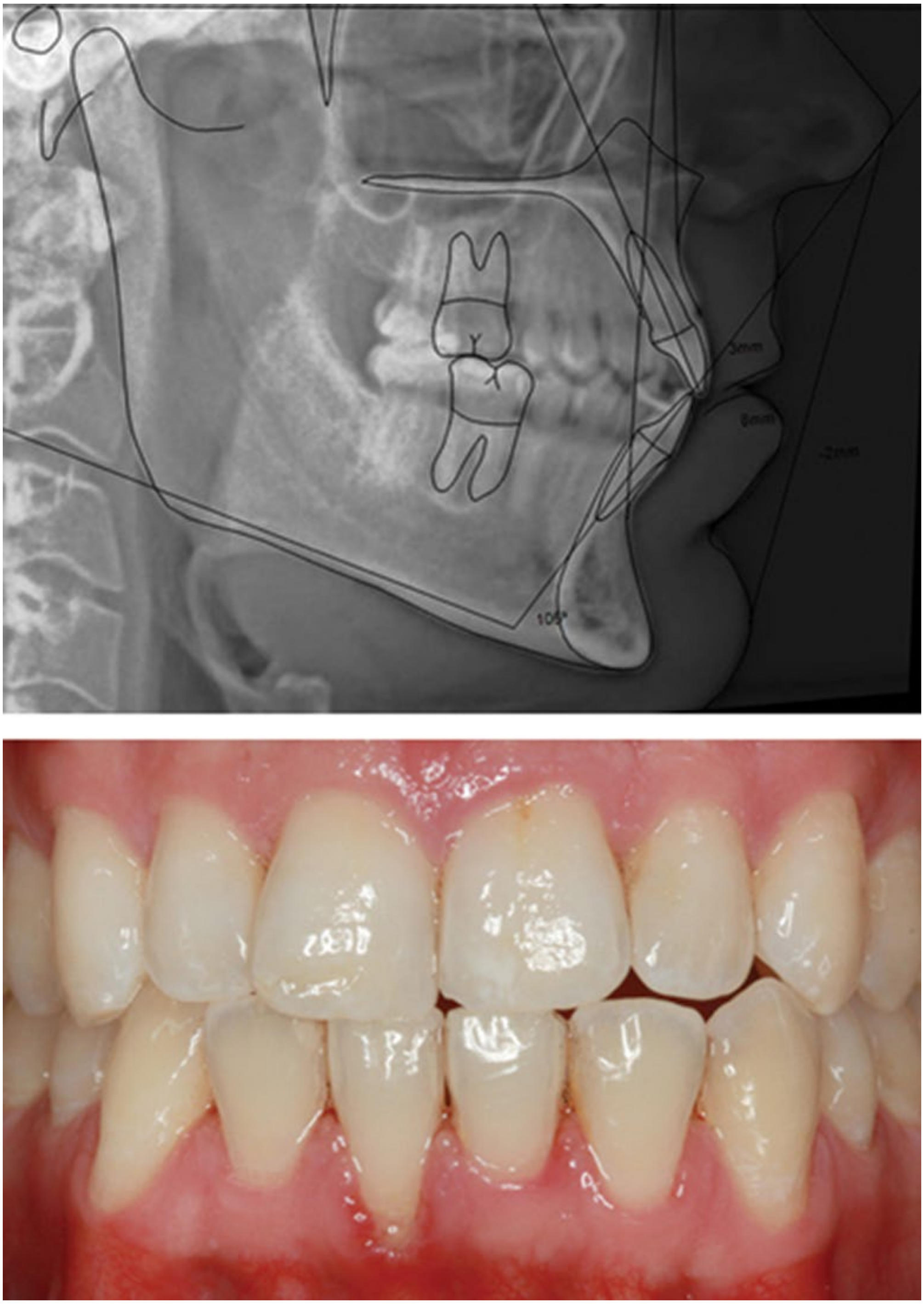

Figure 28.57 Excessive incisor proclination.

decrease arch circumference and increase the likeliness of crowding. Proffit et al.[62] state that "protrusion and crowding are really different aspects of the same phenomenon. If there is not adequate space to align teeth, the result can be crowding, protrusion, or most likely a combination of the two." Therefore, one must be aware of the amount of incisor protrusion to appreciate the results from a space analysis. The amount of incisor protrusion can be determined by cephalometric or facial from analysis. When a clinician decides to procline incisors to create more space within the arch, they must be careful not to do so excessively, which would position the teeth off the underlying alveolar bone. Excessive proclination not only makes proper overjet difficult to achieve, but also increases the likelihood of relapse, and serious periodontal complications (i.e., recession and attachment loss) on the facial aspect of incisors (Figure 28.57).

Tooth size discrepancies

In addition to interarch tooth size discrepancies due to morphology (Figure 28.58) or restorative procedures (Figure 28.59), a patient can also present with interarch tooth size discrepancies. For one to have appropriate interdigitation, overbite and overjet, maxillary and mandibular teeth must be dimensionally proportional to each other. Interarch discrepancies can be found anywhere in the arch; however, Smith et al. found that the mandibular second premolars explained most of the observed differences in the interarch discrepancy, followed by the maxillary lateral incisors, maxillary second premolars, and lower central incisors. Discrepancies in the sizes of these four teeth accounted for approximately 50% of the observed interarch discrepancies.[104]

If interarch discrepancies are not identified before treatment and are not addressed during treatment, compromised results will follow. The most common method used to identify interarch discrepancies is Bolton's analysis. It is performed by measuring the mesiodistal width of each permanent tooth from one first molar to the other. Two standard tables (developed by Bolton, based on his studies) are used to compare the summed widths of the maxillary teeth to the mandibular teeth: one table for the anterior teeth, and another table for the full arch, excluding second and third molars (Figure 28.60). Using both tables together can help identify where the majority of the interarch tooth discrepancy exists, either in the anterior or posterior segments. However, it is important to note that Smith et al. found significant differences in the overall, anterior, and posterior interarch ratios between gender and different ethnicities (whites, blacks, and Hispanics).[104] They found that Bolton's analysis is the most accurate for white females, but suggests that population-specific and male standards are necessary for clinical assessments.[104] Furthermore, they found that the larger the maxillary arch segment length, the greater the discrepancy between Bolton's ratios and the actual ratios. Other methods used to identify interarch tooth discrepancies, which are rarely used, include Kesling's diagnostic setup, Howes' ratio of canine fossa width to total maxillary tooth width, and Neff's anterior coefficient.[105–108]

Figure 28.58 Interarch tooth size discrepancy due to amorphous morphology of the maxillary incisors.

Figure 28.59 Interarch tooth size discrepancy due to restorative procedures.

Tooth deficiencies are corrected restoratively with direct composite, veneers, or full-coverage crowns, while tooth excess is corrected by judicious interproximal stripping. When treating adult patients, the clinician must be aware of the patient's previous restorative procedures (i.e., overcontoured crowns/restorations) that may create Bolton's ratios that appear to be out of balance. When a patient presents with missing teeth, their contralateral equivalents, assuming they are not extensively restored, may be measured and used for Bolton's analysis. However, this is clearly an assumption and should not be solely relied upon for treatment decisions. The more restorations present, the more difficult it is to accurately assess interarch discrepancies accurately.

In summary, the increased awareness of the benefits of a healthy dentition and appealing smile has motivated adult patients to seek a comprehensive approach to their dental treatment. At the same time, the restorative dentist has also come to appreciate the value of integrating orthodontics into a comprehensive rehabilitative treatment plan. Eliminating unfavorable occlusal relationships, positioning teeth to enhance esthetics and periodontal health, can greatly enhance the overall treatment outcome. The goal of achieving an excellent functional and esthetic outcome can be best achieved with an interdisciplinary treatment approach. This comprehensive/interdisciplinary approach brings together various specialty areas of dentistry and their respective recent advances, which greatly benefits the patient and the interdisciplinary team.

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Bolton's Tooth-size Relationships			
Maxillary anterior sum of 3–3	Mandibular anterior sum of 3–3	Maxillary total sum of 6–6	Mandibular total sum of 6–6
40	30.9	86	78.5
41	31.7	88	80.3
42	32.4	90	82.1
43	33.2	92	84.0
44	34.0	94	85.8
45	34.7	96	87.6
46	35.5	98	89.5
47	36.3	100	91.3
48	37.1	102	93.1
49	37.8	104	95.0
50	38.6	106	96.3
51	39.4	108	98.6
52	40.1	110	100.4
53	40.9		
54	41.7		
55	42.5		

Figure 28.60 Bolton's analysis.

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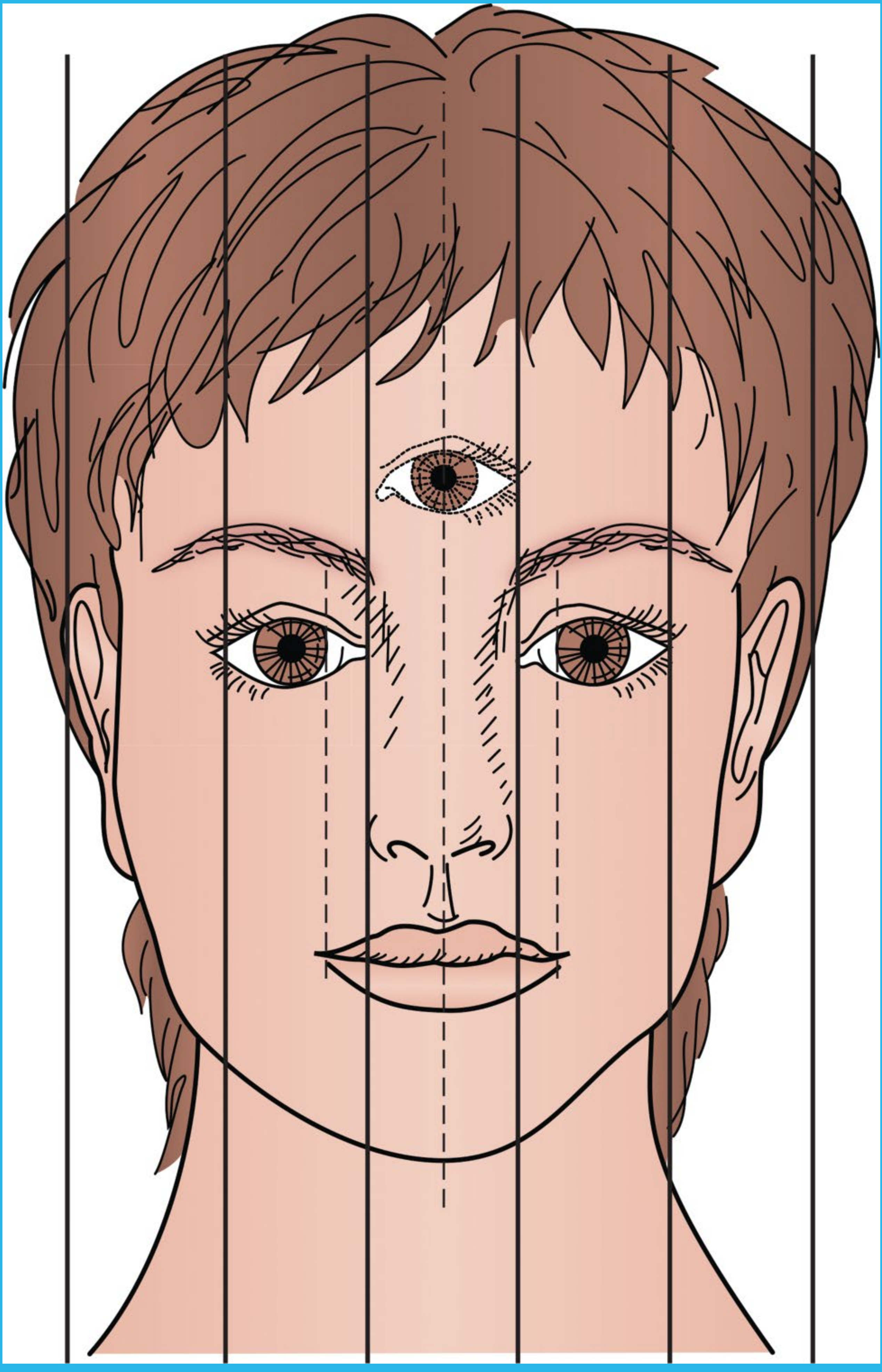

Chapter 29 Surgical Orthodontic Correction of Dentofacial Deformity

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Dentistry has become more aware of the relationship between the dentition and the facial bones, and its impact on facial appearance. The precise, artistic work of the esthetic restorative dentist can be enhanced by orthodontic and surgical optimization and rejuvenation of the facial hard- and soft-tissue framework for the dentition. Such things as abnormal muscle function, lip incompetence, a variety of occlusal problems, and disturbances in facial bone growth contribute to facial disharmony. Today, the recognition and demand for correction of malocclusion and abnormal facial contour in adults are a significant topic in the practice of dentistry and in the specialties of orthodontics and oral and maxillofacial surgery. It is essential that all practitioners continually update their knowledge of the expanding treatment options provided by general dentists and specialists alike.

From the turn of the 20th century through the 1950s, the treatment of dentofacial abnormalities was limited largely to correction of mandibular prognathism by osteotomies of the ramus or body of the mandible. During the following decade, owing to the pioneering efforts of Hugo Obwegesser and other European

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surgeons, surgical procedures were developed to correct mandibular retrognathism, chin deformities, and excessive maxillary growth. Since that time, numerous procedures to treat the entire spectrum of dental, skeletal, and soft-tissue abnormalities have been developed. Optimal esthetic and functional results are now obtainable for all patients with a variety of occlusal and facial defects, as seen in various textbooks today (and in books no longer in print, such as those by Hinds and Kent; Satorianos and Sassouni; Bell, Proffit, and White; Epker and Wolford; and Epker and Fish). Significant clinical and basic science research articles in the oral and maxillofacial surgery and orthodontic literature continue to provide outcome analyses of traditional orthodontic and orthognathic procedures and innovative progress in areas such as adjunctive soft-tissue procedures and evaluation of emerging biomaterials. The introduction of rigid fixation principles with bone plates and screws in the 1980s has eliminated intermaxillary fixation (jaws wired shut) in the large majority of patients. Applications in the 1990s of distraction osteogenesis and continued advancement of these devices offer innovative solutions to difficult deformities. Applications include single jaw distraction, combined maxillomandibular distraction, and mandibular widening.

Unquestionably, some dental malocclusions do not need concomitant orthodontic and surgical procedures and will respond nicely to either modality alone. However, most skeletal malocclusions are too severe to be treated by either specialty alone. A successful outcome that remains stable for the long term often requires a multidisciplinary approach. Following an appropriate diagnosis, the restorative dentist, orthodontist, and surgeon must evaluate the patient and then together formulate a comprehensive treatment plan, clearly communicating the proper sequence for the satisfactory completion of all dental, orthodontic, and surgical procedures. Communication among all parties involved must continue throughout treatment and long-term follow-up. This chapter presents the sequence of events the patient will encounter, including the examination, case presentation, orthodontic treatment, surgical procedures, and follow-up management. Finally, a detailed description of common dentofacial abnormalities is presented in a problem-oriented fashion with illustration of treatment results.

Facial esthetics

The planning of corrective surgery for dentofacial deformities is surely one of the best examples of the interaction of art and science in the field of dentistry. Although it has been often said that beauty is skin deep, understanding facial esthetics requires an in-depth knowledge of how subcutaneous fat, muscle tone, and particularly the underlying supporting skeleton combine and interact to produce the facial appearance.

Modern concepts of facial esthetics, especially in America, are influenced by classical ideals. As professionals, we must strive to be objective in our analysis and planning but must also be aware of cultural biases, physical and racial characteristics, and, most importantly, the patient's desires. The evaluation of the face must be critical of form as it relates to function. Treatment should never alter one to the detriment of the other. In an attempt to evaluate facial form, there are five significant factors that should be considered objectively: age, body type, race, symmetry, and proportion.

Age

The age of a patient is an important determinant of facial form. Underlying skeletal structures are not fully expressed until late adolescence. In adults, there is relative stability of the facial skeletal structure; however, during the aging process, generalized demineralization of bone occurs, which can have subtle effects on form. The distribution of subcutaneous tissue shifts with age, particularly with changes in fat deposits that may result in ocular, temporal, and buccal fat loss and accentuation of the underlying skeletal structures. The skin loses elasticity and begins to wrinkle and sag. Hair may recede, thin, and gray. Dimensional changes can also occur with the loss of teeth and associated alveolar bone.

Body type

Body type relates to age and sex and is generally reflected in facial form. Basic body types include ectomorph (asthenic) types who are thin and angular, mesomorph (sthenic) types who are well proportioned and square, and endomorph (pyknic) types who are heavy set and rounded. Proper relation of facial form to body type is essential for desirable balance.

Racial characteristics

Racial characteristics are increasingly important in today's society. These qualities should be appreciated and should not limit the achievement of esthetic improvement in facial reconstructions. Asians will tend to have rounded faces, and their profile will be straight or slightly concave without defined anterior projection of the zygomas, nasal dorsum, or chin. Those of African origin will tend toward a convex profile with a flat forehead and nasal dorsum juxtaposed with bimaxillary dental alveolar protrusion, prominent lips, and a less-defined chin. Northern Europeans, after whom most cephalometric norms were developed, tend to exhibit a straight or slightly convex profile with a defined anterior projection of the nose, zygomas, and chin.

Symmetry and proportion

The last two factors, symmetry and proportion, are most easily discussed together; also more readily lending themselves to quantification than all five factors listed. Soft- and hard-tissue measurements are recorded in the frontal and profile views, and the treatment can be designed to maximize the esthetic end result.

On frontal view, the face can be divided vertically into thirds (Figure 29.1): the upper third is from the upper hairline to the glabella, the middle third is from the glabella to the subnasale, and the lower third is from the subnasale to the menton. A one-to-one ratio indicates ideal esthetic proportions. The lower third can further be divided in half, with the division at the vermilion

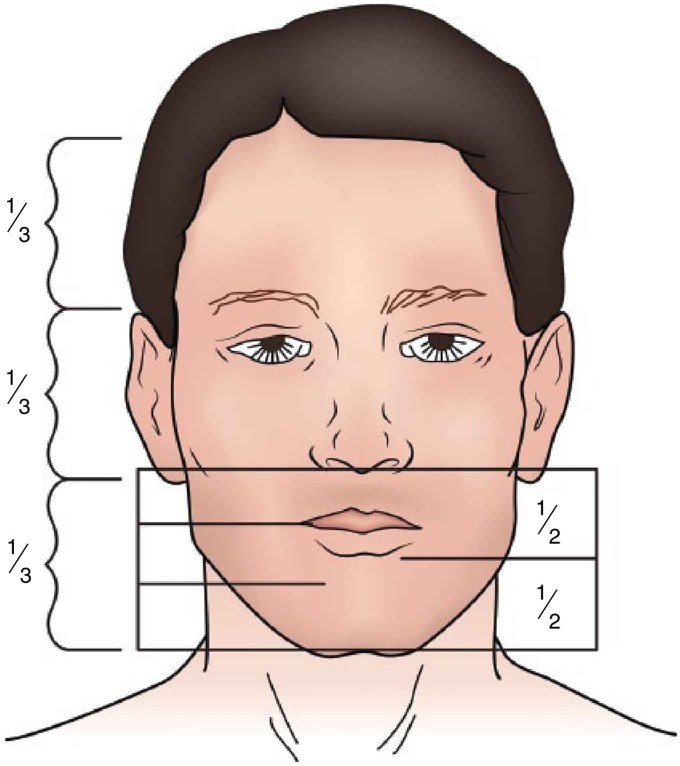

Figure 29.1 Frontal view of the face. Upper, middle, and lower thirds are delineated. Lower third is further divided into halves and thirds.

border of the lower lip, or in thirds, with the upper third ending at the oral commissure (see Figure 29.1).

The smile line is also evaluated on the frontal view. The patient is first evaluated with lips in a relaxed position (or repose); 2–4 mm of the central incisors should be visualized in this relaxed lip position. As the patient is asked to smile, generally 10–12 mm of incisor display is seen. There are minor differences for male and females. Generally, females will tend to show more tooth display both at repose and animation. Note excessive display of incisors and gingiva and corrected normal display in Figure 29.13A and B.

Symmetry and proportion can be judged on frontal examination by dividing the face into fifths, with each fifth being equal to the eye width (Figure 29.2). Midline points should lie on an axis, dividing the face in half, and all paired facial structures should be nearly equidistant from this axis. The intercanthal distance should be one eye width and should correspond to the width of the alar cartilages. The oral commissures should lie on vertical axes tangent to the medial limbus of each eye, and the distance between each axis should be 1.5 times the width of the eye (see Figure 29.2).

Additional proportion evaluations are evident on profile examination. Nasal projection can be judged by the nasofrontal angle (115–130°), the nasofacial angle (30–40°), and a nasomental angle (120–132°). Using a vertical line from the glabella to the menton, a perpendicular line drawn to the nasal tip should be 55–60% of the distance from the point of intersection to the nasion. The distance from the nasal tip to the subnasale

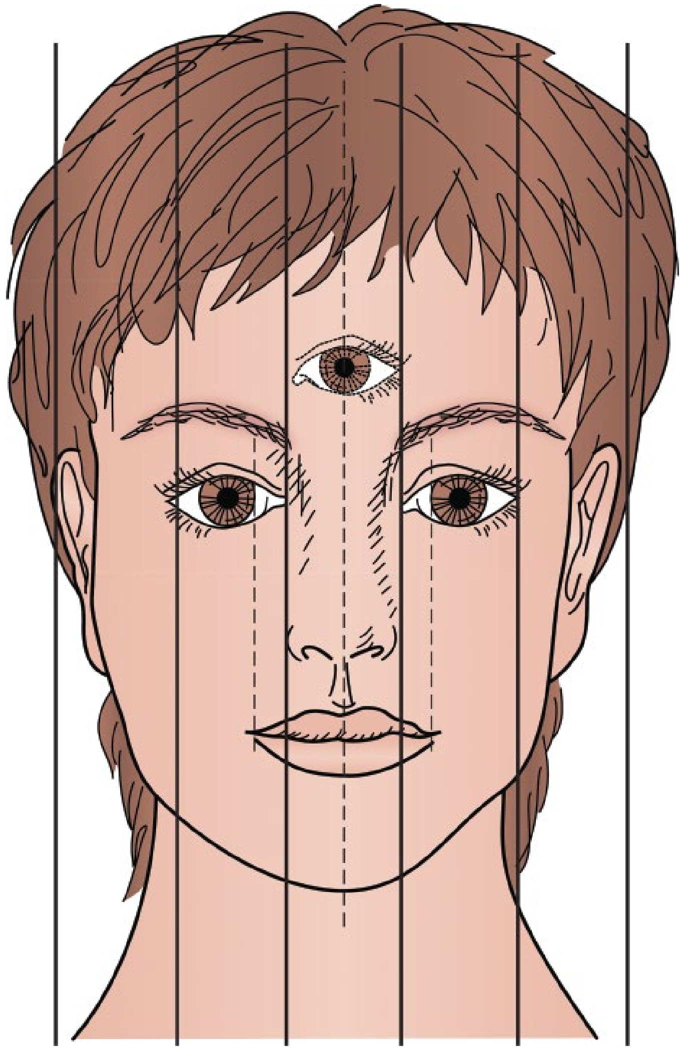

Figure 29.2 Frontal view of the face. Sagittal division of the face into fifths with each fifth equal to one eye width.

should equal the distance from the subnasale to the vermilion border of the upper lip Figure 29.3). Also, on profile examination, the interplay among the lip, chin, and neck can be evaluated (Figure 29.4). The mentocervical angle should be 80–95°. The depth of the labiomental sulcus, measured using a line from the lower lip to the soft-tissue pogonion, should be approximately 4 mm.

The "ideals" described earlier should not be used to establish definitive treatment objectives in all patients. These are only guidelines by which facial harmony may be defined and from which ideas regarding treatment planning may be derived. There are numerous other measures, angles, and analyses that may be used to aid in the diagnosis of a dentofacial deformity. Regardless of what data are collected and which analysis is used, final treatment decisions must be tailored to the individual patient. It is probable that the most important treatment planning information obtained will come from listening to the patient's own treatment goals.

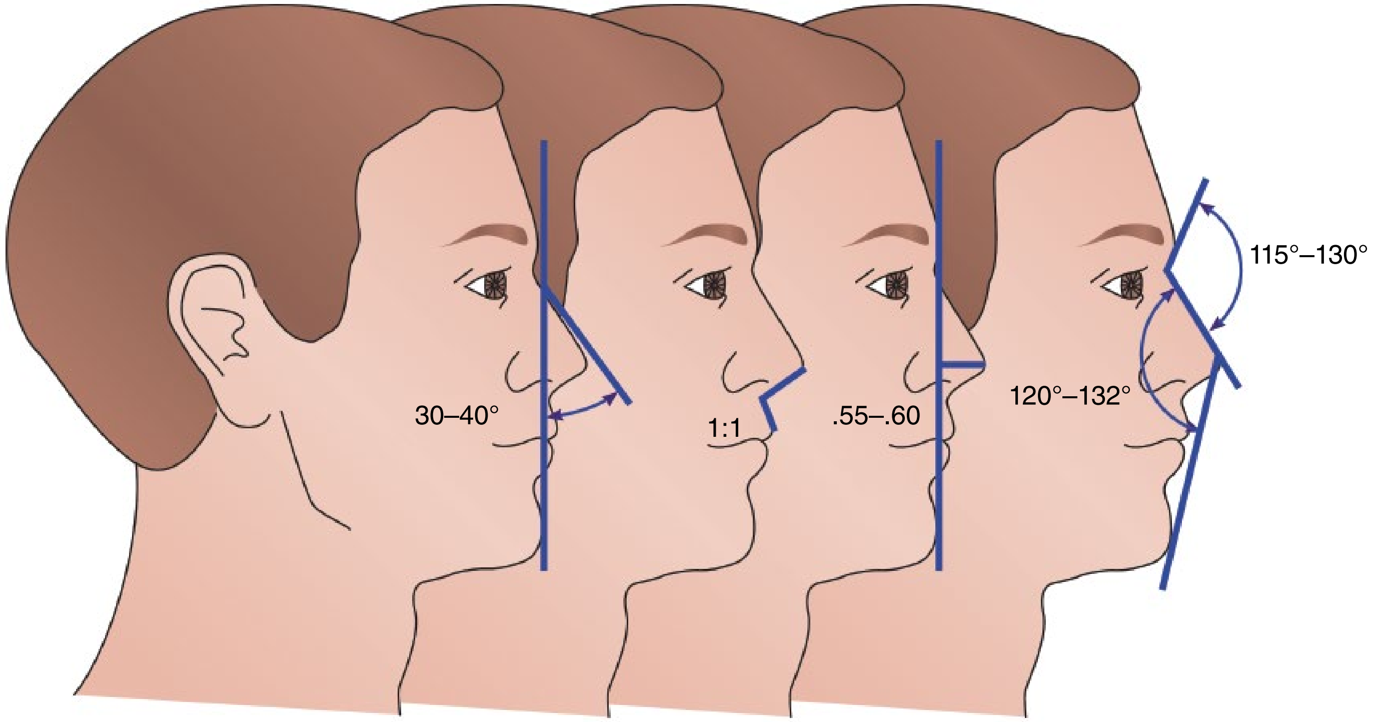

Figure 29.3 Profile views of the face relating the nose to the forehead, lips, and chin. Nasofrontal, nasofacial, and nasomental angles are described, as well as linear measurements of nasal tip projection.

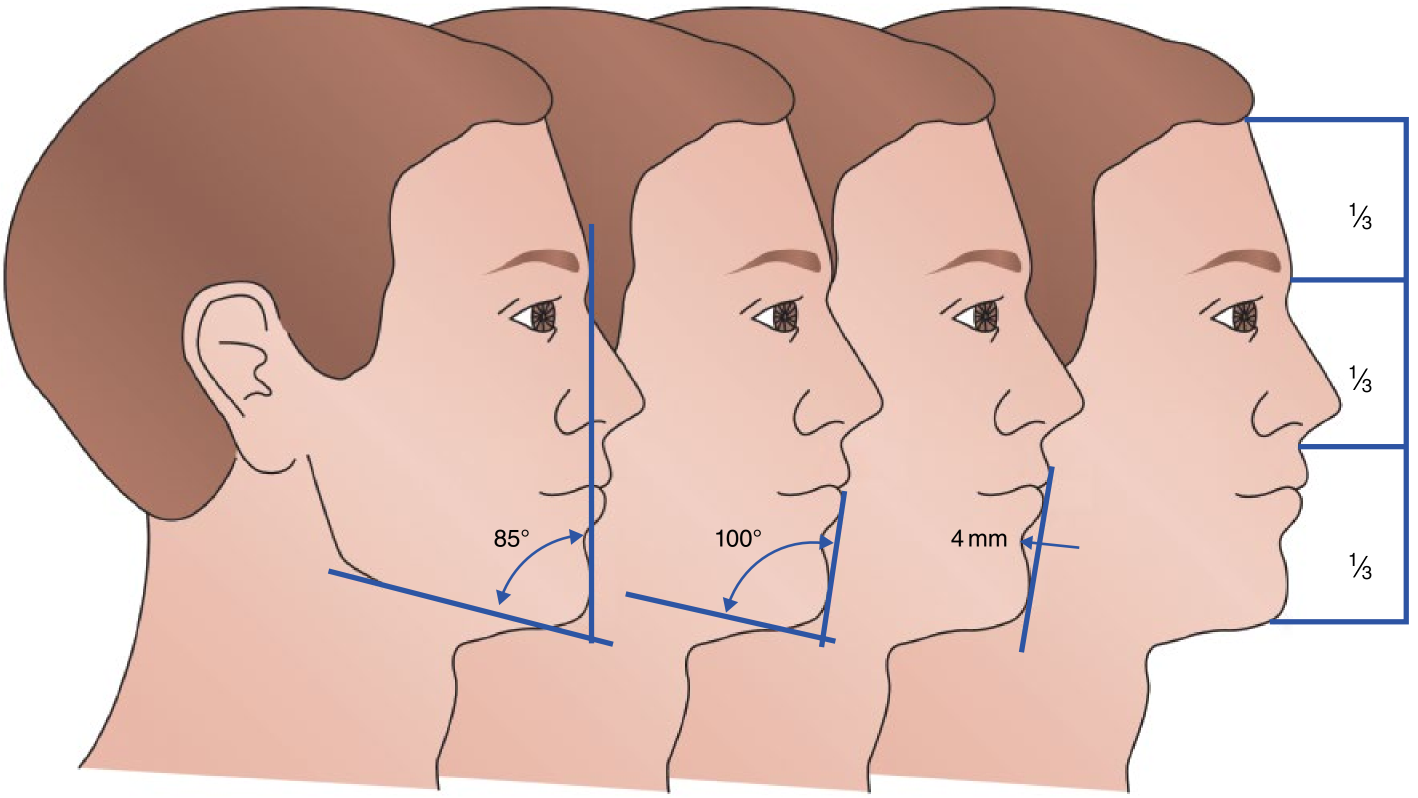

Figure 29.4 Profile views of the face relating the chin to the lips and neck and the labial mental sulcus to the lower lip and chin. The mental cervical angle is described.

Who are the candidates?

Patient expectations

Combined surgical–orthodontic management is a complex process, which requires coordinated efforts among all three dental professionals. Surgical treatment of these dentofacial deformities does not come without risks, costs, and inconvenience. The prospective patient must understand what is involved without "glossing over" the facts. It is especially important to listen to the patient's perception of the problem and then determine what they want to achieve as a result of treatment. If their expectations are inconsistent with their overall behavior, mode of dress, and level of health awareness, questions about their motives should be forthright. If they have a significant deformity and want to be "perfectly normal" or are suffering psychologically, they may be desperately hoping that treatment will enhance their image and success in life. The best possible result of treatment may not satisfy them.

Pediatric patients

In growing individuals, combined surgical–orthodontic treatment is generally avoided. Although most juvenile deformities can be rectified by influencing the growth process, psychological embarrassment or significant impairment of speech and masticatory function may warrant surgical procedures before facial growth is complete. In such cases, it is clearly explained to the patient and parents that further treatment may be necessary. Typically, the surgical phase of treatment is deferred until late adolescence, when growth is complete. Serial hand radiographs are compared to ensure maturation of epiphyseal plates.

The exception to this is the syndromic patient with significant facial deformity. Distraction osteogenesis is increasingly being used to correct deformities in this patient population. Typically, these patients will undergo several orthognathic procedures. The initial procedures such as distraction are aimed at increasing the native airway to eliminate the need for tracheotomies to establish a stable airway. Exciting research in this area is progressing rapidly as innovative applications of distraction are being applied not only to growing patients but also to adults.

Severe skeletal disharmony

There are many adults with malocclusions who exhibit little or no facial disharmony and who can be properly treated with orthodontics alone. However, if a true skeletal imbalance exists, orthodontic treatment cannot achieve proper gnathologic relationships, esthetics, and tooth position over basal bone simultaneously. In cases of severe skeletal disharmony, orthodontic treatment alone usually will not satisfactorily improve the facial profile. In fact, the occlusion may be improved at the expense of the esthetic relationships. The orthodontist should determine prior to initiating treatment whether and to what degree there is a skeletal component to the deformity. In the case of a significant skeletal deformity, the oral and maxillofacial surgeon should be consulted to discuss surgical options.

Adult Class II malocclusions corrected orthodontically are classically treated by extractions in the upper arch only and maximum retraction of the upper anterior segment. With the advent of temporary anchorage devices (TADs), bodily retraction of the maxillary incisors is possible without maxillary posterior teeth moving forward. However, overretraction and flattening of the upper lip need to be considered and are often an esthetic compromise.

Orthodontic treatment of Class III malocclusions can result in severe lingual inclination of the lower incisors and does not correct excess chin prominence. There is little opportunity to bodily retract the lower incisors owing to the very narrow alveolus. In cases where the lower incisors are protruded, extraction of mandibular first premolars along with use of TADs allow for retraction of the lower anterior teeth to establish incisor coupling. Usually, occlusal equilibration is needed to make the Class III molar relationship function well. One of the most difficult factors to overcome is the bilateral posterior crossbites often found with this type. If the midpalatal raphe is patent, it is possible to orthopedically expand the maxilla using "jackscrew"-type devices. Since this raphe will be fused in the late teens or early twenties, many adults cannot be treated with palatal expansion. Compromises will need to be accepted if orthodontics alone is the only alternative.

Since extraction therapy will average a minimum of 18–24 months, many adults will not accept treatment because of the time factor. Some will balk at using headgear, TADs, or rubber bands. Others will insist on wearing ceramic or lingual brackets, making incisor retraction even more difficult.

First visit

The first and most important step for the patient is the recognition that a dentofacial abnormality exists. The patient may have abnormalities in both the maxillary and mandibular regions requiring eventual orthodontic and surgical treatment of both jaws. At this point, the patient should be instructed that additional examination and tests are necessary to accurately locate the deformity and describe treatment possibilities. Each member of the team (general dentist, orthodontist, and oral and maxillofacial surgeon) examines the patient, formulates a diagnosis, and prepares a treatment sequence. The length of orthodontic treatment, types of surgical procedures, cost, and complications cannot be discussed until the diagnostic records are taken and a treatment plan is formulated.

In these days of increased consumer awareness, the orthodontist and surgeon must be scrupulously truthful about all details and risks of proposed treatments even if they cause the patient to decline treatment. When the patient needs and receives guarantees and when the team members are overly enthusiastic, the situation is ripe for mishap. It is common practice to write out in detail a complete diagnostic report citing the treatment modalities and risks and mail signed copies to the patient and other team members. A report such as this, when accompanied by a signed-consent form and signed-prediction tracings, will substantiate a claim that the patient was fully informed and consented to the treatment.

Diagnostic records

To identify the dentofacial deformity and formulate treatment recommendations, diagnostic records usually include a panoramic radiograph, a lateral cephalogram, study casts, and facial, profile, and intraoral photographs. The panoramic radiograph is preferred by the orthodontist and surgeon for assessment of bone size, shape, pathology, and determination of osteotomy sites. The standardized lateral cephalogram is used for performing cephalometric analyses and subsequently making cephalometric prediction tracings. Additional records, such as temporomandibular joint (TMJ) films, frontal cephalograms, and mounted casts, are also used in selected cases. Cone beam computed tomography has become more popular, especially in evaluating asymmetries.

Cephalometric analysis

There are over 300 cephalometric measurements or analyses described in the literature for facial soft-tissue and bony architecture. Even though they provide language by which we communicate, they have limitations. Unavoidable error exists in taking and analyzing the cephalogram, partly because it is susceptible to geometric distortions. The "normal" data to which comparisons are made are derived from "ideal" individuals, and comparisons become less reliable as extremes in skeletal deformity are approached. Neither the cephalogram nor the particular analysis to which the derived data are compared is most important from the diagnostic standpoint—rather, it is how these data correlate with the overall examination and treatment goals. Cephalometrics is more useful for documenting progress and change as the treatment unfolds than for the actual diagnostic process itself. The cephalometric tracing is created utilizing imaging software programs, or acetate paper overlaid on the cephalogram (Figure 29.5A). Changes over time can be compared by superimposing tracings on each other.

Cephalometric prediction tracings

The cephalometric prediction tracing predicts the changes that should occur as a result of orthodontic or surgical treatment. For example, the work-up of a patient with a Class II malocclusion with vertical maxillary excess (VME), mandibular retrognathism, and chin deficiency requires several tracings. Tracing 1 is the patient's existing dentofacial deformity (see Figure 29.5A). An overlay of tracing 2 (Figure 29.5B) on tracing 1 demonstrates maxillary orthodontic tooth movement, superior repositioning of the maxilla by Le Fort I osteotomy, and autorotation of the mandible. Tracing 3 demonstrates the advancement of the mandible by sagittal split osteotomy performed simultaneously with the maxillary surgery (Figure 29.5C). If necessary, a horizontal osteotomy of the chin or a chin implant is placed for augmentation, as shown in tracing 4 (Figure 29.5D). Tracing 5 demonstrates a superimposition of all predicted hard- and soft-tissue changes on tracing 1 (Figure 29.5E). It is important to use the tracings without cephalometric lines, angles, and measurements, which are necessary for diagnostic purposes, as they may be confusing to the patient.

Most orthodontic–orthognathic work-ups today are done with any one of several sophisticated computerized software programs. Digital cephalograms are superimposed on digital lateral facial photographs and captured into the prediction software application. Proposed orthodontic and orthognathic movements are made with the mouse, and the predicted facial form is displayed. Although these visual representations have great value in showing patients what changes can be made, it must be made clear that these are ideal treatment goals. One cannot guarantee that the end result will always be as predicted ideally.

When there are multiple treatment options, it is beneficial to show the patient computer treatment simulations, so that their input can be considered in finalizing the treatment plan.

Figure 29.6A–D shows a patient presenting with a Class III malocclusion. The treatment options are not always clear, and the benefit of diagnostic computer software is that it is relatively easy to do different treatment simulations. When laypeople can compare morphed images of different treatment options, it is easier for them to understand and make informed choices.

Since this patient had a Class III malocclusion that could be treated effectively with different procedures, visual treatment objectives (mandibular set back versus Le Fort I maxillary advancement) helped the patient decide on the best approach to satisfy her individual desires. She liked the fuller midface achieved with the Le Fort I simulation, and that is the treatment approach that was used (Figure 29.6E).

The dental arches were decompensated with a nonextraction treatment plan. Her maxilla was advanced to a Class I dental relationship. The facial changes achieved were more congruent with the patient's needs (Figure 29.6 F–L).

Facial and intraoral photographs

All facial portraits should be of the head in an erect, natural, unstrained posture against a neutral-colored background. Teeth should be in occlusion, with the lips relaxed. For patients with lip incompetence, a second portrait should be taken with the lips closed to depict the amount of lip strain present. Frontal and profile portraits are taken. In Class II deformities, it is helpful for diagnostic purposes to take a second profile view with the mandible postured forward. In Class III deformities secondary to horizontal maxillary deficiency, it is demonstrative to take an additional profile portrait with a layer of gauze under the upper lip. In patients that exhibit a pseudo Class III deformity, a second photograph with the mouth slightly open will help show a more pleasing profile as the mandible rotates downward (clockwise). Facial photographs also include smiling and maximum opening views if hypomobility exists. Finally, photographs of the patient's anterior and posterior occlusion in centric relationship and centric occlusion are taken, as well as occlusal views of the maxilla and mandible denoting arch form.

Study casts

Full-arch casts should be trimmed in centric relation according to the methods described in undergraduate orthodontic textbooks. This trimming is necessary since many of the deformities are "nonocclusions," which cannot be accurately articulated

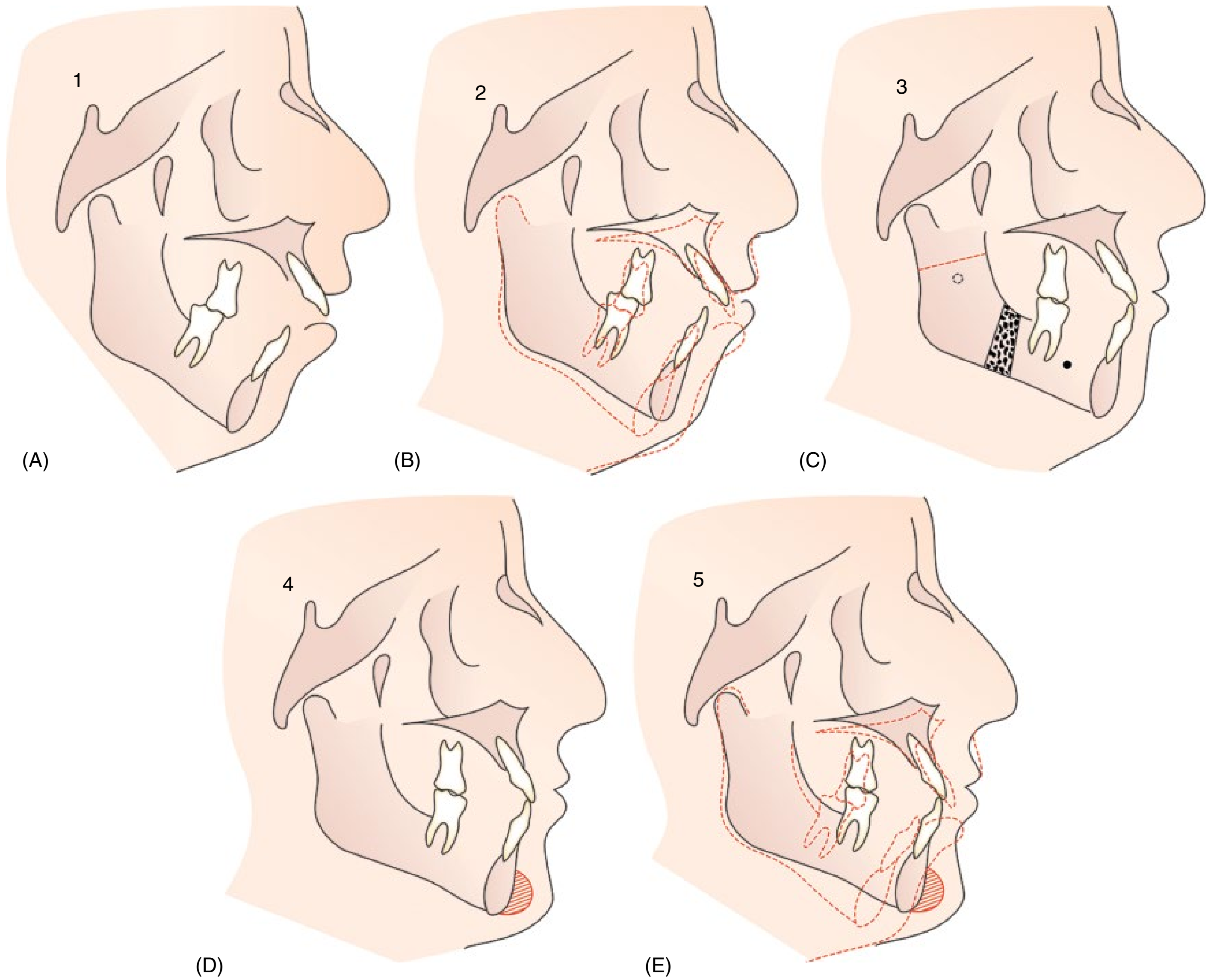

Figure 29.5 **(A–E)** Cephalometric prediction tracing sequence. Tracings 1 through 5 are described in the text.

when the models are held by hand. In severe cases, as well as cases that will undergo significant vertical changes as a result of treatment, mounting of the casts on an articulator with hinge-axis records will be necessary. The decision of precision hinge-axis versus the arbitrary hinge-axis determination is dictated by individual circumstances, such as TMJ deterioration or dysfunction, degree of mandibular autorotation, and obvious asymmetry, among others.

Case presentation visit

Once the diagnosis and general treatment plans have been formulated, the team, consisting of the patient's dentist, orthodontist, and oral and maxillofacial surgeon, renders a final integrated treatment plan. The most effective manner in which to coordinate and present all of this information would be a joint conference among all of the parties involved.

The role of the primary dentist is to coordinate the efforts of the specialists through the diagnostic process and treatment period, since maintenance of the final result will be relegated to them. The general dentist should restore the dentition only to prevent dental emergencies during the surgical and orthodontic treatment. Defective restorations, caries, infection, and periodontal disease must be controlled, and oral hygiene must be monitored. Since the periodontal structures will be challenged during orthodontic and surgical treatment, optimal control and management of periodontal disease should be corrected immediately and monitored throughout the treatment.

It is beneficial to decide at the outset whether conventional orthodontics or a combined surgical–orthodontic treatment plan will be followed. Because of existing skeletal imbalance and facial disharmony, the axial relationships of the teeth are often compromised. For example, lingually inclined lower incisors in mandibular prognathism or labially inclined lower incisors in mandibular retrognathism are naturally occurring dental "compensations" that must be corrected before any surgery is performed. This idealization of the tooth-to-bone relationship will not only enhance the final skeletal–dental balance but will also provide the surgeon with a greater opportunity to reorient the skeletal framework sufficiently to render a substantial improvement in the facial appearance.

Therefore, it is essential that the orthodontist explains to the patient that the presurgical "decompensation" of the dentition accentuates the deformity and can make the malocclusion, facial profile, and speech temporarily worse (Figure 29.7A–F). The patient must understand that this ultimately improves the bony support for the teeth and maximizes the esthetic changes resulting from upcoming surgical procedures.

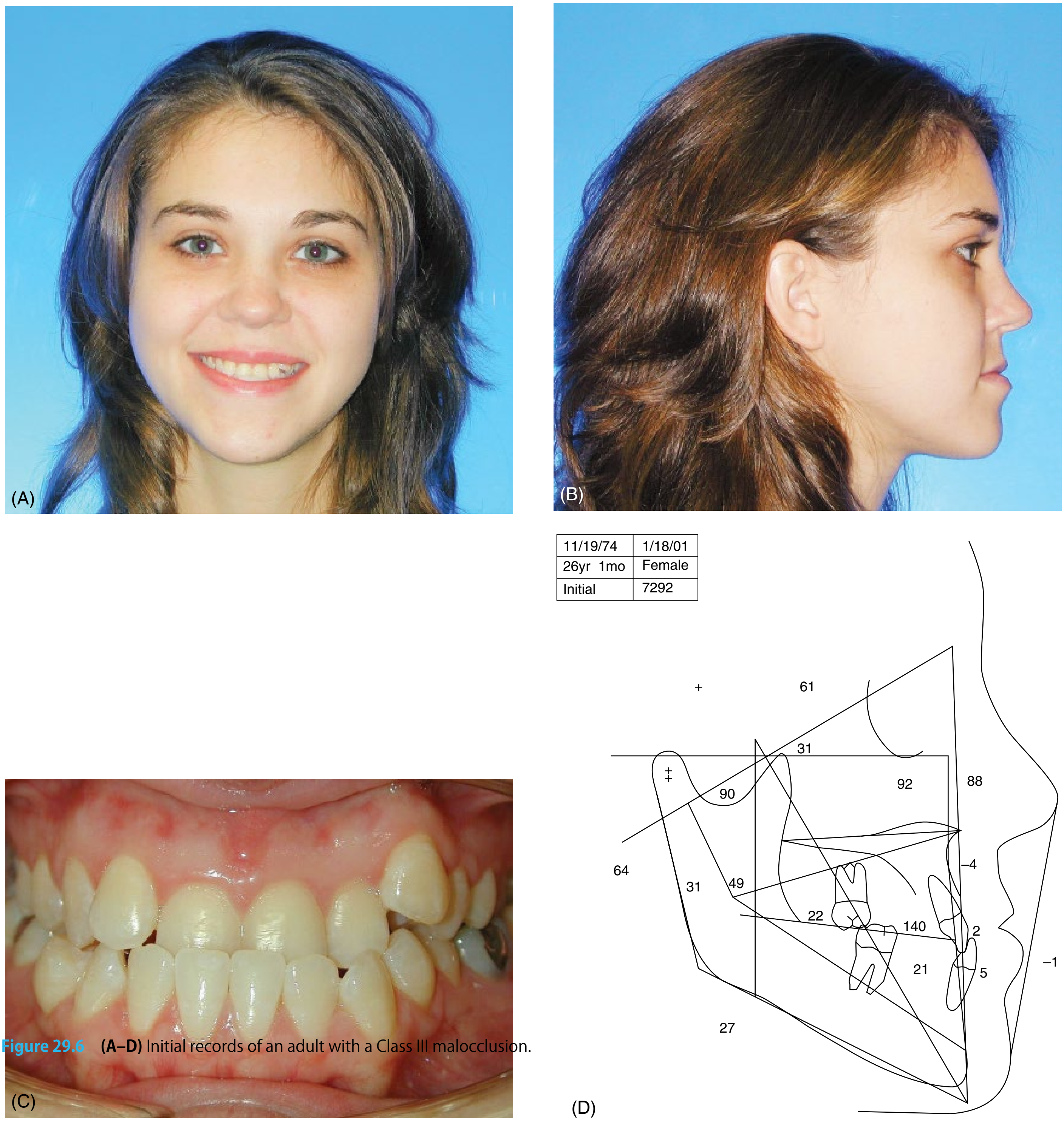

Figure 29.6 **(A–D)** Initial records of an adult with a Class III malocclusion.

In most instances, considerable effort is extended in the presurgical phase to arrange the dental arches so that a nearly ideal occlusion is achieved by the surgical procedure. This will leave

Figure 29.6 **(E)** Initial profile (left); surgical treatment by mandible set back (center); surgical treatment by maxilla advancement (right).

only short-term orthodontic detailing and refinement of the final occlusal scheme postsurgically. This approach offers several important advantages. Once surgery is completed, the patient is usually anxious to be finished. Second, and most importantly, if the immediate postoperative occlusion is stable, then the occlusion is more likely to remain stable for the long term.

Presurgical visit

When it is felt that the presurgical goals of arch alignment have been achieved, a set of progress records consisting of models, a cephalogram, and a panoramic radiograph will be obtained to verify that the patient is ready for surgery. Additional orthodontic treatment may be necessary to satisfy surgical goals.

A week or two before surgery, the patient should visit their general dentist for a thorough prophylaxis and fluoride treatment. The orthodontist will crimp or solder hooks to full-sized passive rectangular arch wires. This gives the surgeon options for intermaxillary fixation or elastics at the time of surgery. Even though the surgeon will be primarily responsible for the care of the patient during the postsurgical healing phase, the general dentist and orthodontist should be available.

Postsurgical treatment

At the conclusion of a 6- to 8-week period, whether intermaxillary fixation (IMF; jaws wired) is used or not, the surgeon will notify the orthodontist that they may begin definitive orthodontic treatment if clinical and radiographic examination indicates satisfactory healing. If bone segments begin to relapse, the orthodontist, working in concert with the surgeon, can nonsurgically reestablish the correct maxillomandibular relationship with elastics.

When occlusal splints are removed, the surgeon instructs the patient in the use of “training” elastics to preserve the skeletal alignment. Orthodontic follow-up as soon as possible is recommended. The orthodontist will inspect the mouth for loose or damaged brackets, wires, and so on. Patients will typically continue the training elastics on a tapering basis for 1–2 months. The surgery wires are removed as soon as the patient is opening comfortably and are replaced with light passive rectangular wires. The objective during and immediately after the surgery is to not produce orthodontic movement and possible surgical relapse. The patient should also be instructed in mobilization exercises to regain the full range of condylar motion. Occasionally, a physical therapy referral will be indicated.

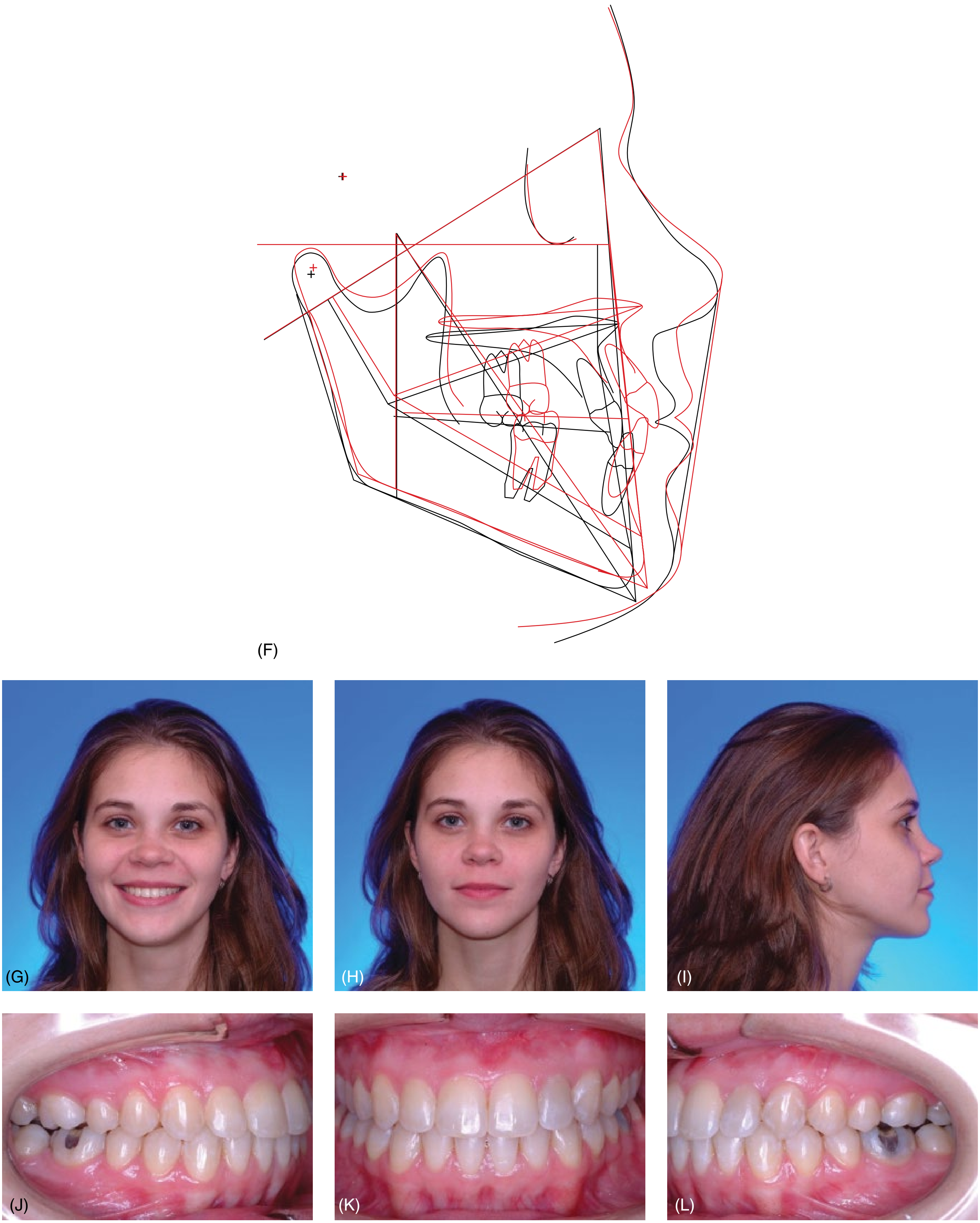

Figure 29.6 **(F–L)** Final records after orthodontics and Le Fort I advancement of the maxilla.

Figure 29.7 **(A)** Correction of mandibular prognathism and Class III malocclusion. Preorthodontic profile of a patient with mandibular prognathism and flat cheekbones.

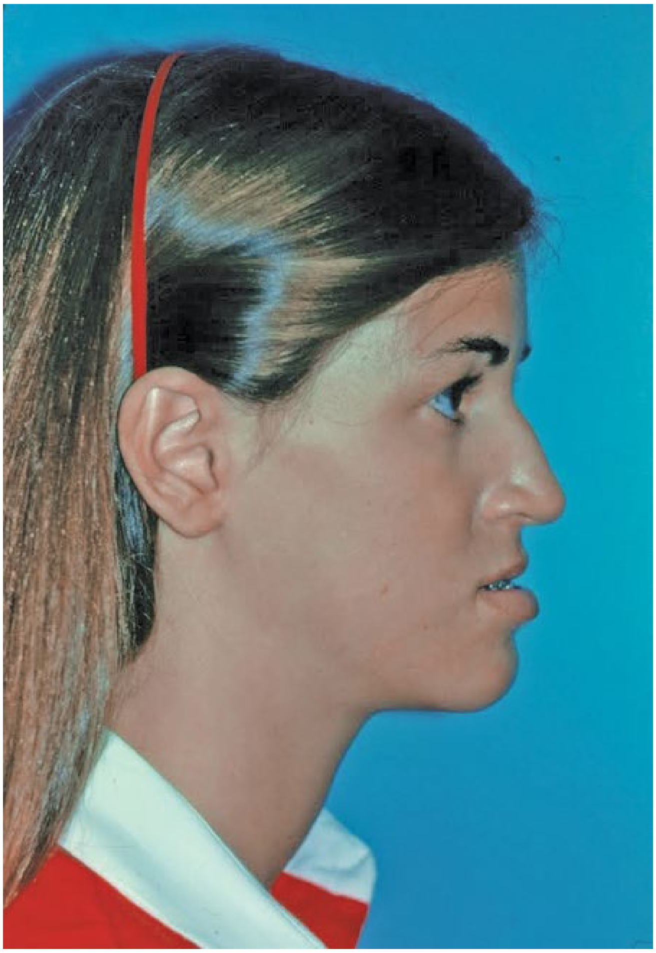

Figure 29.7 **(B)** Postorthodontic, preoperative profile with lower incisors flared to remove dental compensations. Patient intentionally looks worse from orthodontic treatment.

Ideally, the final phase of orthodontic treatment should be straightforward, with most patients completing treatment 4–8 months after surgery. Tooth positioners may be used for a short period after the braces are removed. In open bite cases, a true hinge-axis positioner is desirable. They are usually followed by more traditional retentive devices such as Hawley appliances and bonded lingual wires. Occasionally, a chin-cup is worn at night if relapse or additional growth is anticipated.

Surgical complications and risks

Fortunately, severe complications are rare. Certain surgical procedures carry a higher risk and are discussed in their respective sections. Patients must be adequately informed of these risks, particularly if there is no alternative in the selection of a surgical procedure. Complications, particularly infections, from orthognathic surgery were not uncommon in the past. Today, however, proper selection of surgical procedures, refinement of surgical techniques, improved methods of postoperative fixation with bone plates, control of edema, use of antibiotics, and increased knowledge of the treatment of postoperative infections have resulted in a low incidence of complications.

Injury to teeth

Most common surgical procedures last 2–5 h. The intraoral approach is most common and provides wide exposure of the maxilla and mandible while minimizing facial scars. An exceptional case may require an extraoral approach, particularly when mandibular bone grafts are used. Injuries to the teeth can occur with segmental alveolar osteotomies. With preoperative widening of the interdental space by orthodontics and careful technique, the injury to teeth can be avoided.

Blood loss

Blood loss can be significant during these procedures but is reduced with the increased use of hypotensive anesthesia. Transfusions of blood may be necessary in “double jaw” or more lengthy cases. The technique of autologous transfusion, in which the patient donates blood 2–3 weeks preoperatively, has significantly decreased the incidence of complications associated with transfusions.

Stabilization of operated segments

Stabilization of the operated segments is tantamount to proper healing, prevention of infection, and predictability of long-term stability. Bone segments are stabilized with bone plates and screws. Intermaxillary fixation, routinely required in the past, is now used primarily for cases involving significant mandibular setbacks or if bone plates and screws fail to immobilize jaw segments or are not possible. Early mobilization promotes faster functional bone healing, more rapid return of masticatory function, and facilitation of nutritional maintenance during the early postoperative period.

Postoperative discomfort and symptoms

Postoperative discomfort is generally mild and can be handled with the conservative use of analgesics. Most patients are given a pain regimen not much more significant than third molar surgery. Since there is a potential for significant postoperative edema, it is imperative to have informed the family that the patient may look much worse than they feel. Intraoperative as well as postoperative steriods tend to help manage the postoperative edema. Surgical dietary counseling and the availability of commercially prepared high-calorie, high-protein supplements can minimize weight loss postoperatively and maintain the nutritional balance required for normal wound healing.

Diagnosis and treatment

Common dentofacial deformities are described in terms of their facial, skeletal, and dental characteristics. Treatment sequencing, orthodontic principles, and surgical procedures are now presented as a guide to the most frequently occurring deformities.

Mandibular excess

The facial soft-tissue characteristics of classic mandibular skeletal prognathism or excess are primarily manifested in the profile view (see Figure 29.7A). There is a prominence of the lower lip and chin, a flat mentolabial fold, a normal to slight increase in the lower anterior facial height, a normal to obtuse gonial angle, and an appearance of sallow or deficient zygomas. From the frontal view, an increase in the lower anterior facial height and a flatness or lack of contour in the area of the zygomas and chin is usually evident. Cephalometrically, the point A–nasion–point B (ANB) angle is decreased, whereas the facial angle, sella–nasion–point B (SNB) angle, and the lower anterior facial height are increased. The maxillary incisors are flared, and the lower incisors are lingually inclined. A negative overjet, Class III cuspid and molar relationships, and bilateral crossbites are common. In addition, these cases are generally characterized by severe arch length discrepancies in both arches.

Orthodontically, upper first bicuspids may be removed to correct crowding and flaring of the upper incisors. The lower arch is often treated without extractions, since arch length is gained by tipping the incisal edges forward. This produces proper axial

Figure 29.7 **(C)** Four-year postoperative profile. Surgery included augmentation with cheekbone implants and vertical subcondylar osteotomy (VSO) of the mandible.

inclination of the incisors and fullness in the lower lip (see Figure 29.7B). The resulting worsening of the facial appearance will maximize the facial esthetic result when the mandible is set back by surgery (see Figure 29.7C–F). If mandibular extractions are required, the second bicuspids are usually removed to minimize retraction of the lower incisors. Class II mechanics, or reverse orthodontics, which accentuate the deformity, are often used to achieve these presurgical orthodontic goals. The increase in negative overjet allows for a normal incisor relationship postsurgically and will reestablish a normal mentolabial soft-tissue contour. Bilateral posterior crossbites evident presurgically are usually resolved with the surgical mandibular setback.

At least three variations of prognathism exist. Dentoalveolar prognathism is a horizontal prominence of the lower lip and dentition only. Since the chin is relatively normal in its relation to the upper face, profile prediction tracing of the surgical setback makes the patient appear "chin deficient." Orthodontics alone or alveolar osteotomies are therefore indicated rather than ramus surgery. A transfer of the inferior border may be necessary in bimaxillary prognathism with open bite for graft source and shortening of the facial height (Figure 29.8A and B). Alveolar

Figure 29.7 **(D)** Initial pretreatment Class III malocclusion.

Figure 29.7 **(E)** Final Class I occlusion.

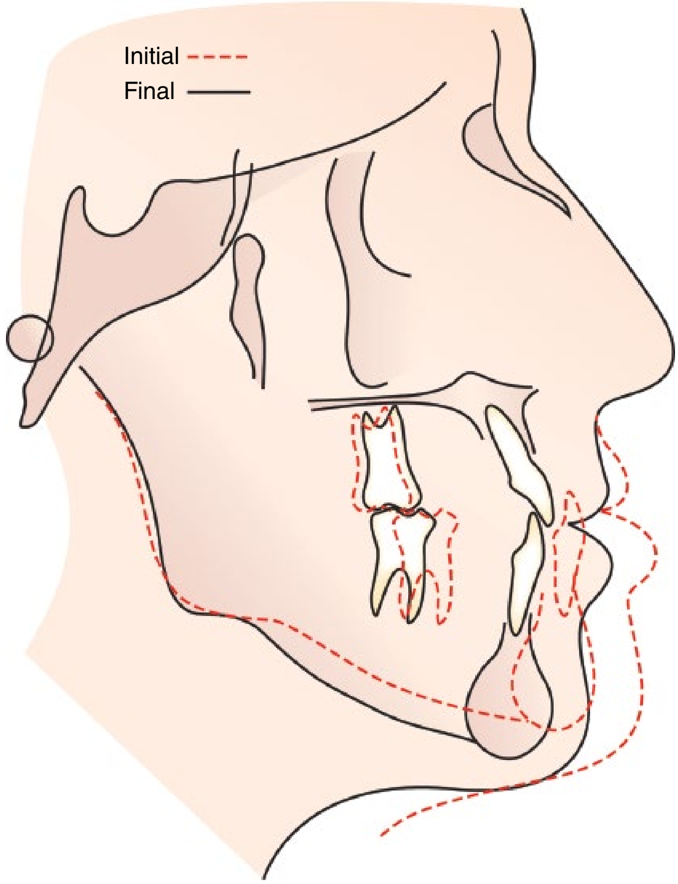

Figure 29.7 **(F)** Pretreatment and final tracing 4 years after surgery.

osteotomies are usually stabilized using splints without IMF. Pseudo or false prognathism is a relative expression of mandibular horizontal excess secondary to a horizontal or vertically deficient maxilla. Correction of the maxillary midfacial deficiency will often obviate the need for mandibular surgery. The diagnosis and treatment are discussed in the section on maxillary deficiency. Prognathism may also be unexpressed in patients with VME. The features of true prognathism become evident when the maxilla is moved superiorly to a normalized position and the mandible autorotates upward and forward.

Surgery for correction of most prognathic cases consists of intraoral osteotomies in the ramus—vertical subcondylar, inverted "L," or sagittal split type. Occasionally, a body ostectomy is indicated. The intraoral VSO or vertical ramus osteotomy (VRO) is performed through a mucosal incision lateral to the midpoint of the anterior border of the ramus extending down to the vestibule opposite the first molar. Subperiosteal reflection of the lateral surface of the ramus and very limited posterior border reflection allow for placement of special retractors. A slightly curved oblique osteotomy is performed with oscillating saws from the anterior sigmoid notch to the angle of the mandible, avoiding the lingual area. The mandible is set back by overlapping of the ramus with the condylar segment (Figure 29.9A–C). The segments are rigidly fixated. Direct wire

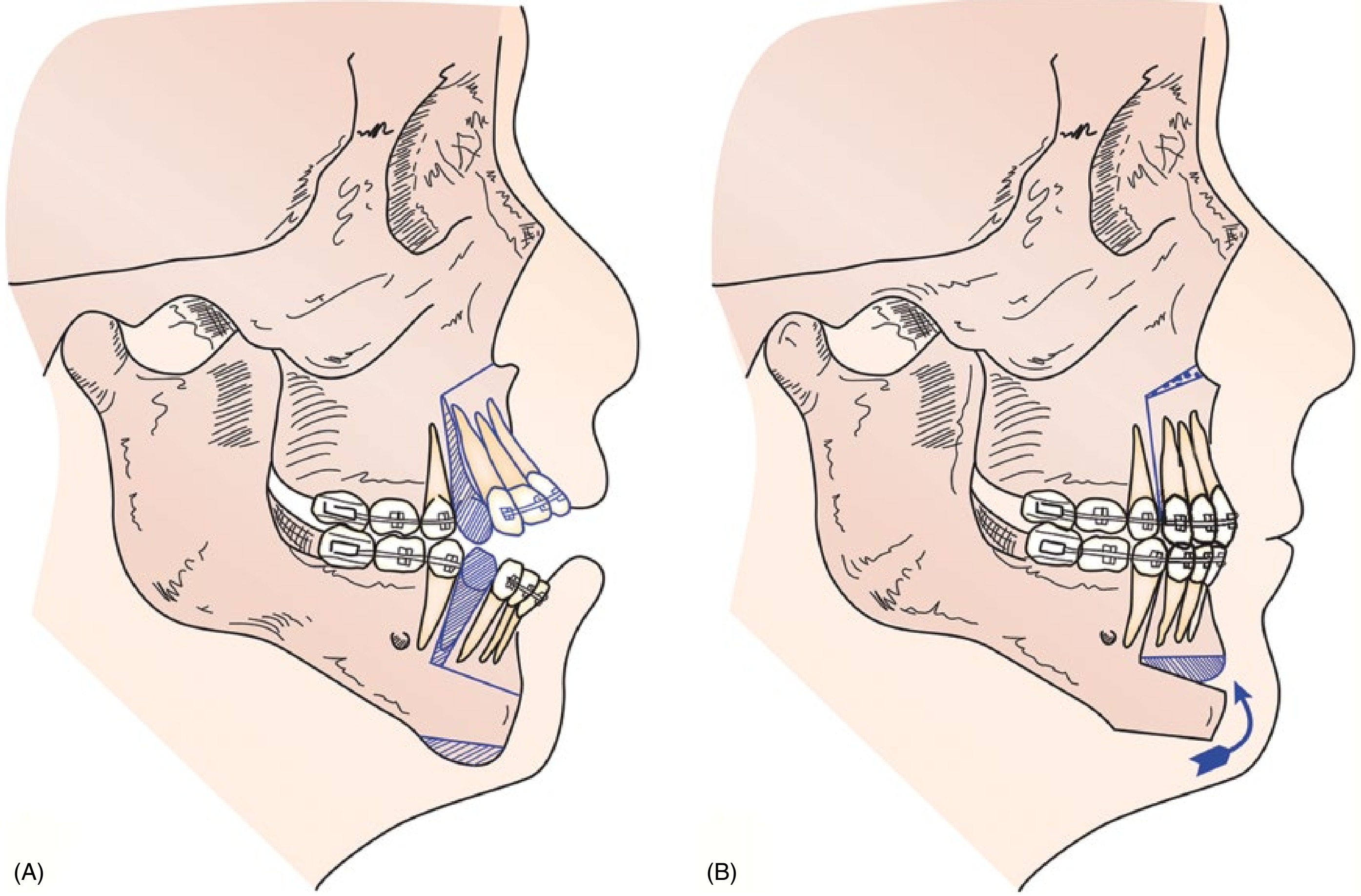

Figure 29.8 **(A, B)** Correction of bimaxillary prognathism, excessive facial length, and open bite by alveolar osteotomies and excision of inferior border.

fixation is sometimes used if bone apposition is questionable or condylar sag is apparent. Intermaxillary fixation with wires or elastics is necessary for 6–8 weeks if rigid fixation is not used. Relapse in the form of a Class III open-bite condition is seen if excessive soft tissue is detached from the condylar segment or if inadequate bone contact occurs between segments. Injury to the inferior alveolar nerve is possible but uncommon. Sensory disturbance associated with vertical ramus osteotomy varies from 0% to 70% with a mean of 9%. The results are usually quite satisfactory with the VRO, a procedure used for over 55 years extraorally and for over 45 years intraorally.

The inverted "L" osteotomy, a modification of the VRO that maintains the coronoid process, is indicated when the ramus of the mandible is lengthened at surgery to close an anterior open bite with prognathism. Bone blocks are wedged along the horizontal cut to maintain the normal condyle–fossa relation. The sagittal split osteotomy, also used for correction of prognathism with or without an open bite, is more frequently used for mandibular deficiency, and the technique is described in the "Mandibular deficiency" section.

The body ostectomy is indicated in unusual and very specific cases of prognathism sometimes seen with open bite that is not attributable to excessive maxillary growth or deep bites. If orthodontics and ramus surgery cannot produce an acceptable Class I occlusion and correct a posterior molar crossbite, a body ostectomy may be indicated. The anterior segment is repositioned according to the ostectomy cut, which may be triangular, rectangular, or stepped. The inferior alveolar nerve may require repositioning to perform the ostectomy. Injury to the nerve during this procedure is possible. Fixation of the segments is with wires or bone plates along the inferior border (Figure 29.10A–C). Mandibular prognathism combined with maxillary deformities such as VME or others may result in extreme deformities requiring surgical correction in both jaws (Figure 29.10C–E).

Mandibular deficiency

In mandibular deficiency, or retrognathism, the soft-tissue characteristics are manifested primarily in the profile view (Figures 29.11A and B and 29.12A–D). There will be a short or normal facial height, a deep or normal labiomental sulcus, horizontal deficiency of the lower lip and chin, but a sometimes adequate chin contour. The maxilla may be normal or slightly protrusive, depressing the lower lip. When the patient protrudes the mandible to a Class I posture, the relative protrusion of the maxillary teeth disappears and the profile view improves. From the frontal view, only the deep mentolabial fold may be apparent (see Figure 29.12A), although often there is evidence of mentalis

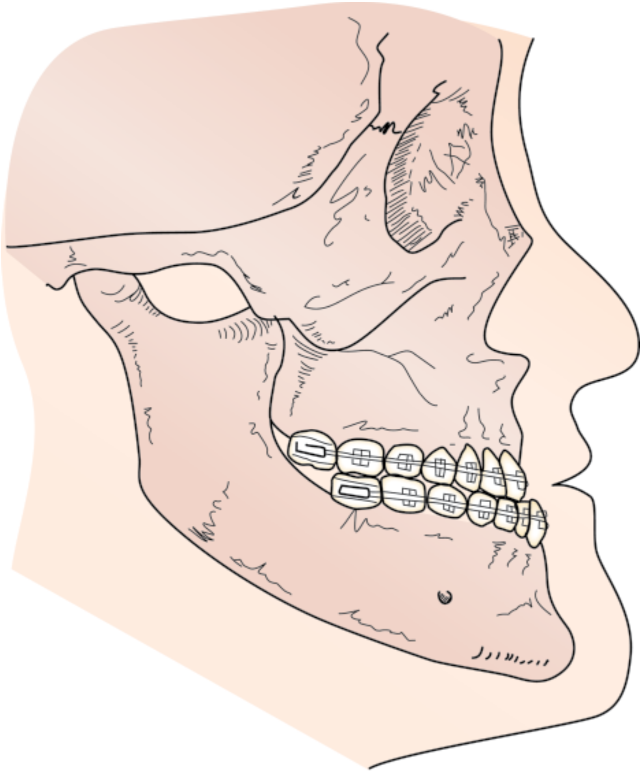

Figure 29.9 **(A)** Profile of hard and soft tissues in classic mandibular prognathism with Class III malocclusion.

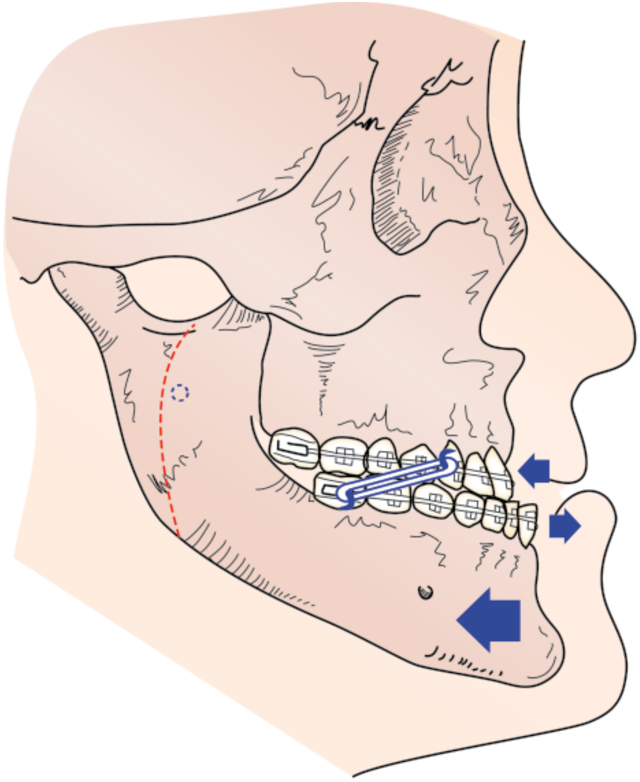

Figure 29.9 **(B)** Preoperative orthodontic tooth movement reverses dental compensations, produces correct inclination of incisors, and worsens facial appearance so that mandibular setback maximizes esthetic results. Note the outline of the proposed VSO.

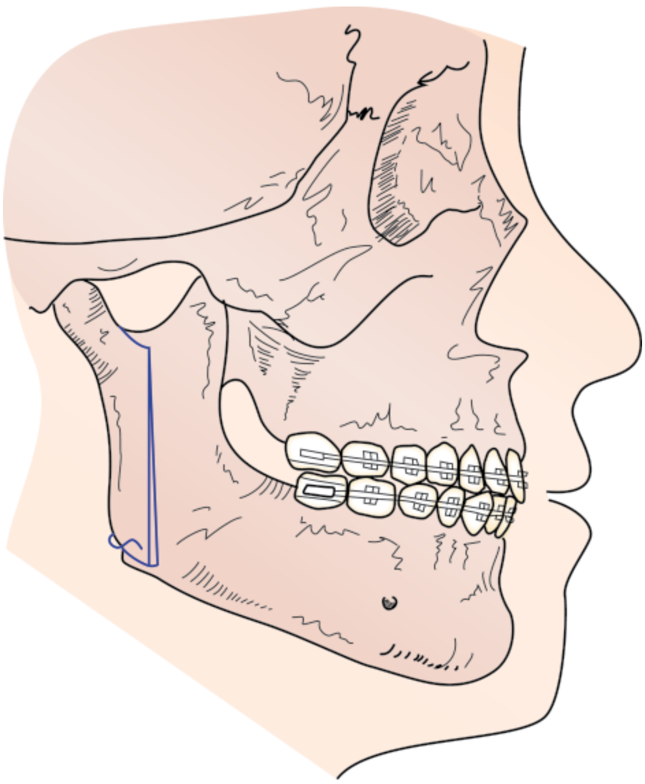

Figure 29.9 **(C)** Postoperative position of mandible and Class I occlusion following VSO.

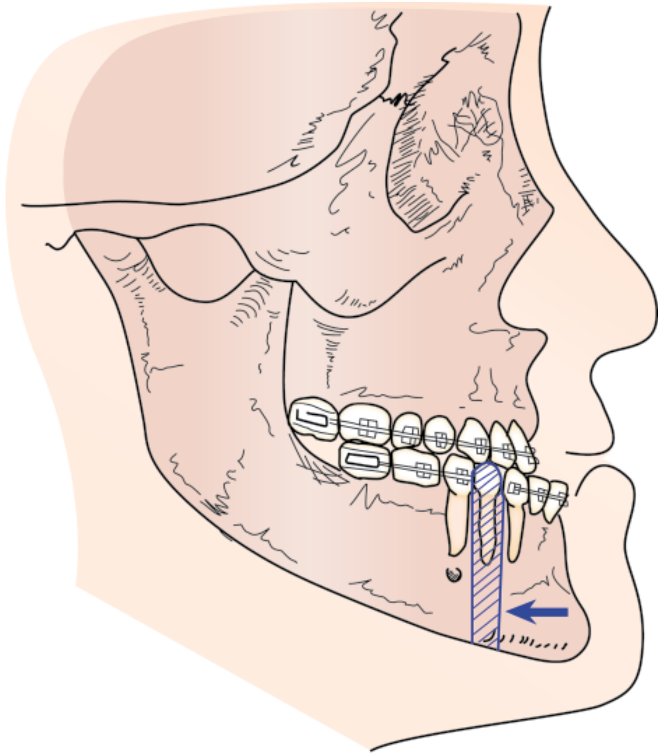

Figure 29.10 **(A)** Correction of mandibular prognathism by body ostectomy through the first premolar site.

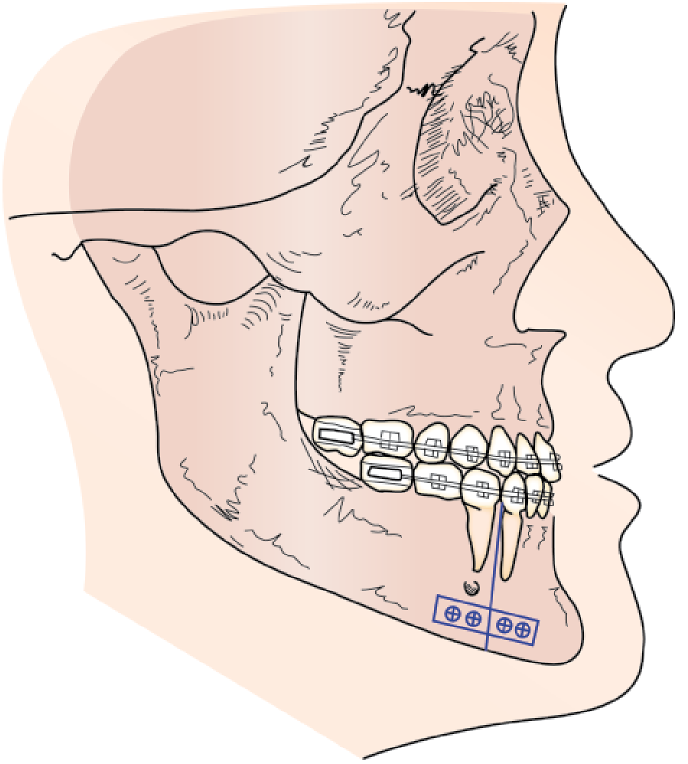

Figure 29.10 **(B)** Postoperative stabilization of the mandible with bone plates.

strain. Cephalometrically, the ANB angle will be increased, the SNB and facial angles will be decreased, and the lower incisors will be protrusive. In Class II, Division 2 types, the maxillary incisors will be retrusive. Dentally, there is an increased overjet, a deep impinging overbite, Class II cuspid and molar relationships bilaterally, and a narrow maxillary arch with transverse discrepancy when the mandible is moved forward.

Orthodontic reversal of dental compensations is necessary to position the teeth over basal bone. The severely flared lower incisors often seen in these cases require lower first premolar bicuspid extractions to achieve significant uprighting. If the horizontal position of the upper incisors is satisfactory, the maxillary second bicuspids may be extracted to exaggerate the Class II molar relationship and minimize the retraction of the maxillary incisors. Seldom are these cases treated with extractions only in the lower arch since Class III molar relationships rarely function well in the occlusal scheme. Class III mechanics are used to retract and upright the lower incisors to the proper axial relationship (see Figure 29.11A). The reciprocal effect of the elastics on the maxillary arch will preclude retraction of the upper incisors, accentuate the overjet, and facilitate maximal surgical advancement of the mandible for improved facial esthetics.

It is preferred to presurgically level the lower arch, although in Class II, Division 2 cases the leveling of the exaggerated curve of Spee, which usually accompanies these types, may be quite difficult. Bite plates are often used to facilitate the leveling. Crowding in the upper arch is usually resolved once the upper incisors have been flared forward to their proper relationship. Class II cases with an acceptable transverse relationship preoperatively may develop posterior crossbites after mandibular advancement. These cases may require significant preoperative maxillary orthodontic expansion or provisions for concomitant surgical expansion of the maxilla.

All surgical procedures for correcting Class II deformities are directed at correcting the majority of horizontal changes with mandibular osteotomies and vertical changes with maxillary osteotomies. Maxillary procedures are as described for VME. The sagittal splitting osteotomy of Obwegesser is by far the most frequently used and time-honored procedure for correction of mandibular deficiency with and without open bite and limited facial asymmetry (see Figure 29.11B). The intraoral incision is similar to that used in the VSO procedure. Soft tissue is detached on the medial surface of the ramus and lateral surface of the body but not the lateral ramus surface. Medial ramus and lateral body cortical cuts are joined with an osteotomy cut along the anterior border of the ramus and external oblique ridge. Splitting of the mandible is performed with wide, thin osteotomes and gentle prying. Visualization of the inferior alveolar nerve prior to final separation is key to avoid injury to the nerve. Detachment of the medial pterygoid muscle usually allows full advancement. When anterior border wiring is used to approximate segments, 6 weeks of IMF are usually adequate because of the large area of cancellous bone apposition. More commonly, rigid fixation with bone screws allows for immediate movement of the mandible; however, patients must still be maintained on a liquid diet for several weeks. Temporary anesthesia of the inferior alveolar

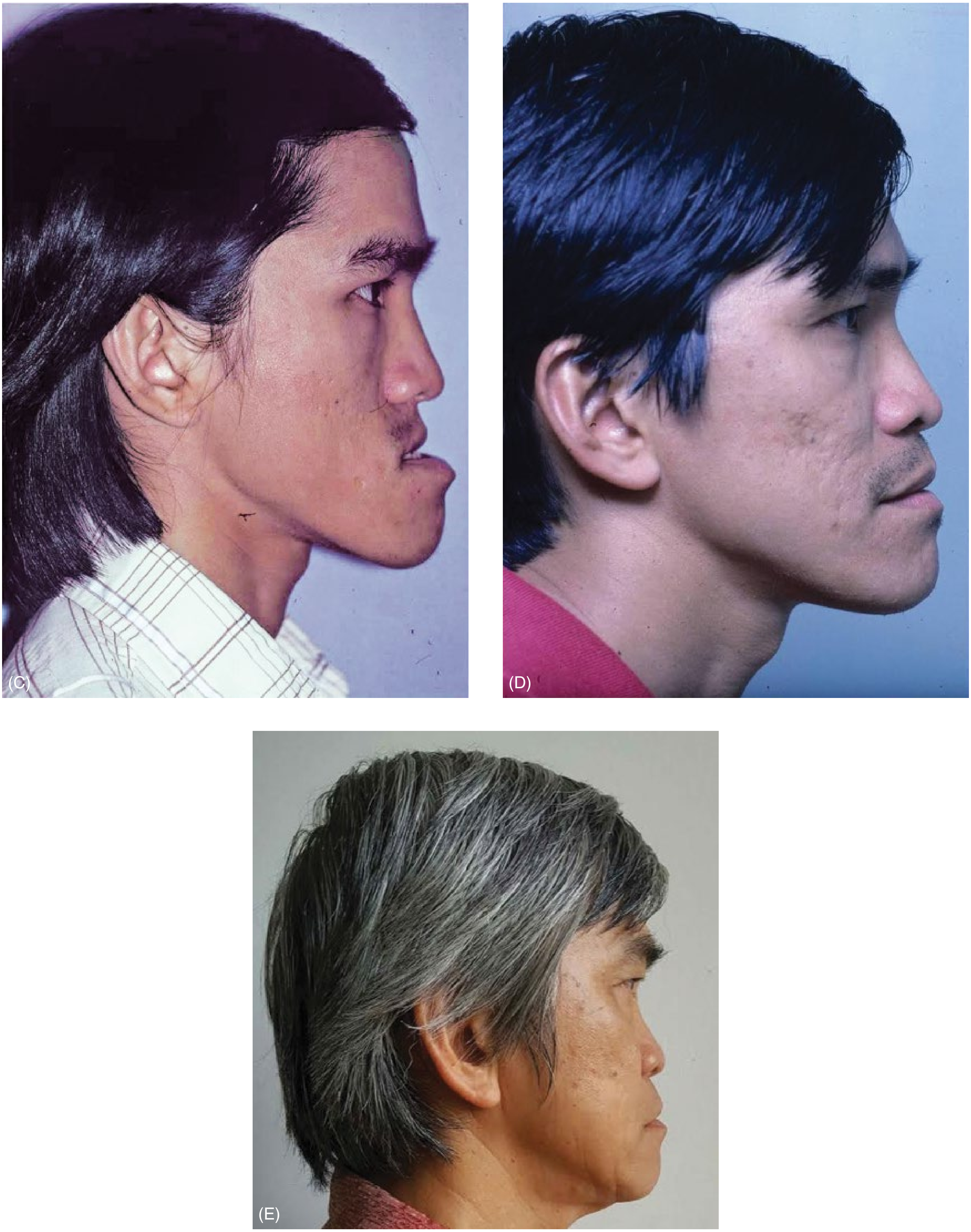

Figure 29.10 **(C)** Presurgical and **(D)** 5-year postsurgical correction of severe mandibular prognathism and maxillary deficiency by body ostectomy of the mandible (setback) and Le Fort I osteotomy of the maxilla (advancement). Postoperative stabilization of the mandible with bone plates. **(E)** The 40-year follow-up.

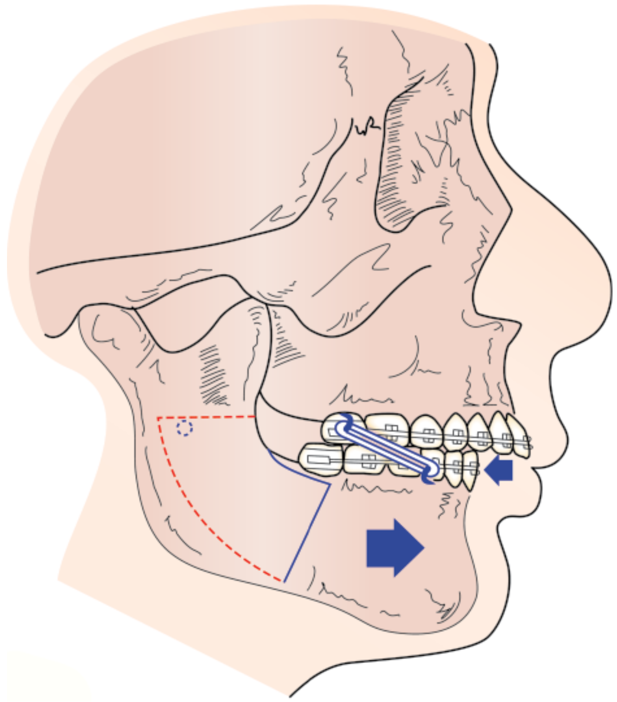

Figure 29.11 **(A)** Profile of hard and soft tissues typical of mandibular deficiency or retrognathism and Class II malocclusion. Preoperative orthodontic treatment reverses dental compensation by uprighting the lower incisors. This permits maximum advancement of the mandible by surgery. Note the outline of the proposed sagittal split osteotomy.

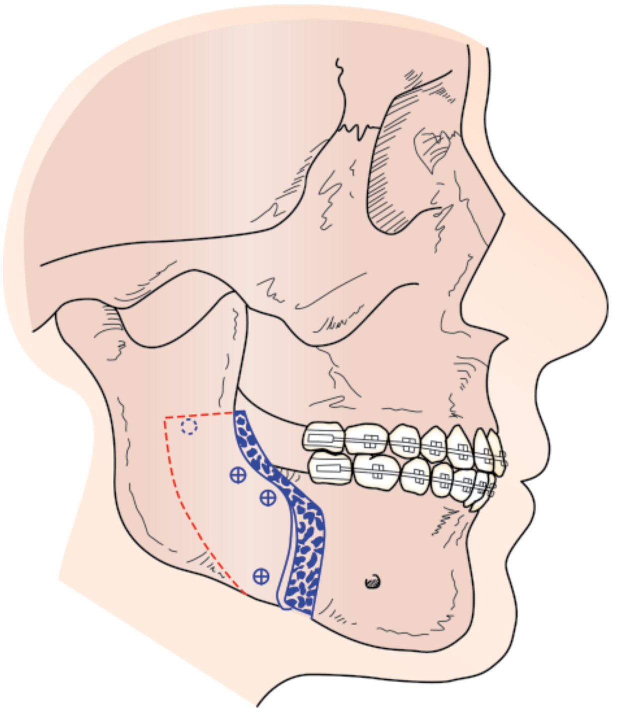

Figure 29.11 **(B)** Mandible advanced by sagittal split osteotomy and stabilized by rigid fixation bone screw technique. Intermaxillary fixation is not required.

Figure 29.12 **(A, B)** Correction of severe mandibular deficiency with microgenia. Preoperative facial appearance. Note that the chin is retruded and deficient in contour.

Figure 29.12 **(C, D)** Postoperative facial appearance following advancement of the mandible and chin by sagittal split osteotomy and chin implant.

Figure 29.13 **(A, B)** Malocclusion and exposed gingiva corrected by superior repositioning of the maxilla with Le Fort I osteotomy.

nerve is frequent, but, fortunately, permanent anesthesia is infrequent. Sensory disturbance associated with sagittal splitting osteotomy varies from 0% to 75% with a mean of 35%. Inappropriate splitting, extensive swelling, and hemorrhage are very infrequent but can occur.

Other procedures, such as "C" or "L" osteotomies, may be performed either intraorally or extraorally. They are, however, reserved for micrognathia, extreme advancement, or other unusual conditions and may require bone grafting. Additional chin advancement by horizontal osteotomy of the symphysis or chin implant for retrognathia or micrognathia is frequently necessary. These procedures are described later.

Maxillary excess

Maxillary excess with a normal mandible rarely occurs as a single entity. It is usually accompanied by mandibular deficiency, mandibular excess, or mandibular asymmetry. The facial soft-tissue characteristics of VME are manifested equally in both the frontal and profile views. The facial features are dominated by a long tapering face with a narrow alar base, increased nasolabial angle, lip incompetence, a highly convex profile, a flat mentolabial fold, and usually a deficient chin. Excessive display of maxillary anterior teeth is seen with the lips at rest, and a "gummy smile" is apparent (Figure 29.13A and B). Cephalometrically, there will be a large increase in the lower anterior facial height and mandibular plane angle and a decrease in posterior facial height. VME occurs with or without an anterior open bite. Horizontal excess or protrusion of the incisors may be seen, and bilateral posterior crossbites are common.

The mandible may be rotated clockwise (down and back) because of VME (Figure 29.14A). When a prediction tracing moves the maxilla superiorly to a normal lip–incisor relationship, the mandible will rotate upward and forward toward a more normal position. If this is not the case, surgery to advance the mandible may also be necessary (Figure 29.14B and C). If VME is accompanied by a normal mandible or mandibular excess, mandibular setback surgery may be necessary to correct a protruding mandible that is rotated forward secondary to maxillary superior positioning.

Although extractions are frequently required to alleviate crowding, it is often desirable to delay extractions in the upper arch until the time of surgery, using the teeth to be extracted to aid in the leveling and alignment of the posterior segments and to preserve the alveolar bony dimensions. By performing segmental osteotomies with a Le Fort I osteotomy, the surgeon can retract and upright protrusive maxillary incisors and expand or advance posterior segments (see Figure 29.14B). If space is required in the arch, the extraction sites should be closed completely preoperatively. The curve of Spee in the lower arch should be leveled completely.

Presurgical orthodontic treatment of VME cases differs greatly from that of prognathic or retrognathic cases. Since the extrusion of teeth via conventional orthodontic mechanics is potentially unstable, mechanics that would produce this effect are avoided in all instances. Intramaxillary mechanics are used extensively, rather than Class II, Class III, or headgear forces, and deliberate care is taken to ensure the preservation of any open bite. Segmental rather than complete arch leveling is necessary in the maxilla to preserve an exaggerated compensating curve or "stepped" occlusion in the canine region (see Figure 29.14B). In those cases in which the maxilla is to be surgically segmentalized and no extractions are contemplated, it is helpful to diverge the dental roots for passage of the surgical saw. Historically, maxillas were segmentalized between the canines and first premolars. With orthodontic support, more osteotomies are performed between the canines and lateral incisors. Since bilateral crossbites often accompany VME cases, it is often preferable to plan for surgical expansion in the posterior segments at the time the osteotomies are performed.

Vertical changes in the maxilla through Le Fort I osteotomy and concomitant vertical and horizontal changes in the mandible by surgery may produce tremendous functional and esthetic results (Figure 29.15A–C). Le Fort I osteotomy of the maxilla is usually performed through a vestibular incision 5 mm superior to the mucogingival junction from the first molar to the first molar. Tunneling beneath the mucoperiosteum to the pterygoid plates and reflection of the nasal mucosa from the floor of the nose allow for osteotomes and air-driven saws to produce osteotomies for down-fracture of the maxilla from pterygoid plates, nasal septum, lateral maxillary, and nasal walls. The amount of bone to be excised is determined from mock surgery and measurements on models mounted on an anatomic articulator. Division of the maxilla in the canine area or between the central incisors allows for a variety of vertical, horizontal, and transverse movements of all segments. Turbinectomy, nasal septal straightening, palatal repositioning, and buccal lipectomies are frequently done to anatomically correct all aspects of VME. An intermediate splint keyed to the unoperated mandible ensures correct superior positioning of the maxilla. Once the maxilla is stabilized with wires or bone plates, mandibular surgery is performed if necessary. The mandible is stabilized with a final splint to the newly positioned maxilla. Intermaxillary fixation is rarely indicated. Rather, light elastics between the maxilla and mandible will correct any minor occlusal discrepancies into the final occlusal splint.

Maxillary deficiency

Maxillary deficiency most commonly associated with other deformities can occur in all three planes of space: anteroposterior, vertical, and transverse. Transverse deficiency or posterior crossbite can be bilateral or unilateral and is most commonly associated with other deformities. The apparent transverse deficiency accompanying true mandibular prognathism is usually resolved with the surgical repositioning of the mandible. Class II deformities usually do not have posterior crossbites until the mandible is advanced into the planned Class I position. Concomitant maxillary posterior segmental osteotomies may be required if palatal expansion is not possible. Many VME cases, especially the open-bite types, have transverse deficiency, which is corrected with segmental Le Fort I osteotomies.

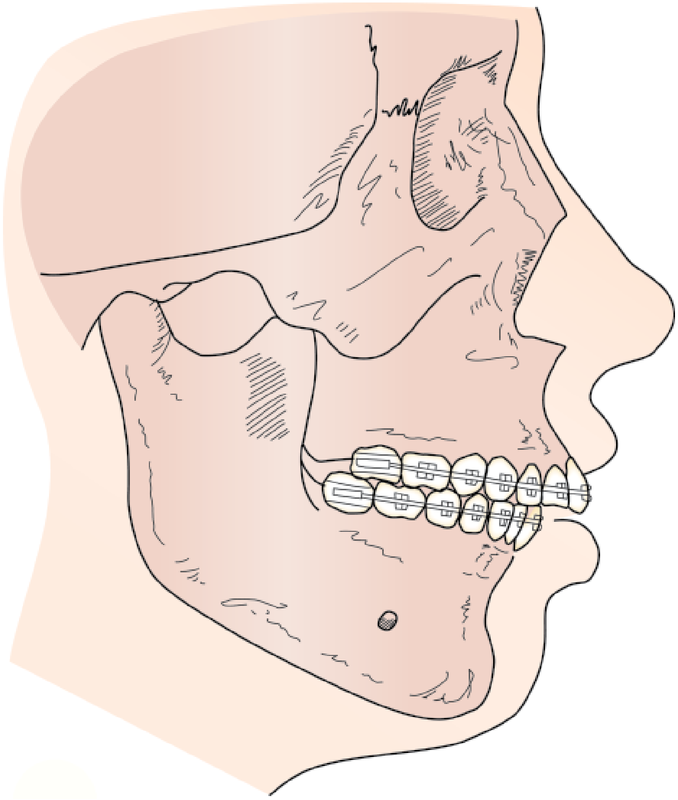

Figure 29.14 **(A)** VME is characterized by excessive exposure of incisors, lip incompetence, mandibular deficiency, and increased anterior facial height.

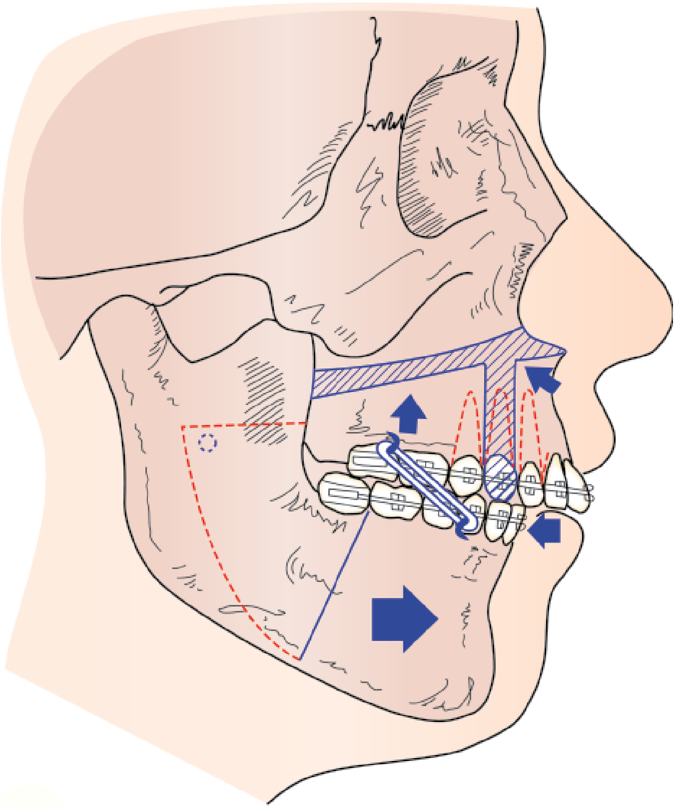

Figure 29.14 **(B)** Preoperative tracing shows orthodontic changes that preserve the deformity by uprighting lower incisors and maintaining the maxillary arch position. Treatment is extraction of maxillary premolars, maxillary and mandibular movement through Le Fort I osteotomy of the maxilla with anterior/posterior splitting, and mandibular advancement by sagittal split osteotomy.

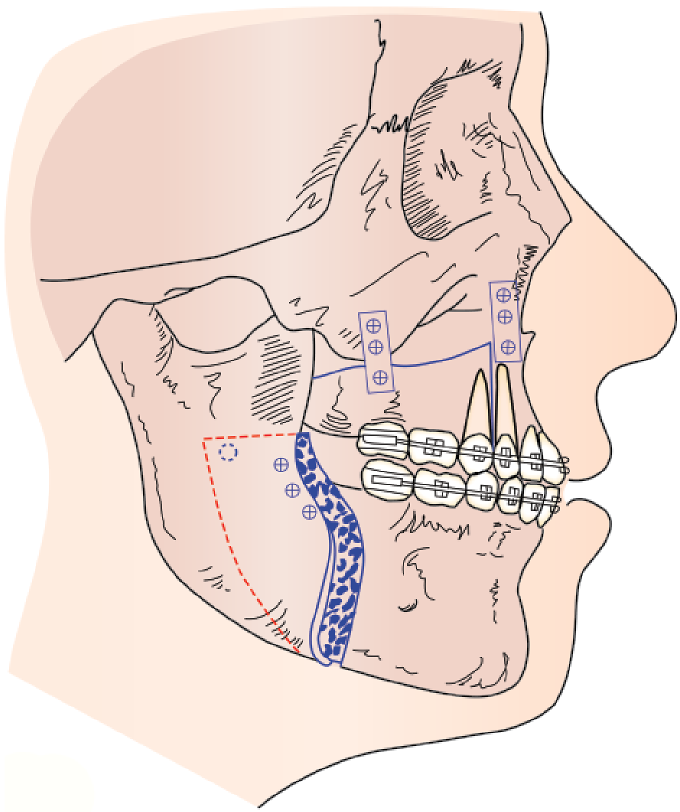

Figure 29.14 **(C)** Stabilization of maxilla and mandible by rigid fixation—bone plates and screws.

Figure 29.15 **(A)** Severe convex dentofacial deformity with VME, mandibular deficiency, and Class II malocclusion. Preoperative profile with relaxed lips shows true amount of lip incompetence.

Figure 29.15 **(B)** Three-year postoperative profile following orthodontic treatment, superior repositioning of the maxilla by Le Fort I osteotomy, advancement of the mandible by sagittal split osteotomy, and an alloplastic cheekbone and chin implant.

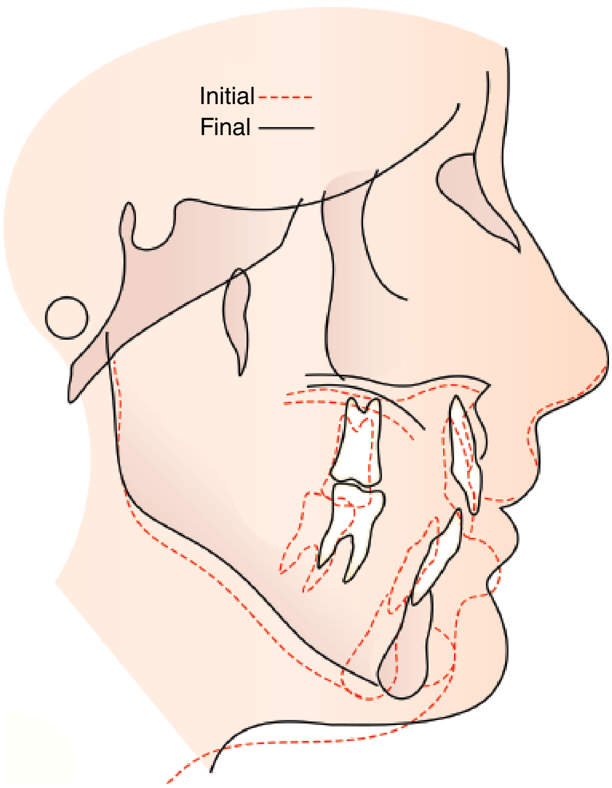

Figure 29.15 **(C)** Initial pretreatment and 3-year final cephalometric tracing.

Figure 29.16 **(A)** Vertical maxillary deficiency corrected by inferior repositioning of the maxilla (downgrafting) with Le Fort I osteotomy and autogenous iliac crest bone graft. Preoperative frontal view demonstrates decreased facial length and hidden maxillary incisors on smiling.

Figure 29.16 **(B)** Postoperative view demonstrates increased facial length and exposure of maxillary incisors.

Vertical maxillary deficiency usually has the appearance of an edentulous patient not wearing an upper denture (Figure 29.16A and B). The soft tissue will appear squashed, with the teeth in occlusion, and the mandible may appear to be prognathic. With the mandible in the normal rest position, significant freeway space is seen, and a more normal profile is observed. Cephalometrically, the SNA will be normal, the SNB may be increased, the mandibular plane may be decreased, and anterior facial dimensions and the ANB will be decreased. The occlusion will vary from borderline Class I to Class III. It is important to note the lack of display of a normal amount of the maxillary incisor with the upper lip at rest. The rest position must always be used for diagnosis and treatment planning since smile patterns vary too much and have only limited value. We treat to idealize the incisor shown at rest, not at smile.

Anteroposterior or horizontal deficiency will have a soft-tissue appearance similar to that of true mandibular prognathism. A decreased SNA and ANB and an obtuse nasolabial angle are characteristic. The addition of several wide strips of wax or a cotton sponge under the upper lip may improve the profile. Patients with cleft lip and palate with failure to develop the normal horizontal and vertical positions of the maxilla represent a common type of horizontal maxillary deficiency (Figure 29.17A–D).

Vertical and horizontal maxillary lengthening or advancement through Le Fort I osteotomy can produce dramatic results (see Figures 29.16 and 29.17). Special consideration must be given to methods of stabilization and fixation. In horizontal deficiencies, the bone of the maxilla is characteristically very thin. With advancement, bone contact may be minimal or inadequate. Stable results are obtained with the use of autologous bone from the iliac crest or cortical–cancellous demineralized bone products placed in defects of the lateral maxillary wall and between the posterior maxillary wall and pterygoid plates. Rigid internal fixation with wires or malleable bone plates will produce predictable results without IMF. If simultaneous mandibular surgery is necessary, rigid fixation of the sagittal split osteotomy may also eliminate IMF.

Facial asymmetry

Diagnosis and surgical orthodontic treatment of facial asymmetry such as condylar hyperplasia or hemifacial microsomia is perhaps more difficult, challenging, and dramatic than any other deformity. Variations of asymmetry are common, corrective procedures are less standardized, and, in many cases, much original thought is required. An elaborate preoperative work-up from multiple radiographic views is required to confirm the diagnosis, eliminate uncommon pathology as an etiology, and arrive at a treatment plan.

There is always a certain amount of asymmetry to the face and to the mandible. In many instances, the face, although slightly asymmetric, is attractive, projects warmth, and is an integral part of an individual's character. Pronounced asymmetry, however, has been detrimental to character development and social and economic progress. Equally important, but only recently appreciated, are the functional deficits associated with facial or mandibular asymmetry. Fortunately, correction of form almost always improves function.

It is the dentist's responsibility to seek surgical evaluation of patients for whom restorative dentistry is proposed to correct an asymmetric mandible or maxilla. In more recent times, numerous uncomplicated surgical procedures have produced dramatic improvements in appearance and function for patients formerly considered beyond help. Because of the complexity of the deformity, treatment is individualized and may involve osteotomies, recontouring, and associated soft-tissue surgery.

A classification of asymmetry is necessary for proper diagnosis and treatment (Table 29.1).

Condylar hyperplasia

This is the most common cause of asymmetry, resulting from overproduction or prolonged production of cartilage in the condyle. The usual deformity is an enlarged condyle and

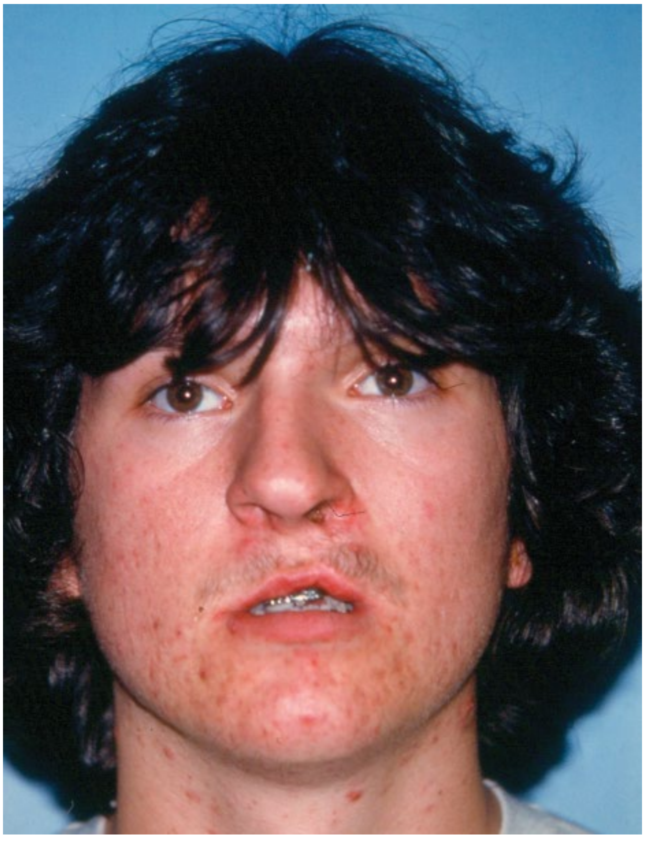

Figure 29.17 **(A)** Vertical, horizontal, and transverse maxillary deficiencies in a patient with cleft lip and palate and severe Class III malocclusion. Preoperative facial appearance.

Figure 29.17 **(B)** Profile before surgery following orthodontic treatment to correct dental compensations.

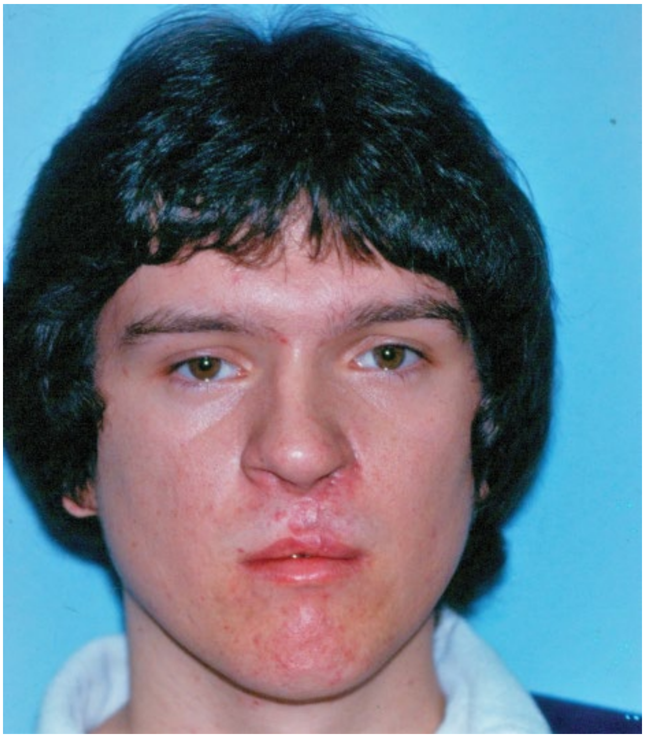

Figure 29.17 **(C)** Postoperative frontal view at 3 years.

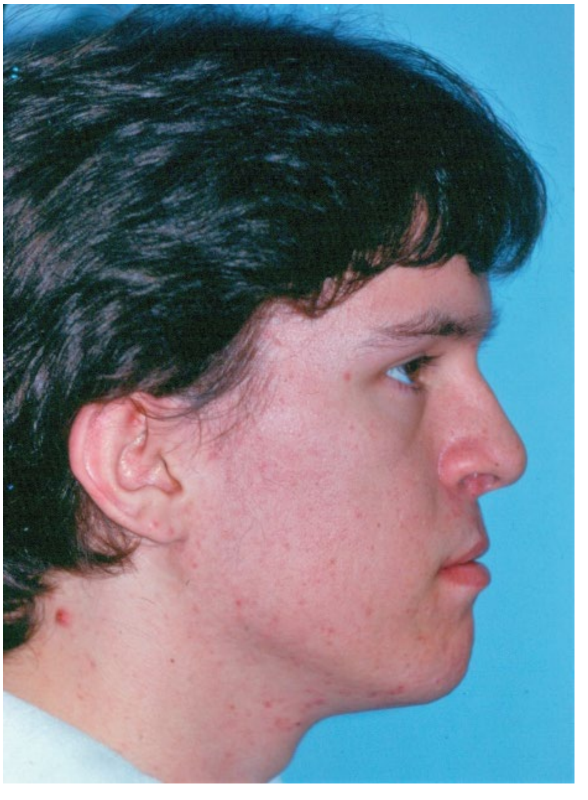

Figure 29.17 **(D)** Profile 3 years following orthodontics, advancement, and expansion of the maxilla by Le Fort I osteotomy with autogenous iliac crest bone graft, closure of oronasal fistula, and secondary repair of the lip.

Table 29.1 Classification of Asymmetry

Overdevelopment
Hemihypertrophy (facial)
Condylar hyperplasia
Mandibular hypertrophy (macrognathia)
Deviation prognathism (laterognathia)
Unilateral masseteric hypertrophy
Alveolar (maxillary or mandibular)
Underdevelopment
Hemifacial microsomia
Condylar hypoplasia
Mandibular hypoplasia
Alveolar (maxillary or mandibular)
Treacher Collins syndrome (mandibulofacial dysostosis)
Acquired states of asymmetry
TMJ ankylosis from trauma
Tumors
Infections
Inflammation

elongated condylar neck. The result is an outward bowing of the ramus and the body and a downward growth of the mandible that may produce an open bite on the involved side and a crossbite on the opposite side. If the onset is before puberty, the maxilla grows downward and maintains some degree of occlusion with the mandible. If the onset were late, one would not expect to find a down-growth of the maxilla but instead a developing open bite.

Treatment planning for facial asymmetry involves careful notation of all facial and dental relationships. The facial, chin, and dental midlines are marked (Figure 29.18A). The vertical differences in right to left mandibular inferior borders are noted, including the degree of occlusal plane cant (Figure 29.18B). Bone scans and serial radiographs are helpful to determine remaining condylar growth potential. Photographs, cephalometric analysis, and models mounted on an anatomic articulator aid in treatment planning. Model surgery determines the exact bony movements to be carried out during surgery (Figure 29.18C–F).

As in the case presented, a Le Fort I osteotomy is performed first to achieve normal tooth–lip esthetics and a level maxilla with correct positioning in all directions. Ramus osteotomies and possible condylectomy follow maxillary surgery.

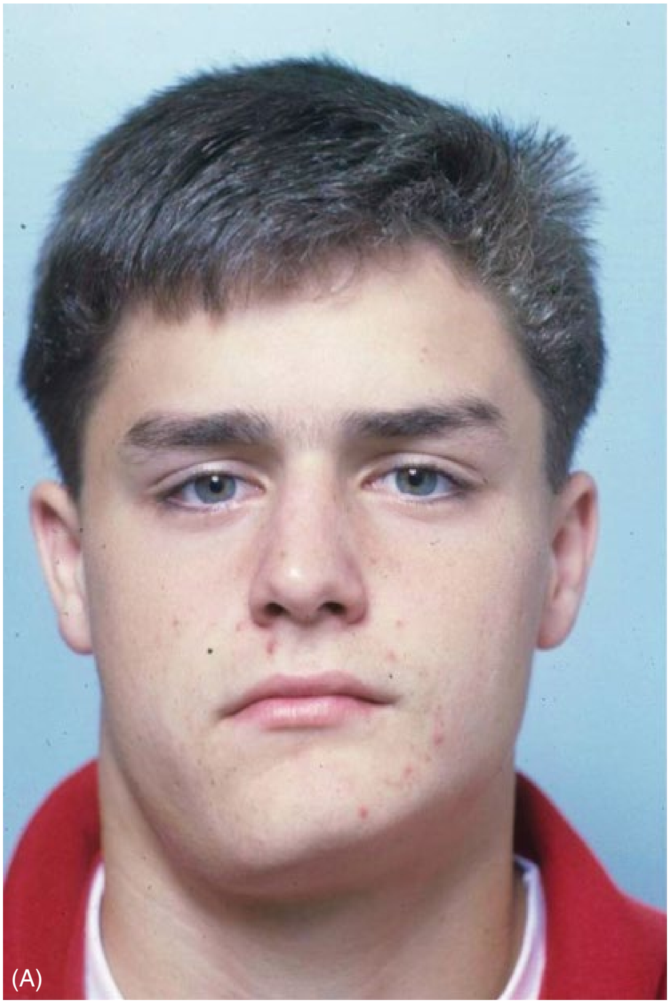

Figure 29.18 **(A, B)** Condylar hyperplasia and mandibular macrognathia, frontal view of patient and radiograph. Note grossly enlarged right condyle and enlarged inferior border of mandible producing severe facial asymmetry and malocclusion.

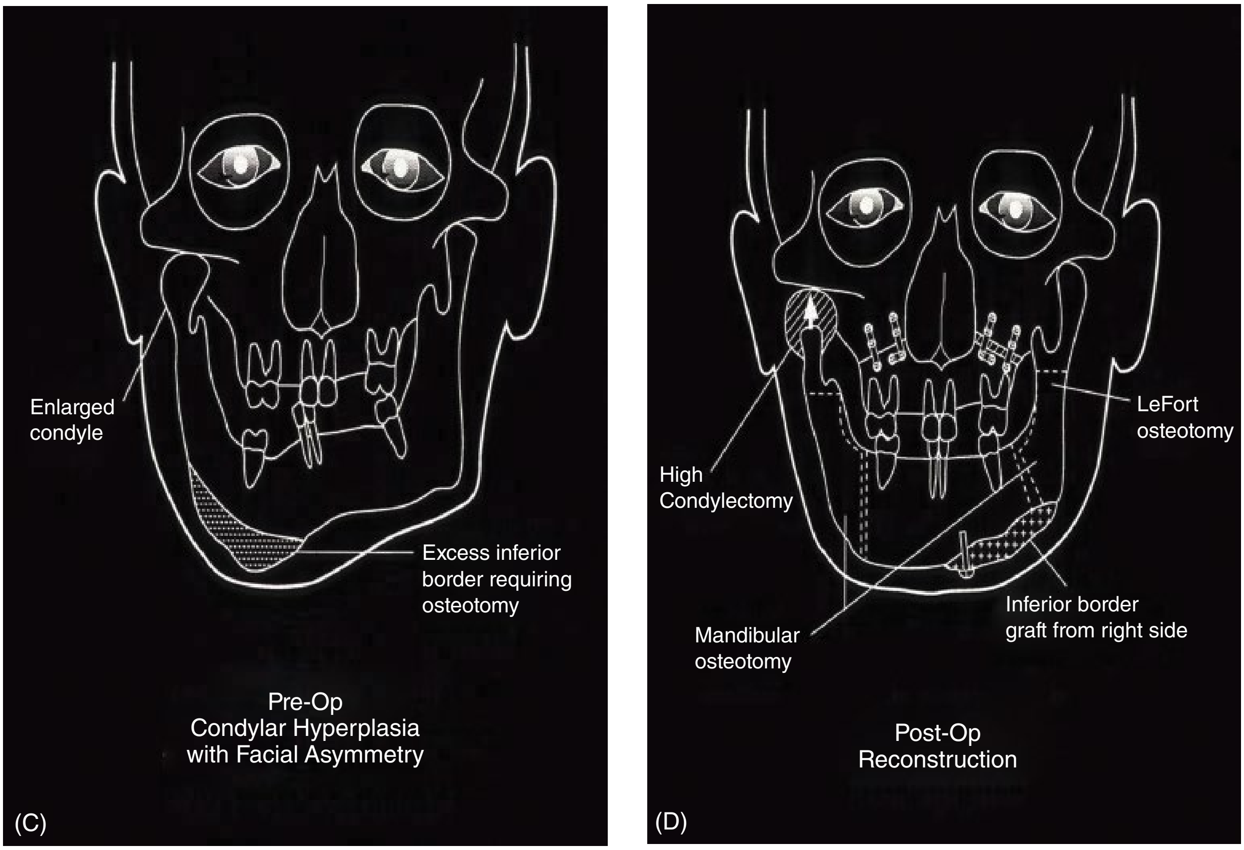

Figure 29.18 **(C, D)** Frontal view cephalometric drawings showing preoperative asymmetry findings **(C)** and multiple operative procedures to obtain postoperative reconstruction symmetry **(D)**.

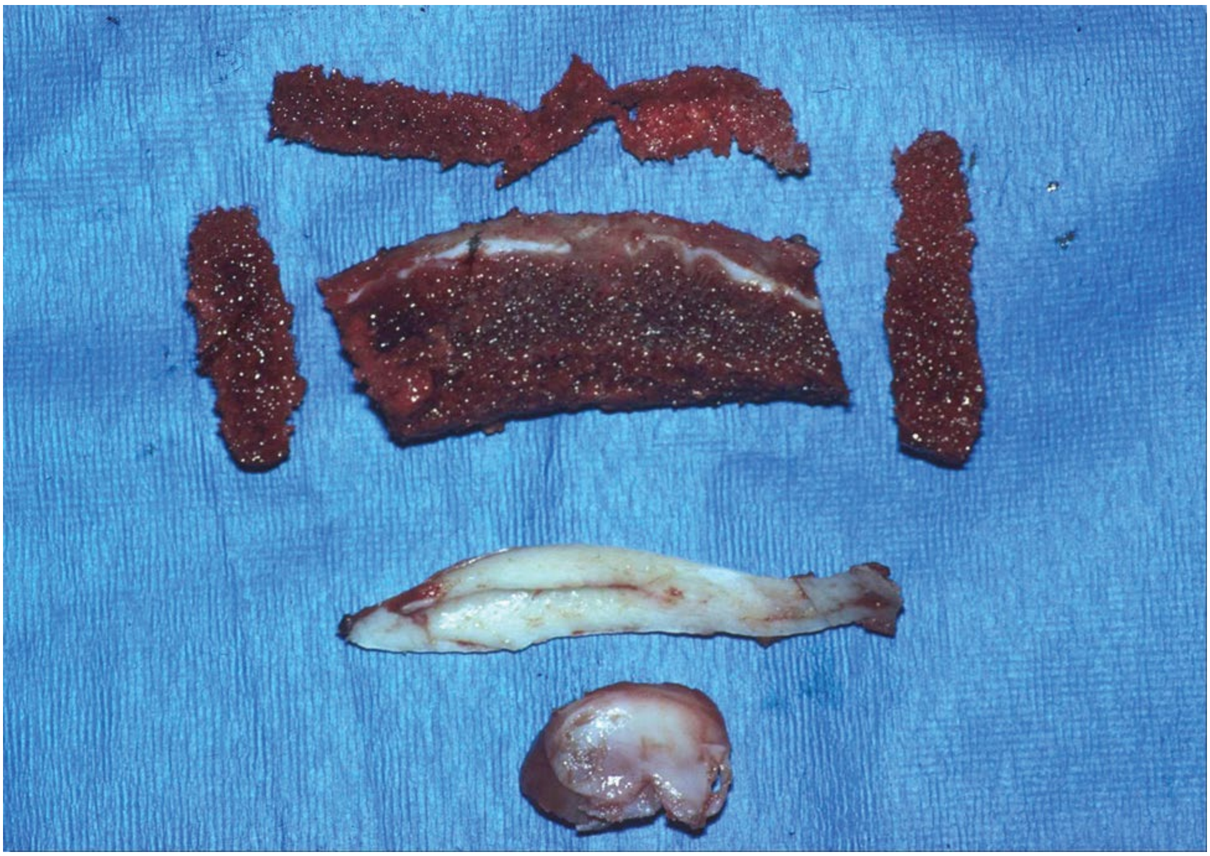

Figure 29.18 **(E)** Bone graft from iliac crest used to downgraft left maxilla. Patient's right excess inferior border of mandible was transferred to left side. Removal of right condyle shortened right side of face.

Figure 29.18 **(F, G)** Postoperative frontal views of patient and his twin brother.

A condylectomy may be indicated in cases of hyperplasia and hypertrophy where additional growth is anticipated and pain and dysfunction are noted. Otherwise, a subcondylar osteotomy is used on the side being shortened, and a sagittal split, or "L" osteotomy with graft, is used on the side being lengthened. (Figure 29.18A–G). Inferior border leveling by ostectomy and genioplasty by sliding horizontal osteotomy may be necessary in severe cases. Facial onlay procedures with alloplasts or tissue transfer are also used to refine symmetry.

Hemifacial microsomia

This is the most common cause of asymmetry, which occurs as a result of failed mandibular condyle growth. It is a distinct unilateral entity within the group of syndromes that encompass failure of growth of derivatives of the first and second branchial arch. It is postulated that stapedial artery hemorrhage in utero leads to a loss of functional matrix responsible for the normal formation of several anatomic structures (most notably ramus, glenoid fossa, and external ear). The extent of the deformity ranges from mild mandibular asymmetry to severe hypoplasia of the mandible and facial skeleton and overlying soft tissues on the affected side. The skeletal defects of hemifacial microsomia with vertical facial shortening are classified according to the morphology of the ramus and temporomandibular articulation. These deformities may be limited to hypoplasia of the ramus and glenoid fossa or may include nearly complete absence of these structures, including the external ear. The lack of mandibular development restricts maxillary growth on the affected side, and this produces upward occlusal plane canting. Alterations in orbit and zygoma position and size are common in severe cases. The chin becomes displaced to the affected side with Class II malocclusion. Once the occlusion is surgically and orthodontically corrected, hard- and soft-tissue asymmetric problems frequently require secondary grafting or implant procedures (Figure 29.19A–K).

Distraction osteogenesis

Distraction osteogenesis is a surgical technique in which there is an osteotomy created and the two segments are progressively moved apart. The procedure consists of an osteotomy, a latency period, a distraction device activation period, a consolidation period, and a bony remodeling period.

Distraction has been established as a predictable method for maxillary and mandibular bone elongation, with generation of bone in the distraction site. This is the result of slow pulling apart of the bone edges with an external or internal fixator that

Figure 29.19 **(A, B)** Frontal and profile views of patient with hemifacial microsomia. Missing ear had been reconstructed with abdominal graft as a child. Today, missing external ears are more esthetically reconstructed using skull-placed dental implants to support a prosthetic ear. Note severe retrognathia of mandible with facial asymmetry.

mechanically creates a gap in which new bone generates between the two edges. Mandibular distraction osteogenesis is indicated when severe mandibular retrognathia or micrognathia is present. Mandibular advancements of 10–20 mm are difficult to perform with a sagittal split osteotomy. Acute mandibular lengthening of 10–20 mm requires significant stripping and stretching of the musculature and soft tissue attached to the mandible, with an increased chance of skeletal relapse. Distraction osteogenesis techniques allow gradual soft-tissue adaptation, and proliferation in response to mandibular lengthening. The distraction process, or callus manipulation, occurs at a rate ranging from 0.5 to 2 mm a day. The rate will depend on the age of the patient and the type of osteotomy. The gold standard for clinical distraction osteogenesis is 1 mm a day, divided into two or four activations per day. The distance of distraction is determined by the amount of skeletal and occlusal change desired. Transoral activation arms are typically removed under local anesthetic and/or sedation at the completion of the distraction.

The consolidation period in adults should be a minimum of 3 months and can be extended up to 6 months as needed.

Devices can be intraoral or extraoral, and there are numerous advantages and disadvantages of each. The main advantage to the intraoral devices is that the device is located under the soft tissue and socially preferred by the patients. Disadvantages include the device cannot perform three-dimensional corrections, less control of vector lengthening in relation to the extraoral devices, and a second operation for device removal is required.

The most striking feature of distraction osteogenesis is the significant distance of lengthening that can be achieved with new bone formation.

Surgically assisted orthodontics

Corticotomy-assisted orthodontic treatment can offer several unique options to address the limitations of traditional orthodontic treatment in adults. A review of the literature in this surgically assisted technique reveals several distinct advantages. These include a reduced treatment time, enhanced expansion, differential tooth movement, increased traction of impacted teeth, and improved postorthodontic stability. Corticotomy has been described in orthopedics dating back to the early 1900s. Köle introduced a surgical procedure involving both osteotomy and corticotomy to accelerate orthodontic tooth movement, based on the concept that teeth move faster when the resistance exerted by the surrounding cortical bone is reduced via a surgical procedure. Köle further explained that the reduced resistance

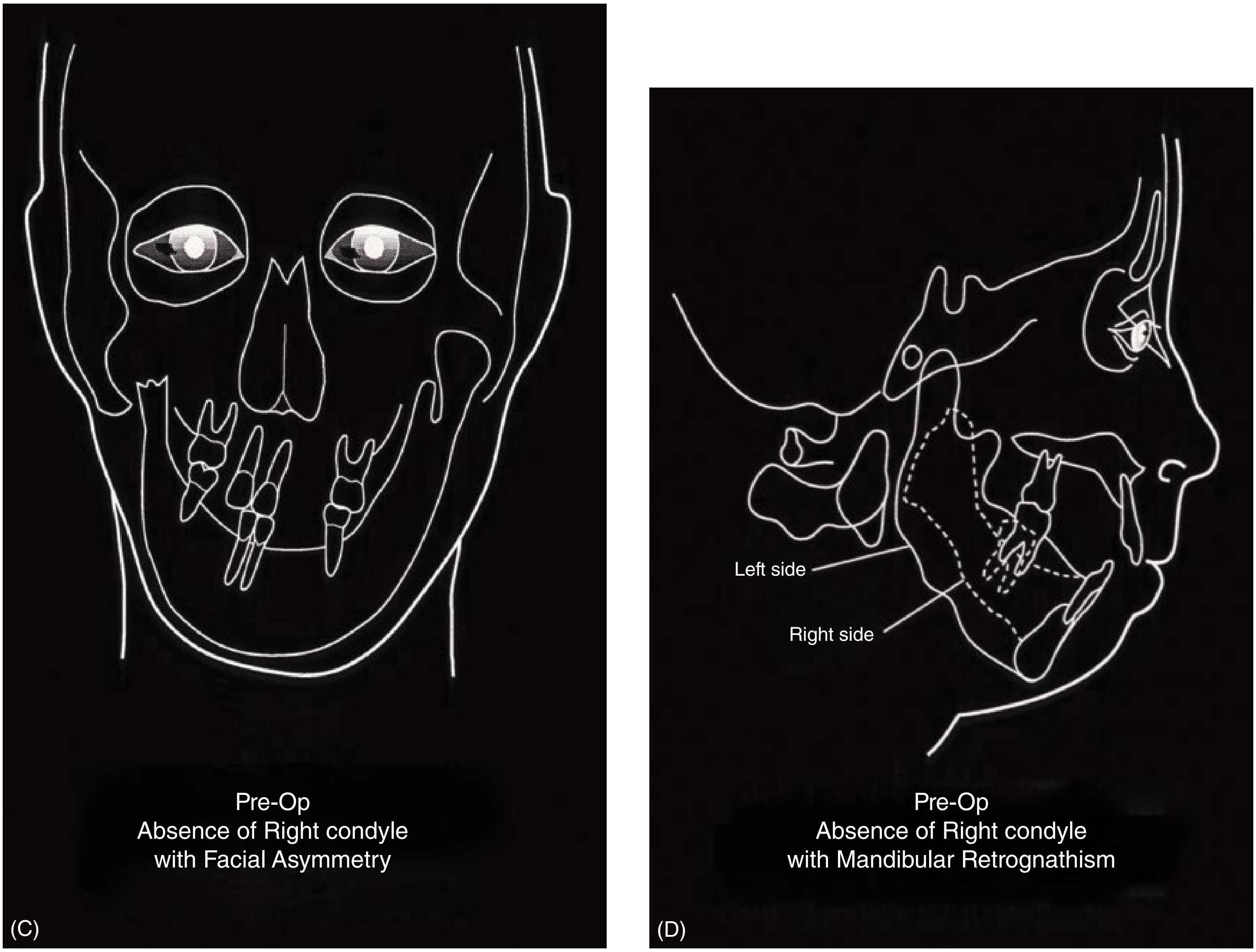

Figure 29.19 **(C, D)** Preoperative drawings demonstrate retrognathia, missing condyle, and malocclusion with facial asymmetry.

enhances an en bloc movement of the entire alveolar cortical segment, which is connected by softer medullary bone, including the confined teeth, when exposed to orthodontic forces. Frost found a direct correlation between the severity of bone corticotomy and/or osteotomy and the intensity of the healing response, leading to accelerated bone turnover at the surgical site. This was designated as "regional acceleratory phenomenon," which was explained as a temporary stage of localized soft- and hard-tissue remodeling that resulted in rebuilding of the injured sites to a normal state through recruitment of osteoclasts and osteoblasts via local intercellular mediator mechanisms involving precursors, supporting cells, blood capillaries, and lymph.

The accelerated osteogenic orthodontics (AOO) technique described by Wilcko is as follows: full-thickness flaps are reflected labially and lingually using sulcular releasing incisions. Vertical releasing incisions can be used, but they should be positioned at least one tooth away from the "bone activation." Flaps should be carefully reflected beyond the apices of the teeth to avoid damaging the neurovascular complexes exiting the alveolus and to allow adequate decortication around the apices. Selective alveolar decortication is performed in the form of 0.5 mm cuts into the cortical bone, combined with selective medullary penetration to enhance bleeding. This poses little threat to tooth vitality and makes AOO much safer than the osteotomy technique, in which cuts extend into the medullary bone around the teeth that are to be moved. Adequate bioabsorbable grafting material is placed over the injured bone. Flaps are then repositioned and sutured into place. Sutures should be left in place for a minimum of 2 weeks. Tooth movement should start 1 or 2 weeks after surgery. Unlike conventional orthodontics, the orthodontic appliance should be activated every 2 weeks until the end of treatment after periodontal AOO. There are several indications in which this surgical technique can be offered to patients: resolve crowding and shorten treatment time, accelerate canine retraction after premolar extraction, enhance postorthodontic stability, facilitate eruption of impacted teeth, facilitate slow orthodontic expansion, molar intrusion, and open bite correction.

There are certain limitations to this technique. Patients with poor periodontal health or gingival recession are not

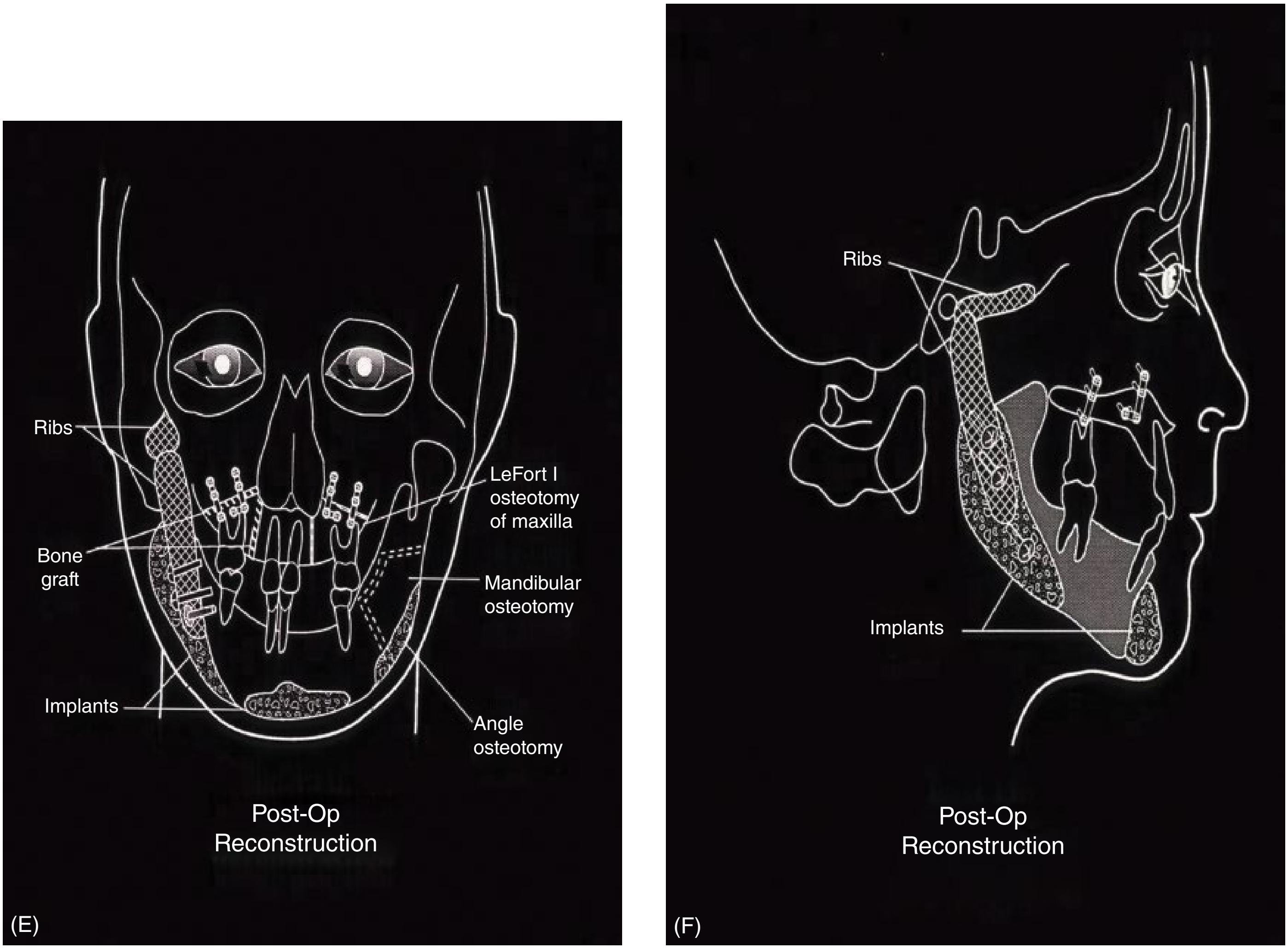

Figure 29.19 **(E, F)** Postoperative drawings demonstrate reconstruction of right condyle, glenoid fossa, and ramus with autogenous rib graft, left mandibular osteotomies, Le Fort I osteotomy of maxilla with bone graft to level and lengthen the right maxilla, and multiple chin and facial implants.

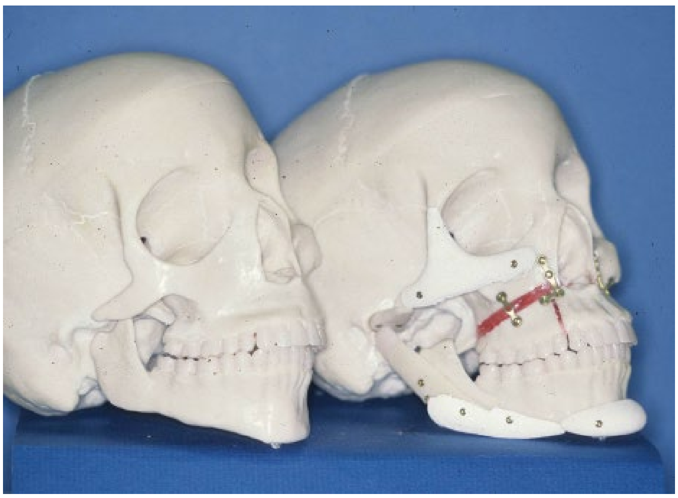

Figure 29.19 **(G)** Deformity and reconstruction reproduced on plastic skulls.

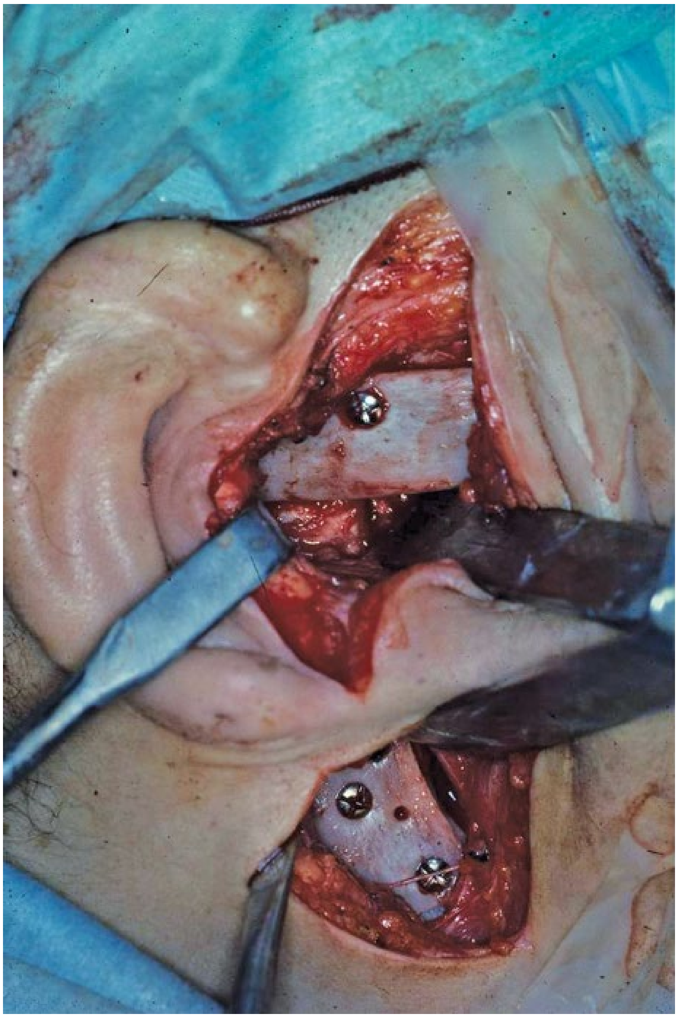

Figure 29.19 **(H)** Surgical view of right autogenous rib graft to restore fossa, condyle and deficient ramus.

appropriate candidates. Complications of AOO include slight interdental bone loss and loss of gingival attachment. There have also been reports of hematomas along with the expected postoperative swelling and pain.

Adjunctive hard- and soft-tissue procedures

The most common adjunctive procedure performed at the time of orthognathic surgery is genioplasty (chin reshaping). Other procedures commonly performed simultaneously include rhinoplasty, septoplasty, onlay augmentation, submental lipectomy/liposculpture, buccal lipectomy, platysmaplasty, lip augmentation, reduction cheiloplasty, V–Y lip advancement (to lengthen the upper lip), and alar cinch (to narrow the alar base).

Osteotomies and alloplastic implant augmentation are commonly employed when facial contour deficit exists in the presence of a normal occlusion or when maxillary or mandibular surgery to correct malocclusion fails to satisfy esthetic requirements. When properly performed, both the osteotomy and alloplastic augmentation are quite stable. Chin contour correction by an osteotomy is usually performed through an intraoral vestibular incision. Horizontal augmentation or advancement of a deficient chin occurs with a sliding horizontal osteotomy of the symphysis (Figure 29.20), a chin implant, or a combination thereof for extreme deformity. The chin is pedicled to the genioglossus and geniohyoid muscles to maintain blood supply, and direct wiring or plating stabilizes the segment. The soft-tissue augmentation change is at least 70% of the amount of bone advancement (Figure 29.21A–D).

If excessive vertical dimension exists, a wedge of bone may be removed. Likewise, a short chin may be lengthened by interposing bone or hydroxylapatite blocks. Prominent and excessively long chins may be reduced by chin shaves but are more accurately corrected by reverse sliding of the symphysis with a horizontal osteotomy and/or ostectomy of excess bone.

Alloplastic implants used for mandibular, facial, and cranial augmentation most commonly employed today include silicone rubber (i.e., Implantech, Ventura, CA), porous polyethylene (i.e., Medpore, Porex Surgical, Newnan, GA), and expanded polytetrafluoroethylene (i.e., Gore-Tex, W.L. Gore and Associates, Flagstaff, AZ). These materials are preformed to fit particular anatomic areas and can be trimmed and/or recontoured. They are placed subperiostally through intraoral incisions and secured with sutures, wires, or bone screws. Chin and cheekbone augmentations with alloplast are very commonly used to enhance the surgical treatment of dentofacial deformities (see Figures 29.7C, 29.15B, and 29.21D).

Role of orthognathic surgery in treating obstructive sleep apnea

Obstructive sleep apnea (OSA) has come to the forefront as a major public health concern. Researchers are continuously finding different ways in which interrupted or lack of sleep is detrimental to our health, mostly through inflammatory effects and a decrease in the body's natural ability to repair inflammatory damage during sleep. Altered sleep affects the cardiovascular, pulmonary, renal, endocrine, and vascular systems in general and all systems in specific manners that create multiple health issues. Probably the most obvious effect is on the brain with daytime sleepiness, altered cognitive abilities, and increased risk of stroke. OSA is characterized by repeated pauses or obstructions in breathing, usually combined with snoring. This leads to fragmented sleep and decreases in oxyhemoglobin saturation, both damaging to all body systems. The incidence of OSA has been estimated to be as high as 90 million Americans. Almost half of individuals above the age of 40 snore, and the incidence of sleep apnea in those individuals is at least 17% of men and 15% of women. Although obesity is given as the cause of the majority of OSA cases, a significant percentage of individuals have an anatomic predisposition to airway collapse due to retrusive jaws and relative decreased space for the tongue.

Although the primary medical treatment of OSA is the use of continuous positive airway pressure (CPAP), appropriate dental treatment can be just as important. Dental practitioners need to recognize existing dental skeletal patterns as well as future effects of orthodontic treatment, either of which may be detrimental to the patient's airway health. A seemingly innocuous four bicuspid

Figure 29.19 **(I, J)** Preoperative and postoperative profiles.

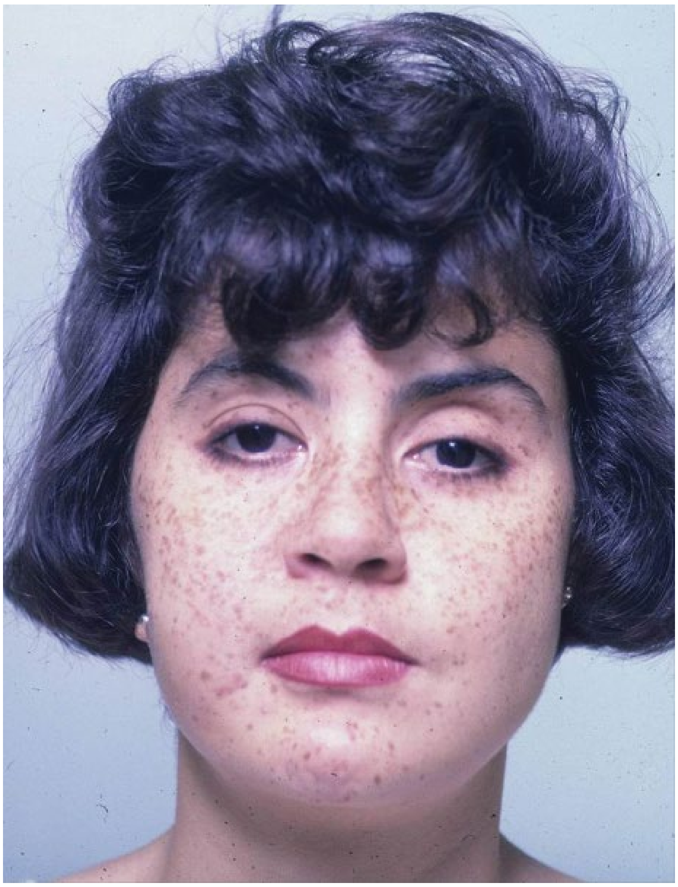

Figure 29.19 **(K)** The 10-year frontal view of face.

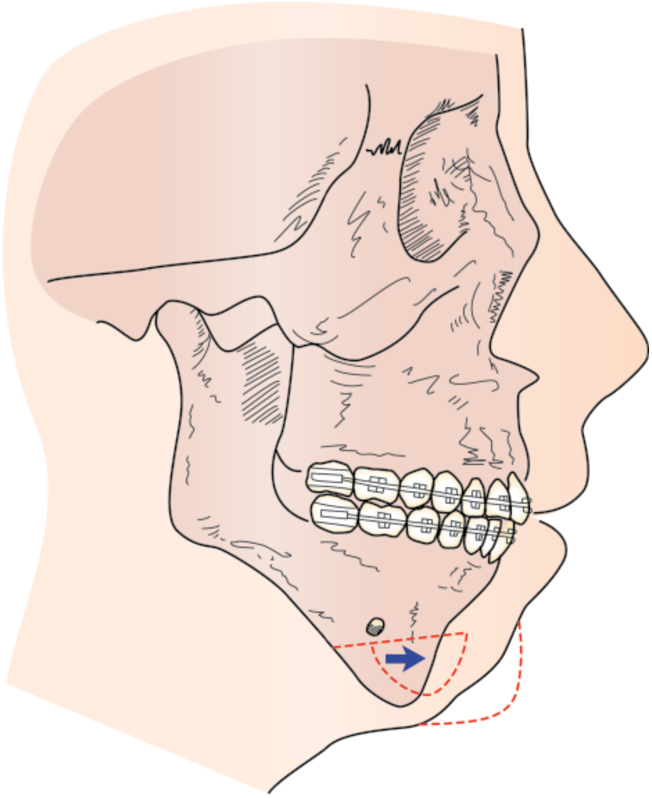

Figure 29.20 Tracing advancement genioplasty by intraoral sliding horizontal osteotomy of the symphysis.

extraction to camouflage a Class II or III malocclusion or a surgeon's failure to not minimize a mandibular setback are examples of adverse consequences when that patient reaches their 40s or 50s. The facial skeleton provides much of the support for the upper airway and, as such, orthodontic treatment that reduces the upper airway space should be a concern as the patient ages. As doctors, the rule of *primum non nocere*, or first do no harm, has to be considered when undertaking procedures that decrease the volume of the upper airway space.

The use of concepts and procedures learned from orthognathic surgery has recently become a promising treatment for individuals affected by OSA. In orthognathic surgery, the surgeon uses maxillary and mandibular osteotomies to effect a change in the patient's facial skeleton to improve masticatory function, speech, and appearance. In orthognathic surgery or telegnathic surgery to treat OSA, the surgeon uses these procedures to increase the posterior airway space, increase space for the tongue, and in 97–98% of the patients cure OSA. Since OSA has become such a large public health concern, and many patients tolerate CPAP poorly, options such as oral repositioning devices and orthognathic surgery have become valid alternatives to cure OSA. Compliance is a large problem with CPAP, and even some oral repositioning devices; therefore, mandibular/maxillary advancement orthognathic surgery can be a life-saving procedure for many individuals.

Although orthognathic surgery often simultaneously corrects OSA and produces a pleasing esthetic/occlusal change, orthognathic surgery for the treatment of OSA has a defined purpose and may have a potentially different outcome than orthognathic surgery used for the correction of a craniofacial deformity alone. If a middle-aged patient with OSA has an underlying craniofacial deformity, many will have a facial skeleton with cephalometric norms. The general idea in orthognathic surgery to cure OSA is to pull the facial skeleton and the tongue away from the posterior pharyngeal wall; thus, some patients will look as if their lower face is too prominent. This gives some middle-aged patients the appearance as if they have had a face lift, and is thus aesthetically pleasing. Other patients will look abnormal. The thought process has to be altered to consider that the surgery is being done not for appearance improvement but rather to cure the patient of a deadly malady.

Figure 29.22A illustrates the changes that occur in a normocephalic male that decrease the posterior airspace. The illustration projects how aging increases the length of the soft palate from negative-pressure snoring and irritation. This, combined with relative increases in tongue size and excess fat, results in the creation of the conditions favorable for the development of OSA.

Figure 29.21 **(A)** Preoperative frontal view of patient with chin deficiency.

Figure 29.21 **(B)** Preoperative profile appearance.

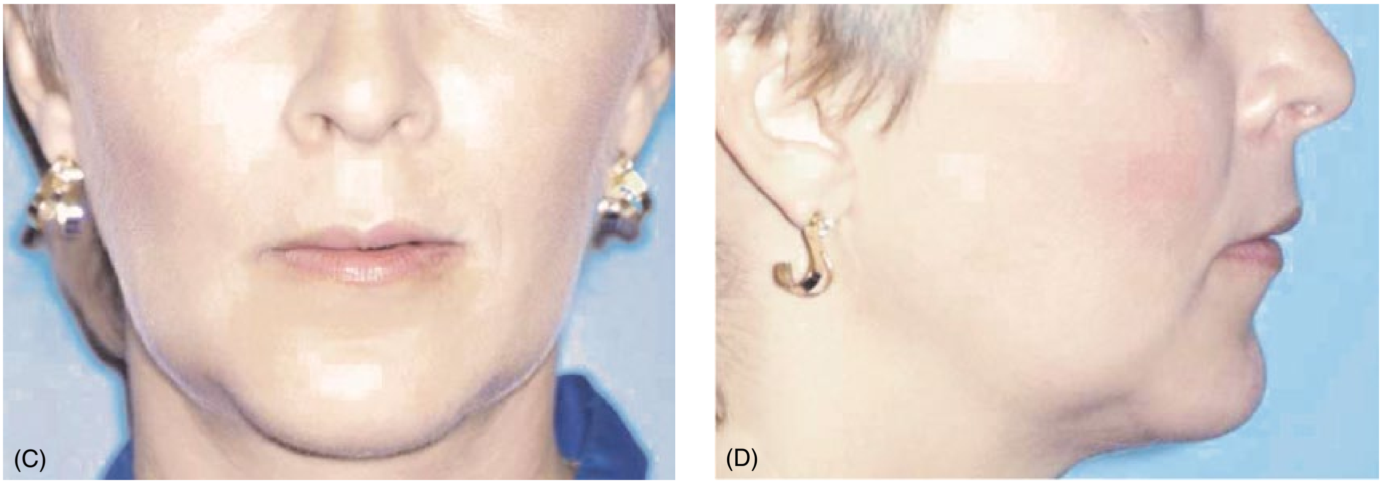

Figure 29.21 **(C, D)** Postoperative appearance following advancement of the chin with sliding horizontal osteotomy and chin implant placed over advanced chin.

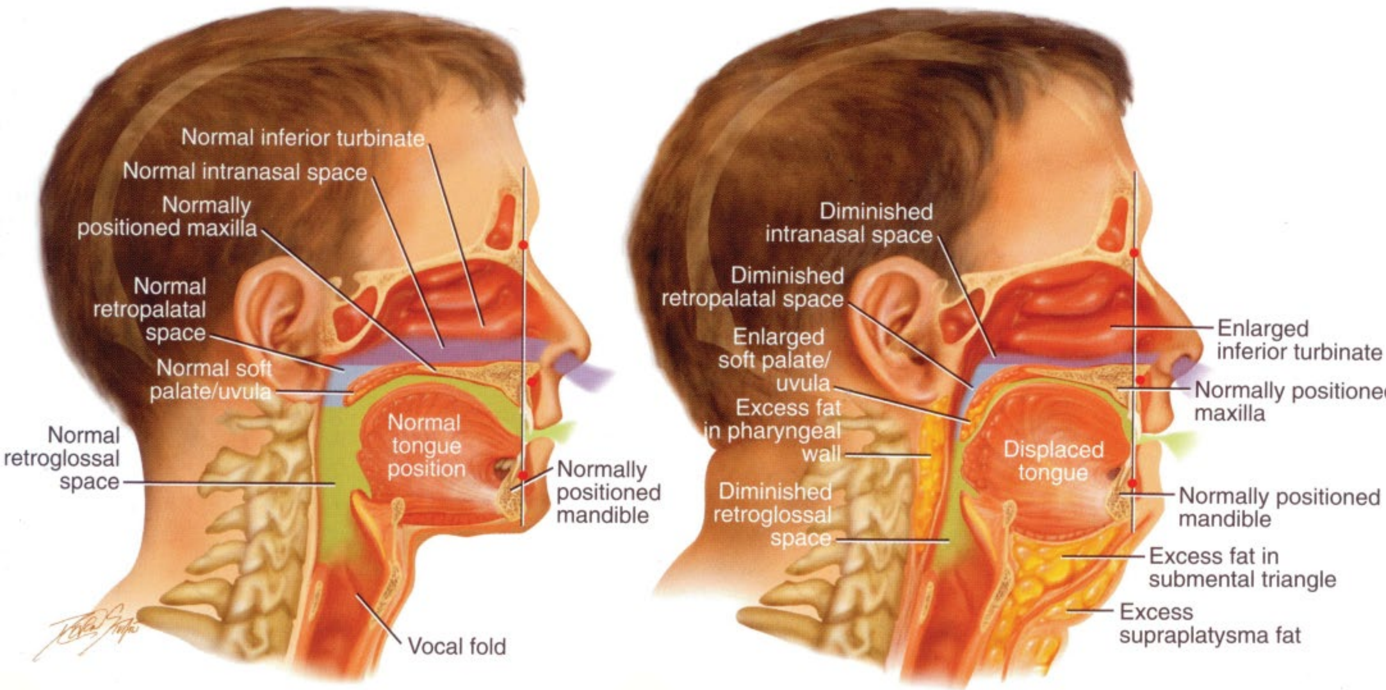

Figure 29.22 **(A)** Illustration of the changes that occur in a normocephalic male that decrease the posterior airspace. *Source:* Figure courtesy of Dr Jeffrey C. Posnick, *Orthognathic Surgery. Principles and Practice*. 2014. Published by Saunders, an imprint of Elsevier Inc. Chapter 26, Figure 26-1, page 995.

Figure 29.22B illustrates how a patient with a preexisting hypoplastic mandible predisposes a patient for OSA and how maxillomandibular advancement surgery can effect a change that is not only esthetically pleasing but is beneficial to the patient's health as it makes positive effects on the airway space.

Figure 29.22C illustrates a necessary maxillomandibular advancement to correct OSA in a middle-aged man with a short face jaw growth pattern and a harmonious occlusion.

The usual workup involves obtaining a polysomnogram (sleep study) to determine the severity of OSA. Patients with apnea–hypopnea index (AHI) per hour of above 20 with oxygen desaturations below 90% are candidates for maxillomandibular advancement if their symptoms dictate and they are unable or unwilling to use CPAP. In addition to the polysomnogram, a cephalometric workup which may include software that can measure and detect the area of greatest constriction is used to plan the surgery. Most practitioners aim for a 10 mm advancement with a counterclockwise rotation of the maxillomandibular complex. Such large advancements may necessitate impaction of the anterior maxilla to prevent too much tooth show but also add to the desired counterclockwise movement.

Surgical cures of OSA are considered if the AHI can be lowered to below 5. Many patients begin with AHIs of above 80, and a reduction of the AHI to below 15 is considered a success but not a cure.

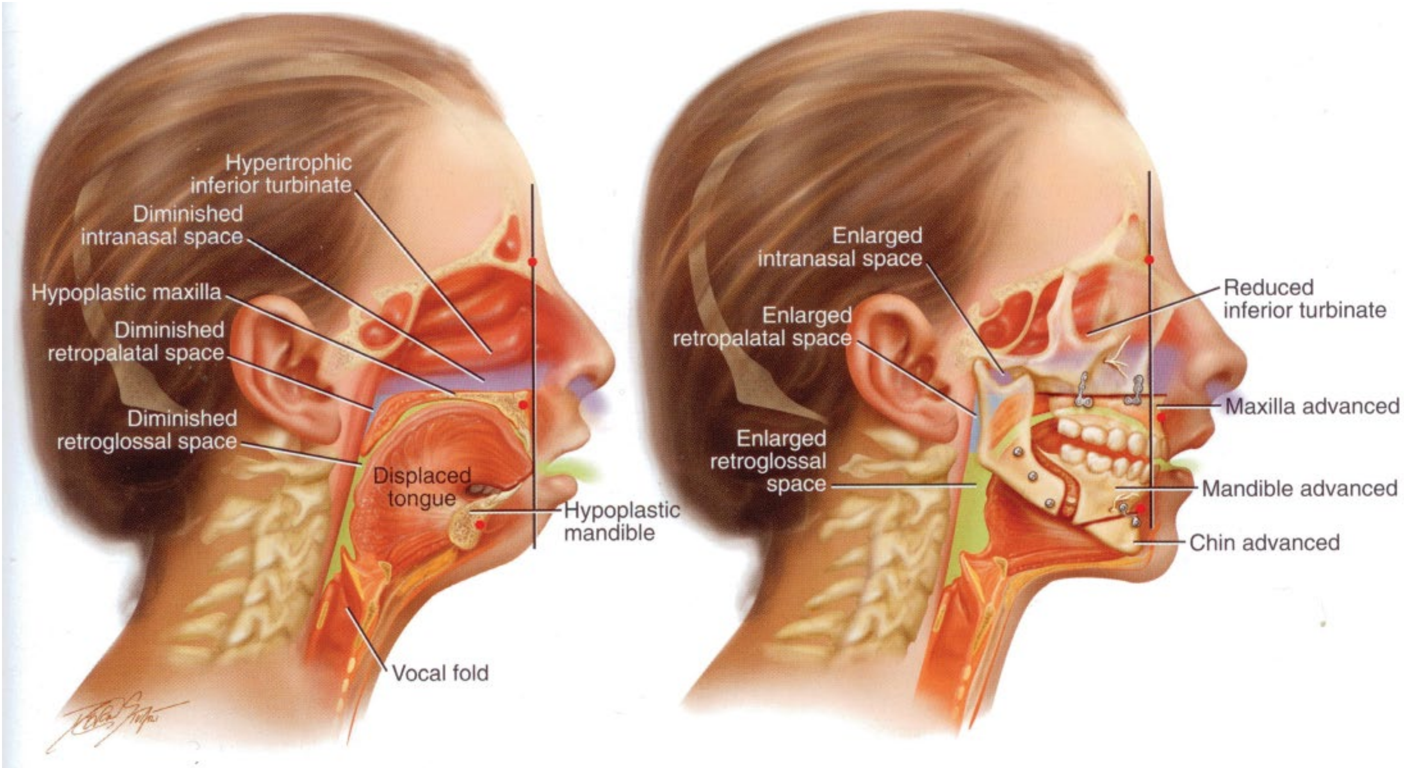

Figure 29.22 **(B)** Illustration of how a patient with a preexisting hypoplastic mandible predisposes a patient for OSA. *Source:* Figure courtesy of Dr Jeffrey C. Posnick, *Orthognathic Surgery. Principles and Practice*. 2014. Published by Saunders, an imprint of Elsevier Inc. Chapter 26, Figure 26-2, page 997.

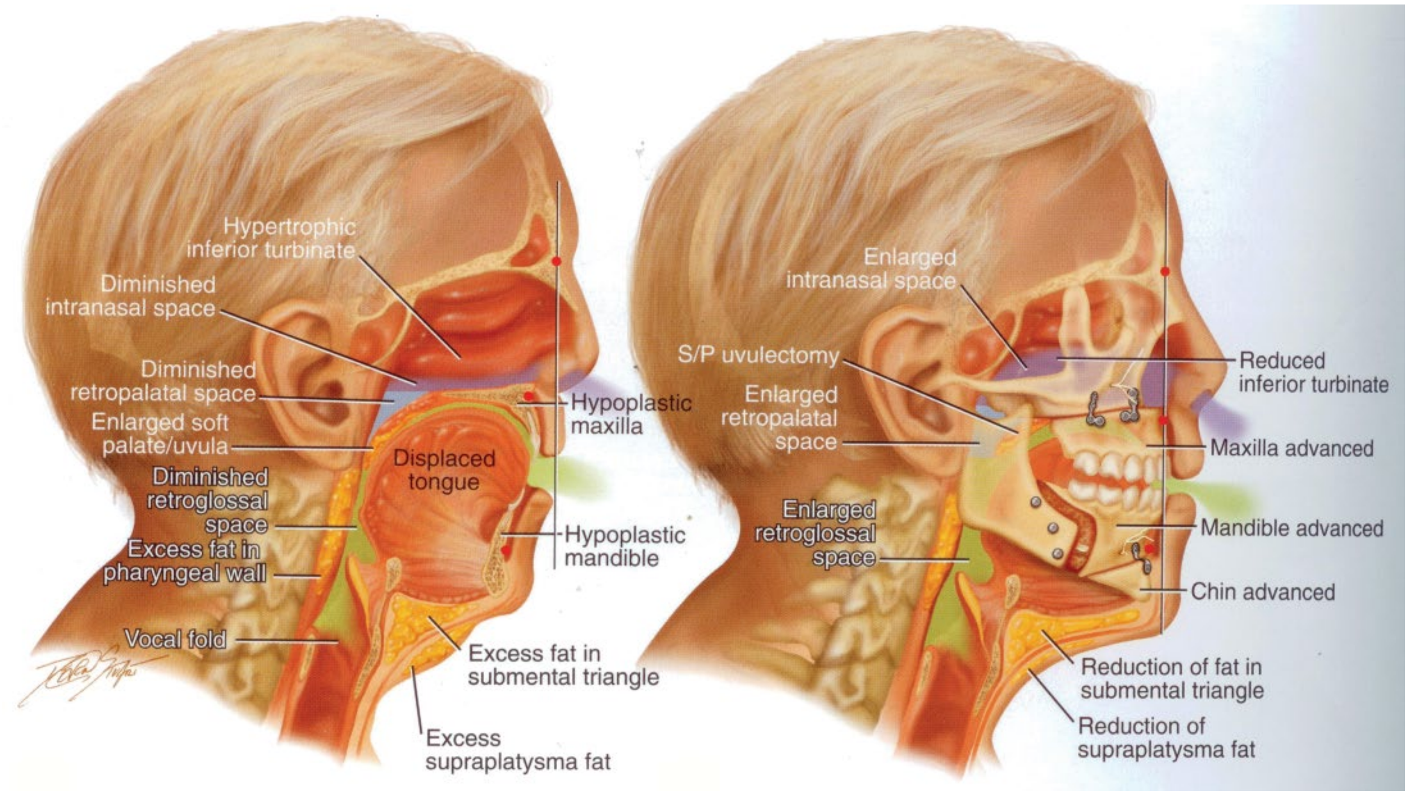

Figure 29.22 **(C)** Illustration of a necessary maxillomandibular advancement to correct OSA in a middle-aged man. *Source:* Figure courtesy of Dr Jeffrey C. Posnick, *Orthognathic Surgery. Principles and Practice*. 2014. Published by Saunders, an imprint of Elsevier Inc. Chapter 26, Figure 26-3, page 998.

Figure 29.22 **(D)** This 18-year-old female had OSA as a result of severe juvenile rheumatoid arthritis which had produced severe bilateral resorptions of condyles. **(E)** Her maxilla was advanced 6 mm and her mandible 15 mm, along with a 7 mm chin advancement genioplasty. A good esthetic and functional result was achieved that cured her OSA.

Figure 29.22 **(F)** This patient also suffered from OSA. **(G)** Her significant mandibular advancement cured her OSA, and although the chin protruded excessively, she was nonetheless very pleased.

The patient in Figure 29.22D and E achieved an OSA cure with esthetic improvement via maxillomandibular advancement, while the patient in Figure 29.22 F and G achieved OSA cure from maxillomandibular advancement at the expense of a too prominent lower face. She was nevertheless pleased.

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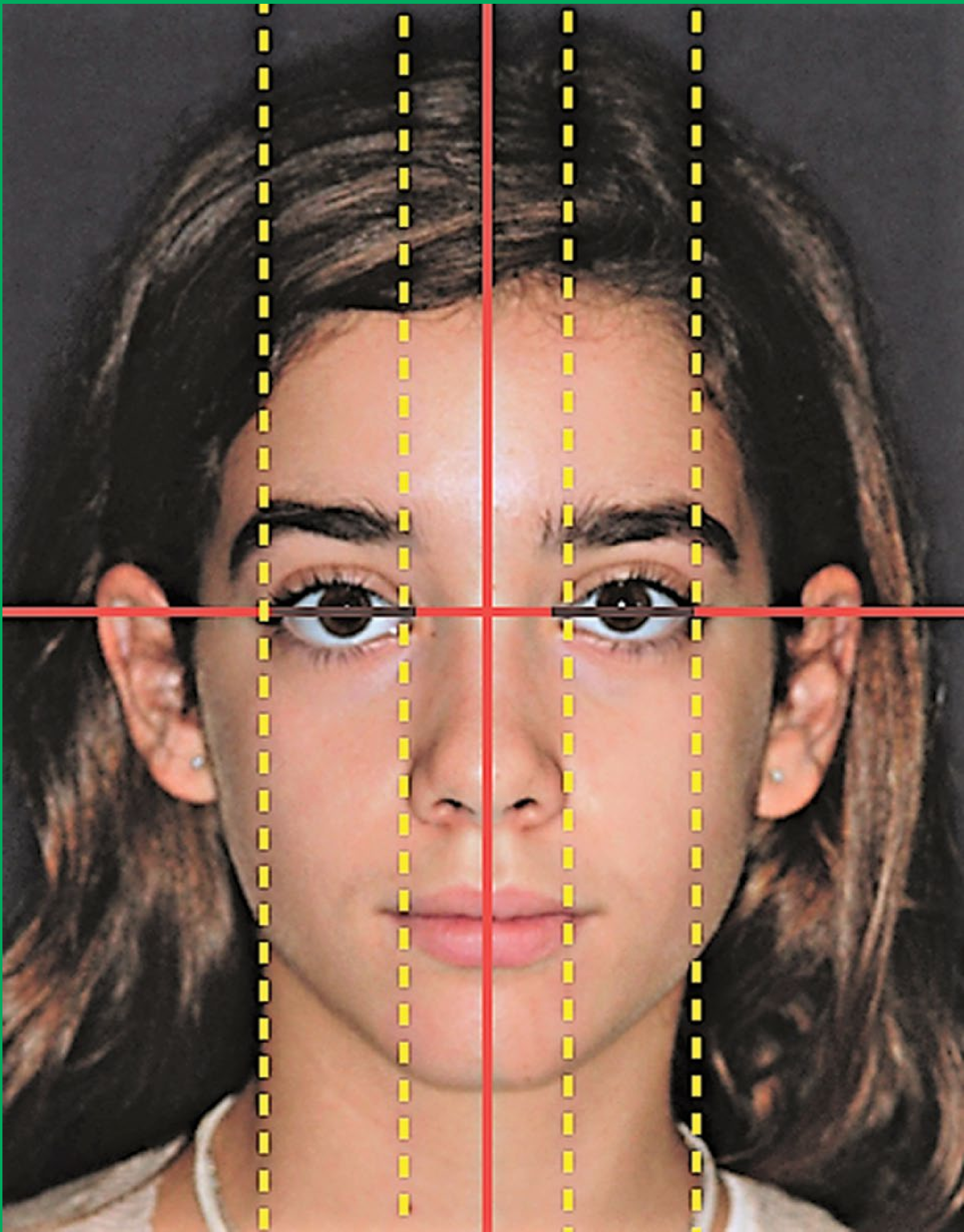
PART 6
ESTHETIC PROBLEMS OF SPECIAL POPULATIONS, FACIAL CONSIDERATIONS, AND SUPPORTING STRUCTURES



Chapter 30 Pediatric Dentistry

Claudia Caprioglio, DDS, MS, Alberto Caprioglio, DDS, MS, and Damaso Caprioglio MD, MS

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To quote Jean Cocteau, "A defect of our body, if corrected, can improve our soul," or, to paraphrase an old Jewish saying, "He who gives a smile to a child gives a smile to the world."

In the period that spans the end of deciduous and the beginning of early mixed denition, the esthetics and harmony of the dental arches are determined by physiological changes in the teeth and the presence of diastemas, a correct canine relationship, and a correct occlusal plane. The occlusion of the primary dentition should be considered a biological unit with specific esthetic, functional, and skeletal characteristics, and the main role of the pediatric dentist is to monitor its evolution throughout childhood and adolescence.

The pediatric dentist's duty is actually twofold: to perform preventive and/or conservative dentistry and also to apply the space management techniques necessary to ensure an optimal morphofunctional outcome.

To allow a modern, dynamic approach to pediatric dentistry, close interaction between the dentist, parents, and child is crucial. Furthermore, the chosen approach, methods, and timing of application are more likely to be correct if the child is first seen

Ronald E. Goldstein's Esthetics in Dentistry, Third Edition. Edited by Ronald E. Goldstein, Stephen J. Chu, Ernesto A. Lee, and Christian F.J. Stappert.

very early on, at 2–3 years of age. Children are naturally fearful of new experiences, and in the case of dental treatment this fear is linked not only to the technology used—high-tech instruments are involved—but also to cultural, environmental, and psychological factors. Thus, a correct psychological approach is essential to gain the child's trust and cooperation, which are necessary for successful treatment.

The goal of pediatric dentistry is to educate both children and parents about clinical prevention (fluoride use, pit and fissure sealants) and tertiary prevention (the limiting of complications and restoration of optimal conditions).[1,2] The common objective is tissue preservation: new techniques and instruments such as digital radiology with low radiation emission, diagnostic lasers, dental operative microscope, minimally invasive therapy (ozone therapy, air abrasion, and laser micropreparation) allow a stress-free approach and are very effective treatment options.[3]

Materials and techniques

Therapeutic strategies used in the primary dentition must be based on careful evaluation of the physiological state of the deciduous tooth and of the likely efficacy of the treatment. A careful diagnostic workup must be performed to arrive at an accurate prognosis. Furthermore, pulp and periodontal lesions of the primary dentition differ from those of the permanent dentition, and a poor awareness of the available pulp treatment options may result in insignificant therapeutic improvements, and thus treatment failures and, consequently, unnecessary additional treatment procedures and use of materials. The reader is advised to consult the literature for more detailed information on this aspect.[4–6]

The currently available materials for the restoration of teeth in primary and mixed dentition are briefly described here.

The introduction of light-cured composite resins has changed clinical pediatric dentistry. These materials are, indeed, welcome treatment options that address both esthetic and functional issues. Their advantages are their considerable hardness, high rigidity, and high resistance to compression. However, these materials are very technique sensitive and can show marginal infiltrations, reduced wear resistance, polymerization contractions, surface roughness, and discoloration.

Composite resins are the materials of choice to restore anterior teeth, the recommended ones being microfilled hybrid composite resins. More research into these materials has led to considerable improvements, particularly in traumatology, and thus to the possibility of achieving tooth fragment reattachment. This, in turn, has allowed dentists to exploit true biological restorations to achieve a good anterior guide, improved resistance to wear, and higher color stability in the follow-up years.[7,8]

Composite resins can be used for Class I and II restorations of posterior teeth, where etching time is an extremely important factor.[9] Furthermore, the use of a glass ionomer cement as a cavity base and reconstruction of the tooth by applying the incremental technique and using a rubber dam have been found to reduce the wear index and improve cavity adhesion. Marginal adaptation is, instead, influenced by the kind of polymerization (direct or incremental).[10]

Glass ionomers and modified ionomer cements

These materials first appeared in the early 1970s. They are composed of a powder, a calcium–fluoride–aluminum silicate glass, and a liquid, generally a polyacrylic or polymaleic acid. Considering their capacity to bond with dentin, fluoride-leaching properties, and high resilience, these materials have proved to be useful in the treatment of caries lesions in primary molar teeth.

Resin cements are the most popular and most routinely used cements in dentistry. The main dental cements available for stabilizing porcelain-fused-to-metal, all-ceramic, or all-metal restorations include resin-modified glass ionomer (RMGI) cements, resins requiring a separate self-etching bonding agent, resins that incorporate a self-etching primer, and resins used with total-etch bonding systems.[11] Although these materials have a higher percentage of failure than amalgam (33% versus 20%), and although they lack abrasion resistance, translucence, and multiple color choices, they nevertheless offer great advantages: minimal destruction of sound tooth tissue and less use of local anesthetic.

RMGI cements are polymerizable materials whose resin compound also improves fracture resistance. They are recommended for Class I and II restorations in primary teeth, which typically do not last beyond 3 years. RMGIs are associated with little or no tooth sensitivity postoperatively, form a natural chemical bond with the tooth structure, offer moderate strength compared with other cements, release fluoride ions, are relatively insoluble in oral fluids, and have demonstrated positive in vitro clinical characteristics.[12,13]

Compomers

Introduced in the early 1990s, compomers are materials made from mixed composite resins with an acid modification; therefore, they are more similar to composite resins than glass ionomers. They do not have improved characteristics of resins, but they are easy to handle, which reduces operating times and makes them a good option for restorations. In a study that evaluated and measured compression resistance, flexion resistance, microhardness, and surface roughness of three different compomers, the values obtained were compared with those of a composite resin and an RMGI cement. The flexion and compression resistance values and the microhardness of the compomers tested were found to be higher than those of the cement but lower than those of the composite resin, whereas no significant differences in surface roughness values were reported.

Compomers demonstrate the following properties:

- good adhesion to dental tissues (a dentinal adhesive is used instead of acid etching);

- easy handling, enhanced by the possibility of incremental polymerization;
- a reduced marginal fissure due to their property of absorbing water during hardening;
- a good fluoride absorption-release system;
- an acceptable range of colors and brightnesses that allows good esthetic results, albeit not quite comparable to those of composite resin.[14]

Thanks to the availability of these dental restorative materials, the pediatric dentist can apply preventive treatments and perform early conservative therapy and, in the most severe cases, restore function and improve esthetics. Improved treatment techniques, better materials, and a heightened awareness of the benefits of preventive dentistry are together allowing more predictable results based on achievement of the postulates of successful pediatric dentistry:

- optimal esthetic restoration;
- elimination of infection, inflammation, and pain;
- maintenance of the arch perimeter length;
- stimulation of alveolar growth.

There are also alternative treatment solutions that exist based on other means of cavity excavation, namely ozone therapy and laser therapy.

Ozone therapy

Ozone is a strong oxidizing agent, present in nature as triatomic oxygen (O_3). Rich in energy but with a very unstable structure, O_3 has a very effective and rapid oxidizing action. It also has a strong disinfecting power and an effective antibacterial activity, also on cariogenic bacteria. Ozone therapy is able to disinfect the treated area and to induce biofilm acid proteins lysis. Despite the use of rotary instruments, anesthesia is not required during pediatric treatments using this technology; because the carious dentin is sterilized, it does not need to be removed. Ozone therapy is useful for treating fissure, root, and cervical caries, for Class V restorations, and for desensitizing carious cervical tooth substance. The ozone generated is delivered by a multilumen tube and special handpiece with a silicon single-use cup; a hermetic seal must be obtained, and application time ranges from 10 to 60 s.[15,16]

Laser-assisted pediatric dentistry: minimally invasive treatment

Laser technologies are alternative methods that sometimes complement and sometimes replace traditional techniques; various applications, using different laser wavelengths, are possible on both soft and hard tissues.

Although this is not the place for a detailed discussion of the physical basis of laser therapy, it should nevertheless be remembered that the various wavelengths interact in different ways with the different chromophores (hemoglobin, water, hydroxyapatite) contained in the target tissues (mucous membranes, gingiva, dental tissue); thus, treatments are influenced by the optical affinity and absorption coefficients of the tissues for each particular wavelength. This issue is still debated in the literature; indeed, with various wavelengths advocated for hard tissue removal, there continues to be certain heterogeneity with regard to recommended laser parameters and power densities. Erbium lasers (Er:YAG and Er,Cr:YSGG) are the most efficient for cavity preparation and, when the parameters are right, they have low thermal side effects.

Although there is clearly a great need for "gold standards," these would be difficult to establish in practice, given the variety of laser parameters (pulse repetition rates, amount of cooling, energy delivered per pulse, and types of pulse, etc.) and the existence of target tissue-related factors that also influence the interaction (i.e., whether the target tissue is healthy enamel, decayed enamel, or dentin, and the extent of its (de) mineralization).

Laser–tissue interaction

Laser light (laser energy) may interact with the target tissue in four different ways, depending on its optical properties:

- It may be absorbed by the target tissue. The amount that is absorbed depends on certain characteristics of the tissue, such as pigmentation and water content, and on the laser wavelength and emission mode.
- It may be transmitted through the tissue (transmission is the opposite of absorption). This has no effect on the target tissue. This phenomenon is highly dependent on the wavelength of the laser light.
- It may be reflected from the tissue surface (reflection). This, too, has no effect on the target tissue. A caries-detecting laser device (DIAGNODENT®-kavo) uses reflected light to measure the amount of sound tooth structure. Two types of reflection are described: specular and diffuse.
- It may be scattered. Scattering weakens the intended energy and possibly produces no useful biological effect.

Hard tissue removal: absorption and laser ablation

Hard tissue laser ablation exploits a series of biophysical properties, such as wavelength, energy density, and pulse duration of the laser radiation, as well as the properties of the tissue (tissue interaction). The laser energy must be absorbed by the target to achieve tissue removal, which, in this context, is the primary beneficial effect of laser energy. The goal of dental laser applications is to optimize this photobiological effect.

The lasers used in dentistry to remove hard tissue are those belonging to the erbium family. Both the solid-state Er:YAG laser (2940 nm) and the Er,Cr:YSGG laser (2780 nm) have a high affinity for water and hydroxyapatite. This explains their effectiveness when working on enamel, dentin, and bone.

The energy is transferred to the target tissue through a handpiece attached to an articulated arm or an optical fiber. The handpieces used in dentistry may be contact-free (noncontact) or contact, straight, or angled. Erbium lasers can be regulated by the operator, who can adjust pulse energy (millijoules), frequency (hertz or pulses per second), and duration (long, short, very short), the air–water spray, and the size of the focal spot (increased: focused mode; decreased: defocused mode). Various studies and clinical reports have shown that the laser, often used as an alternative to rotary instruments in pediatric restorative dentistry, offers an added measure of safety and new scope for minimally invasive interventions even in the treatment of very young children. Overall, it is better accepted than traditional techniques.[15,17]

The mechanisms underlying tooth structure removal, which is based on the principle of ablation or decomposition of biological materials, are photochemical, photothermal, and plasma mediated.

Currently, laser removal of tooth substance is based on the principle of thermal ablation: laser energy is coupled into the irradiated material by an absorption process that yields a rise in temperature. A shockwave is created when the energy dissipates explosively as a volumetric expansion of the water contained in the hard tissue. This process is called *cavitation*. Efficient conversion of this incoming energy into a temperature increase depends on the presence of an absorptive component in the irradiated material. All dental hard tissues contain water; water molecules in the target tissue become superheated, an explosion occurs, and, in turn, the tooth structure and/or caries is ablated.

Laser removal of tooth substance generates a characteristic popping sound. The free-running pulse-mode provides the maximum power to facilitate the explosive expansion; with an adequate amount of water spray, thermal pulp damage can be avoided; temperature rises up to 3–5 °C. The Er,Cr:YSGG laser system generates a loud snapping sound even when used in a noncontact mode; it is an effect termed "plasma decoupling" of the beam with a hydrokinetic cutting. The microexplosion of the water molecules removes the decayed dental hard tissue (mechanical effect); however, because the water contained in the decayed hard tissue evaporates rapidly, the healthy tissue is conserved (thermal effect).[18]

With these technologies, it is essential to use the correct parameter settings to prevent structural alterations and/or pulp reactions and preserve the integrity of the cells. Enamel treated with correctly set lasers appears chalky, without carbonization, and with the characteristic lava-flow appearance: grooves, flakes, shelves, and sharp edges are all features more indicative of microexplosions than of melting; other features are open prisms and dentin with open tubules and a difference in the mineral thickness between peritubular and intertubular dentin.

The clinical applications of erbium lasers range from prevention to conservative treatment of primary and permanent teeth (immature and mature) affected by superficial (tooth enamel hypoplasia, mild discolorations) or deep lesions.

Pediatric laser treatment generally offers the following advantages:

- minimum invasiveness;
- selectiveness and effective cleansing;
- less (or no) anesthesia;
- positive psychological impact.[3,19]

Adhesion to erbium-lased tooth structure

The adhesion of composite to lased surfaces continues to be a controversial topic. Many authors have reported that adhesion to laser-ablated or laser-etched dentin and enamel of permanent teeth is lower than adhesion to surfaces treated conventionally (with rotary preparation and acid etching). Studies stress the importance of energy output and of avoiding substructural damage, the need for standardized laser energy outputs for different tooth substrates, and the need to acid etch both dentin and enamel, even after laser conditioning and in primary dentition.

Although Er:YAG laser ablation creates a smear-layer-free dentin surface, acid etching nevertheless seems to be necessary to expose any dentin collagen that is needed to allow hybridization with the bonding agent. The term "laser etching," used several times in the laser literature, refers to the laser-induced modification of the tooth surface at lower fluence; a more appropriate term would be "laser conditioning." Recrystallization of the dentinal apatite possibly with the formation of an additional phase of calcium phosphate results in vitrification. The degree of vitrification inevitably depends on the amount of laser energy the dental substrate is subjected to, given that the phenomenon is induced by the production of heat. It has been reported that Er:YAG laser irradiation reduces the carbon-to-phosphorus ratio and leads to the formation of more stable and less acid-soluble compounds that can hamper the chemical adhesion of ionomer cements and the activity of etching and conditioning products. A more acid-resistant surface was found after Er:YAG laser treatment in enamel; this feature also seemed to be present in peritubular dentin. On lasing at subablative energy densities, it emerged that temperature induces loss of carbonate; carbonate loss begins at 100 °C and becomes more intensive at 700 °C. Complete carbonate loss is reached at around 1000 °C (melting point). Chemical alterations may also appear on laser-irradiated dentin after application of subablative Er:YAG laser energy densities: degradation, loss of H_2O, and an increase of OH were reported. In addition, factors such as pulse duration, output energy, and water cooling have been seen to influence the chemical composition of the Er:YAG-lased dentin substrate. The excessive heat that can be generated during cavity preparation may cause denaturation of the collagen network and a decrease in dentin permeability. The importance of energy output cannot be understated, and there is clearly a need to establish relevant gold standards for optimal enamel and dentin preparations, as well as for conditioning.

The bond strengths of the currently favored three-step etch-and-rinse adhesives and of the two-step etch-and-rinse adhesives used in Er:YAG-lased cavities are higher than those of the newer self-etching systems. The current data on the bond strengths associated with the use of laser systems on enamel and dentin surfaces suggest that it is better to avoid using these systems and that acid etching of lased surfaces is still to be preferred.

Glass ionomers are auto-adhesive materials that bond to dental tissue through combined micromechanical and chemical mechanisms. The Er:YAG laser creates a rough surface that could favor this material retention. Data on the tensile bond strength of glass ionomer cements in association with laser dentistry are very scarce. All studies on microleakage in association with glass ionomer cements, both pure and resin-modified, showed that these materials failed to prevent microleakage, regardless of whether the tooth substance was lased or prepared with a high-speed handpiece. Furthermore, it was demonstrated that leakage at the gingival margin was, in both cases, higher than at the occlusal enamel margins.

Soft-tissue applications

The laser as a means of removing diseased oral tissue and treating lesions of the oral mucosa has specific applications in the field of pediatric dentistry. All laser wavelengths with optical affinity for hemoglobin and water (the chromophores contained in gingival tissue and the oral mucosa) can be used for these applications; argon, KTP, diode, Nd:YAG, and CO_2 lasers are useful for soft-tissue cutting, vaporization, and decontamination. Also, because of their excellent coagulating and haemostatic actions, they are also ideal for vascular lesions. The Er,Cr:YSGG and Er:YAG lasers are also effective for these applications owing to the good absorption of their wavelengths by the water contained in the gingival tissues and mucosa, but they provide less effective bleeding control. The use of an air–water jet delivered through the handpiece of the erbium laser allows a clean incision and vaporization of the soft tissues with a limited increase in temperature; furthermore, the absence of peripheral necrotic tissue makes it possible to carry out very accurate biopsies.

Many authors agree on the advantages offered by laser applications for the treatment of soft tissues: these lasers are quick and easy to use, reduce the use of local anesthesia, allow excellent control of bleeding during incision making, provide effective decontamination, allow the use of sutureless techniques, and result in postoperative healing by second intention, which is often asymptomatic due to the laser's decontaminating, antalgic, and biostimulant effects; there is, therefore, also less need for analgesic anti-inflammatory medications.

Lasers are suitable for the following procedures:

- soft-tissue surgery (gingivectomies, gingivoplasties, surgical cutting, removal of foreign bodies, frenectomies, operculum cutting);
- treatment of periodontal defects;
- socket decontamination;
- biostimulation;
- treatment of labial herpes, oral aphthosis, hemangiomas, fibromas, papillomas, epulis, mucocele, eruption problems, or dentigerous cysts.

The use of lasers, with different wavelengths, is well documented in adult endodontics, but few studies have been conducted in the field of pediatric endodontics. Lasers in endodontics are indicated for pulp capping, pulpotomy, and root canal disinfection.

The PubMed library indexes several studies that investigate laser performance in maintaining pulp tissue vitality. Different devices, and thus different laser wavelengths and parameters, are used in these studies. A common feature was the low level of laser power applied (0.5–1.0 W), delivered in a defocused mode, preferably using a low repetition rate or superpulsed mode.[20]

Esthetic dentistry: operating procedures

Over the past 15 years, composite resins have been revolutionized. Their adhesion, polish, and esthetics have improved so much that they are now the best restoration material for anterior teeth damaged by caries or trauma, direct or indirect. One of the undeniable merits of this kind of restoration is the "reversibility" of the treatment, which allows it to be redone when necessary.

Procedure

Step 1: Carefully evaluate the tooth shape and the position of the contralateral tooth, so as to plan the reconstruction.

Step 2: Choose the color of the restoration, as the subsequent isolation with a rubber dam will not allow an accurate assessment of this aspect.

Step 3: Isolate the area and remove the carious lesion, taking care to conserve as much healthy tooth tissue as possible.

Step 4: Laser preparation. The erbium family of lasers can provide effective thermomechanical ablation of tooth tissues without side effects on surrounding tissues, removing the smear layer, opening and cleansing dentinal tubules, and effecting decontamination.

Step 5: Reconstruction. Ensure modeling is as precise as possible to reduce chair time and improve the final esthetic outcome.

Step 6: Finishing. It is sometimes possible to use a flame-shaped diamond bur to reproduce the microanatomy of the rather irregular enamel surface. The finishing phase is completed by using disks of different granulometry and rubber polishers.

Step 7: Remove the rubber dam and evaluate the results. Next, polish the interproximal areas with pop-on disks and abrasive strips, taking care not to remove the contact point. Then, polish the other areas of the buccal face using rubber cups and polishing pastes with decreasing particle size.

Step 8: Color check. After initial dehydration, the tooth regains its original color. Note that chromatic evaluations should be postponed to the subsequent visit.

Clinical case 30.1: Preventive resin restoration in a 7.2-year-old

Problem

This 7.2-year-old female had a Class I carious lesion in tooth #3. The cavity shape and size are determined by the extent of the carious process; nevertheless, it is important to treat the patient with minimum preparation.

Treatment

Erbium lasers, in accordance with the concept of microdentistry, allow considerable sparing of tissue. The preparation is extended to the surrounding sulcus, thereby obtaining a sealed preventive resin restoration. The use of restorative materials (flow composite or glass ionomer cement) is combined with sealing of the sulcus (Figure 30.1).

(Output energy 150 mJ to 10 Hz for enamel, 100 mJ to 10 Hz for dentin—SMART 2940 PLUS/DEKA.)

Result

A good esthetic outcome with effective decontamination and tissue conditioning thanks to the highly selective action of the laser beam and the removal of only decayed tissue that ensured minimum tissue loss (Figure 30.2).

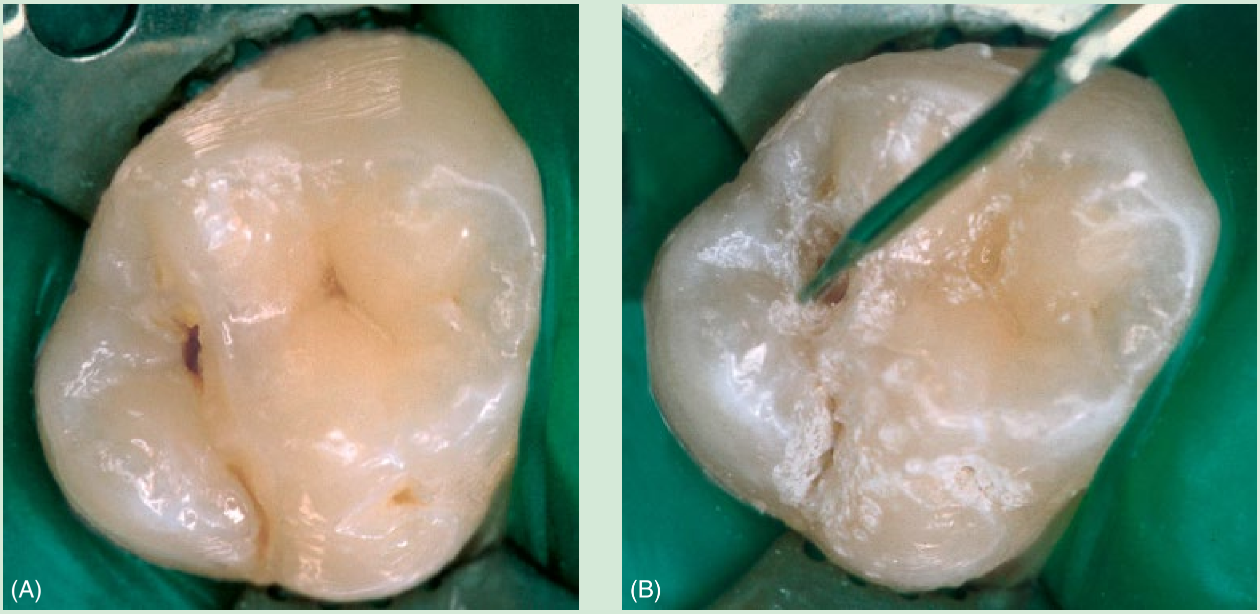

Figure 30.1 Class I carious lesion of tooth # 3 **(A)**. Minimally invasive laser-assisted preparation and manual removal of softened tissue **(B)**.

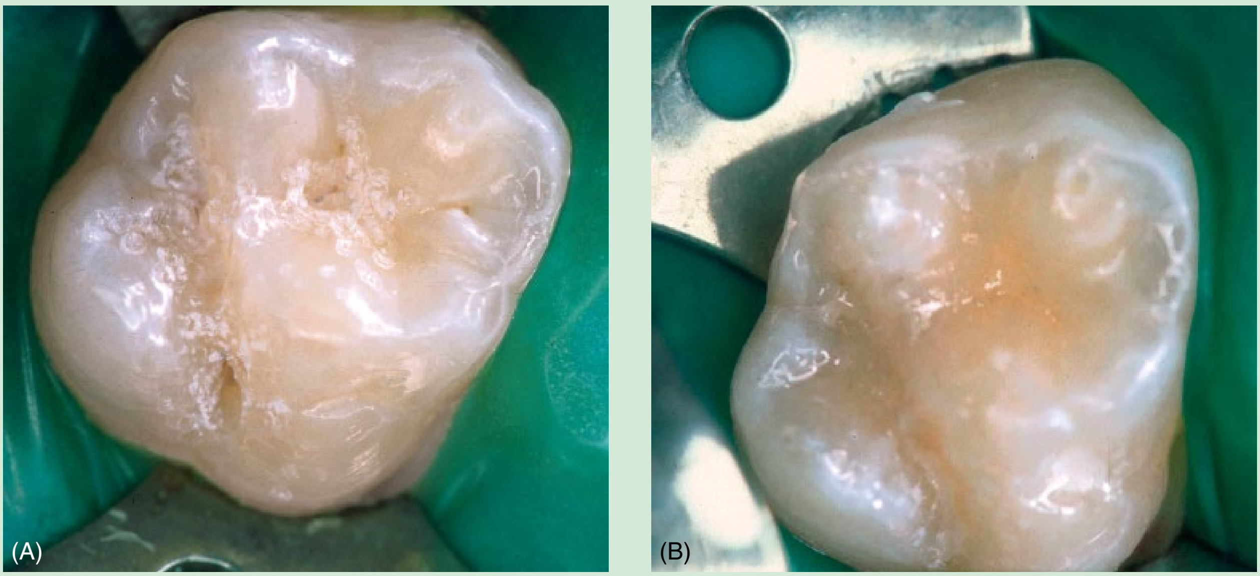

Figure 30.2 Occlusal view before acid etching **(A)** and final restoration of the palatal site with flow composite resin and application of a pit and fissure sealant to the occlusal site **(B).**

Clinical case 30.2: Amelodentinal dysplasia

Problem

This 8.1-year old female had amelodentinal dysplasia of preventively sealed tooth #14. We needed ensure minimum tissue loss and a conservative approach in a young patient at risk of decay.

Treatment

Enamel or amelodentinal dysplasias, often described as complications of dental traumas, or simply regarded as nonpathological structural abnormalities, are clinical situations in which the esthetic aspect is of paramount importance, even in young children. Laser-assisted therapy is an easy approach allowing good compliance. It is also more economic than other prosthetic therapies and provides a good esthetic outcome with minimum tissue loss. In this case, the hypoplastic area is removed working at low wattage and low output rates, leaving a cratered and extremely irregular surface with a very chalky appearance (Figure 30.3).

Result

Close re-creation of the often quite irregular microanatomy of this young patient's teeth, thanks to the procedure chosen: etching and application of adhesive bonding, use of more opaque composite materials, manual finishing of margins, and polishing (Figure 30.4).

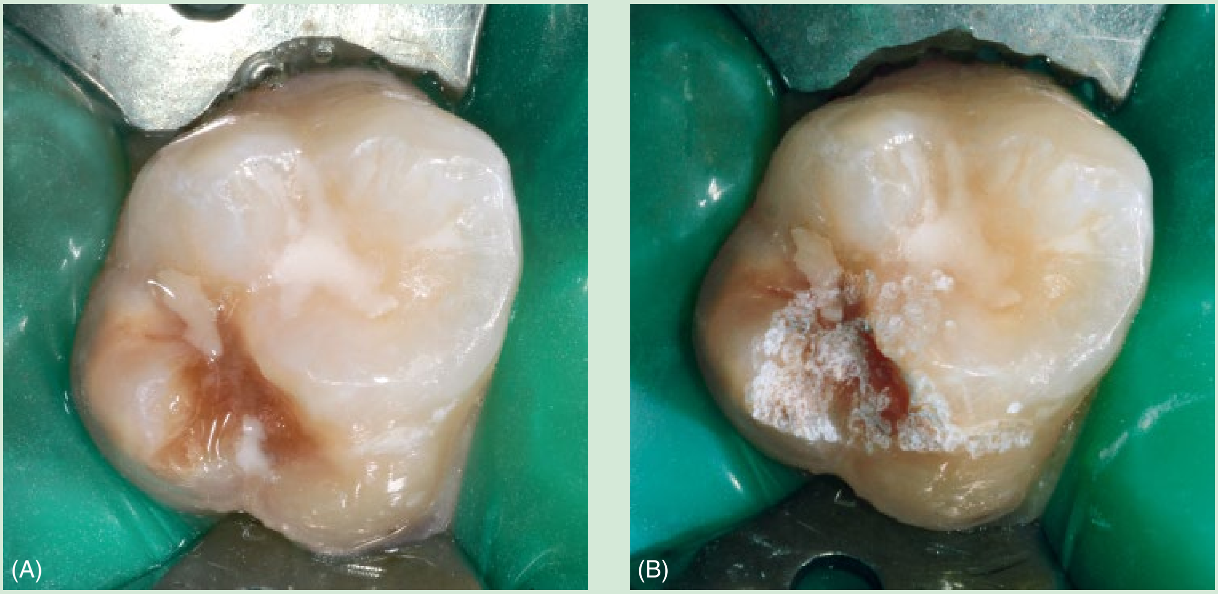

Figure 30.3 Amelodentinal dysplasia of tooth #14 **(A)** which is prepared with an Er:YAG laser **(B)**.

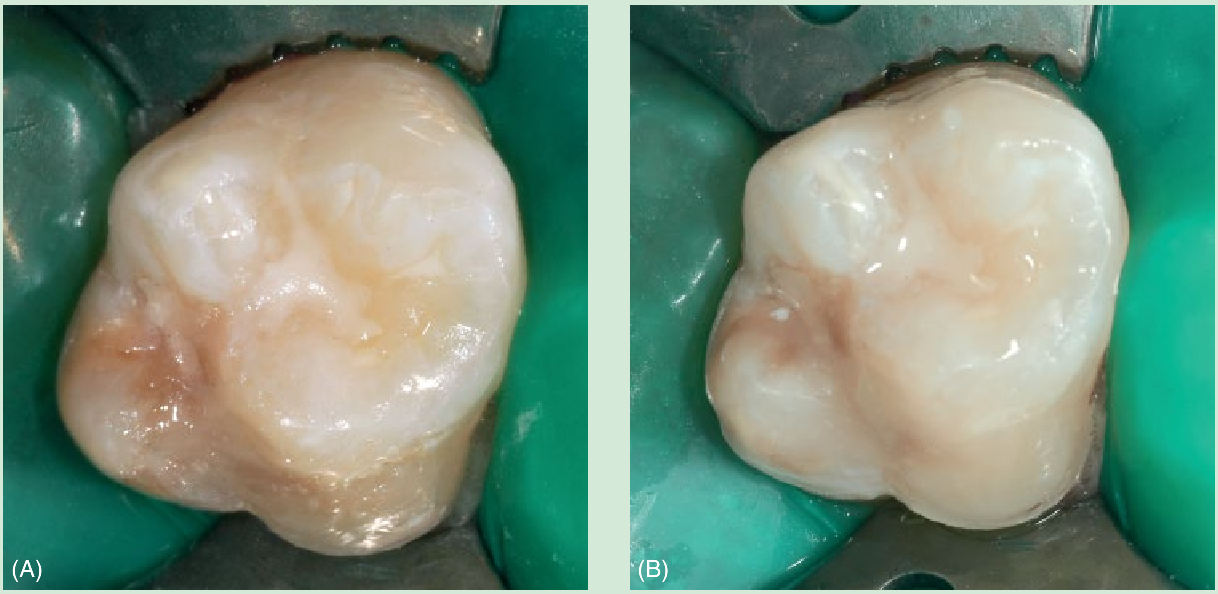

Figure 30.4 Laser preparation guarantees minimum tissue loss **(A)** and a good esthetic final outcome **(B)**.

Clinical case 30.3: A 6.2-year-old male with extensive cavities

Problem

This 6-year-old male patient with interproximal caries of tooth L was not compliant. It was necessary to raise the patient's tolerance threshold through an effective ablation of hard tissue involving no mechanical trauma and reduced or no use of anesthetics.

Treatment

Erbium lasers bring about rapid evaporation of the water contained in decayed tooth enamel and dentin and have an effective ablative effect on hard tissues. Providing the correct parameters are adhered to, structural alterations and/or pulp reactions can be prevented and postoperative complications are reduced (Figures 30.5 and 30.6).

There are several important anatomical ultrastructural differences between permanent and deciduous teeth at the level of enamel and dentin. The enamel prisms of deciduous teeth, unlike those of permanent teeth, do not show an orderly spatial organization. The large superficial crystals are irregular due to posteruption maturation, and the enamel is often aprismatic, which explains why deciduous teeth are more opaque. The aprismatic enamel is more frequently found at the interproximal, vestibular, and oral aspects of the crown. Moreover, the enamel of primary teeth is less mineralized and more porous.

As regards the dentin, the main differences between permanent and deciduous teeth concern the size and number of the dentinal tubules. Operating parameters have to be reduced when working on enamel and dentine of primary teeth, depending on the water and mineral composition of these tissues.

Result

The restoration achieved the esthetic objective and restored normal function and anatomy (Figure 30.7).

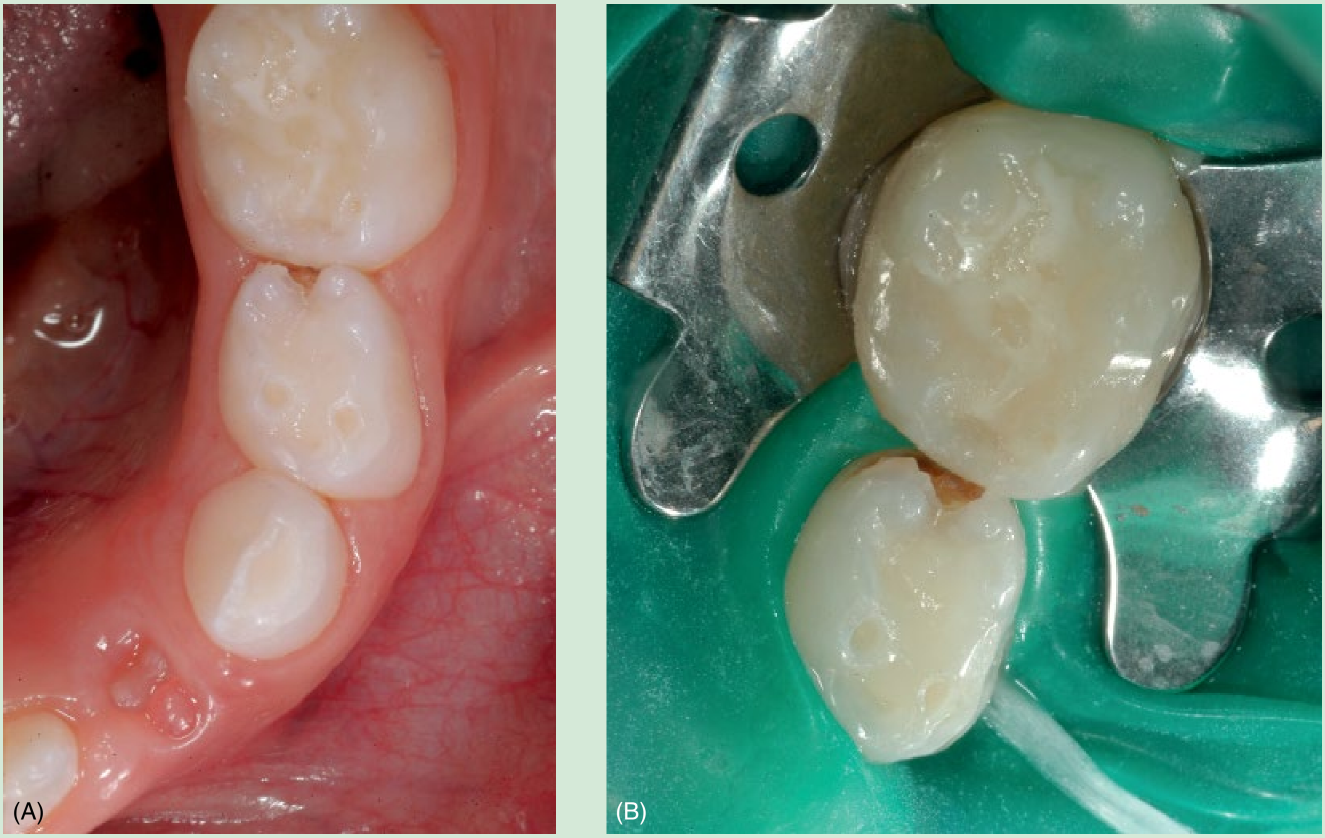

Figure 30.5 Interproximal lesion of tooth L in a very young patient of 6.2 years **(A)**. Rubber dam isolation **(B)**.

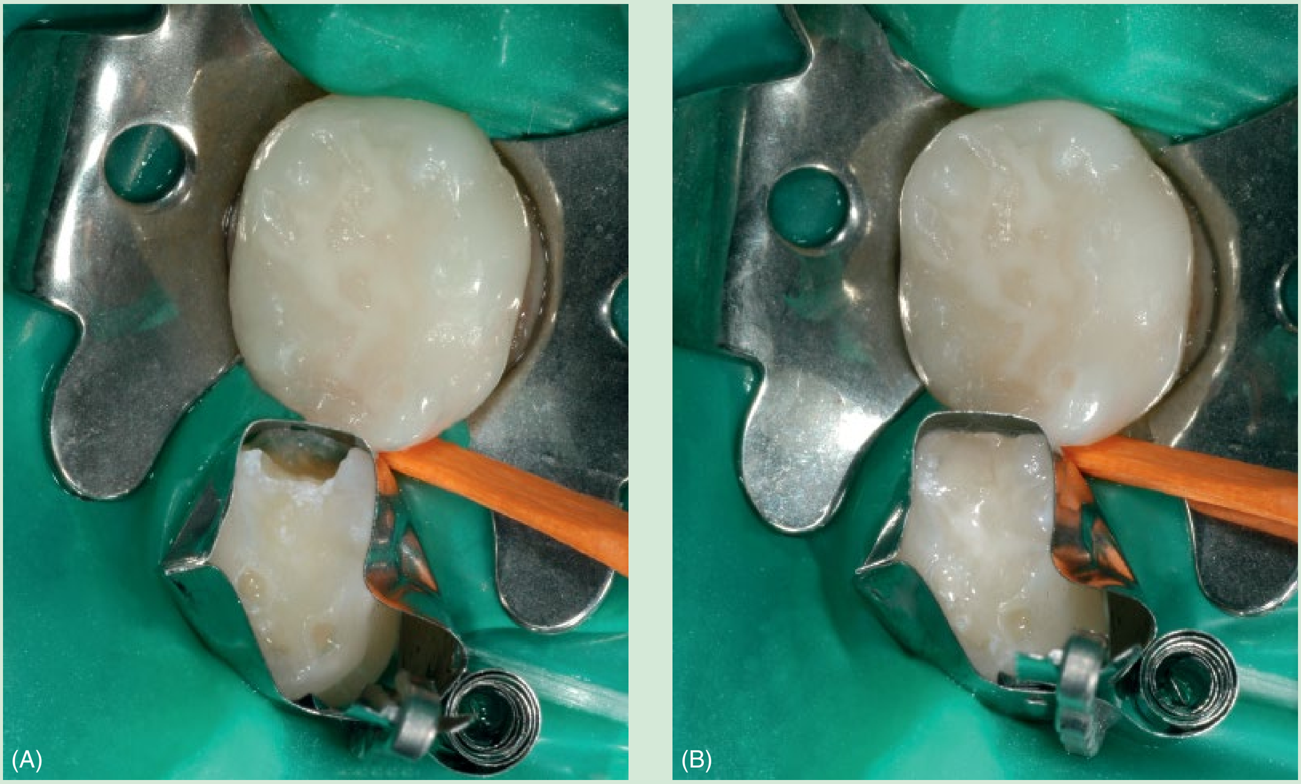

Figure 30.6 Initial preparation with an erbium laser **(A)**. Enamel and dentin are etched, rinsed and dried. The bonding agent is applied **(B)**.

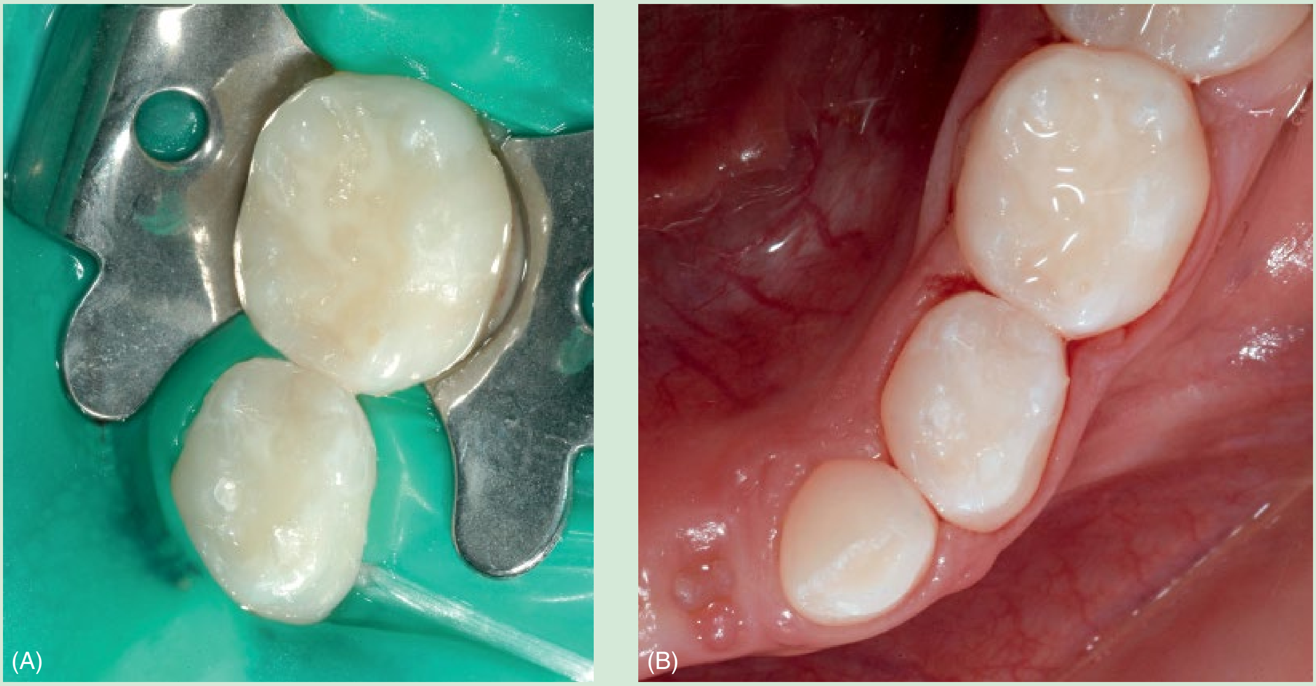

Figure 30.7 A thin layer of flow composite resin is placed and the restoration is completed **(A)**. Final outcome after finishing and polishing **(B)**.

Clinical case 30.4: Enamel hypoplasia

Problem

An 8.4-year-old male patient had severe and diffuse enamel hypoplasia and poor oral hygiene. Surface structure and texture needed restoration with a minimally invasive cavity preparation (Figure 30.8).

Treatment

Ablation of the decayed tissue using an Er:YAG laser. Clinical cases confirm that an acceptable ablation speed and safe procedure can be obtained using lower pulse rates and moderate energy levels (Figure 30.9).

Result

Restoration of morphology and color through the anatomical layering technique. The restoration is built up with one to two layers of dental material (opaque) of the same hue, but with different chroma (the first labial layer having the highest saturation) and a layer of enamel material (translucent). Finishing and polishing with different polishing disks and rubber polishers. A highly reflective surface gloss may be obtained using an abrasive polishing paste (Figure 30.10).

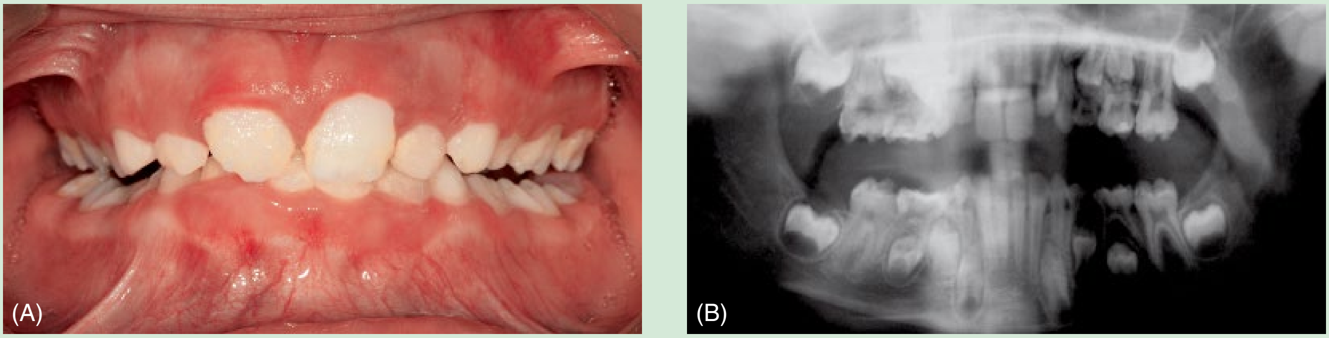

Figure 30.8 Severe enamel hypoplasia in a young patient with poor oral hygiene **(A)**. Orthopantomograph **(B)**.

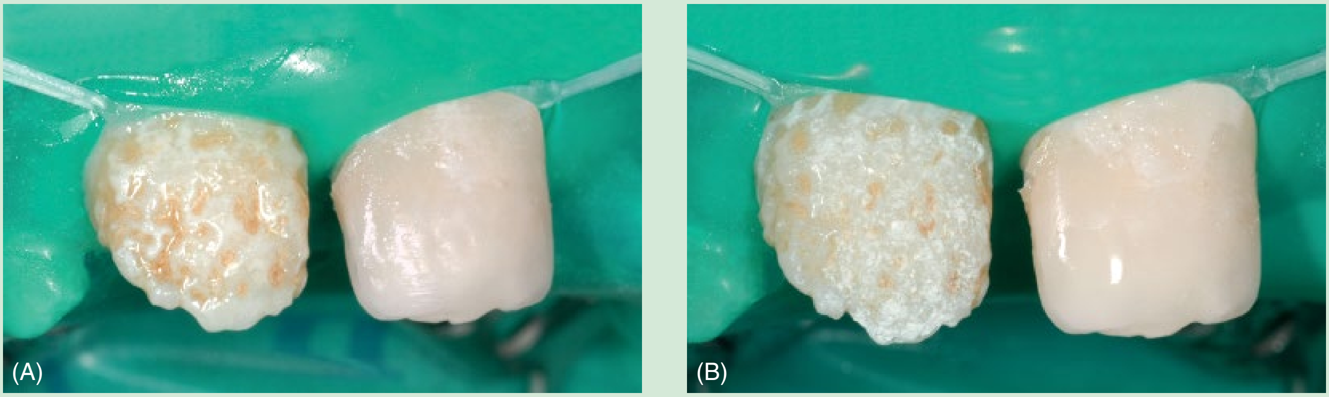

Figure 30.9 Isolation with rubber dam and waxed dental floss. Tooth #9 had already been restored. Postoperative view of tooth #8 **(A)** after laser ablation. Labial view after water rinse and air drying **(B)**.

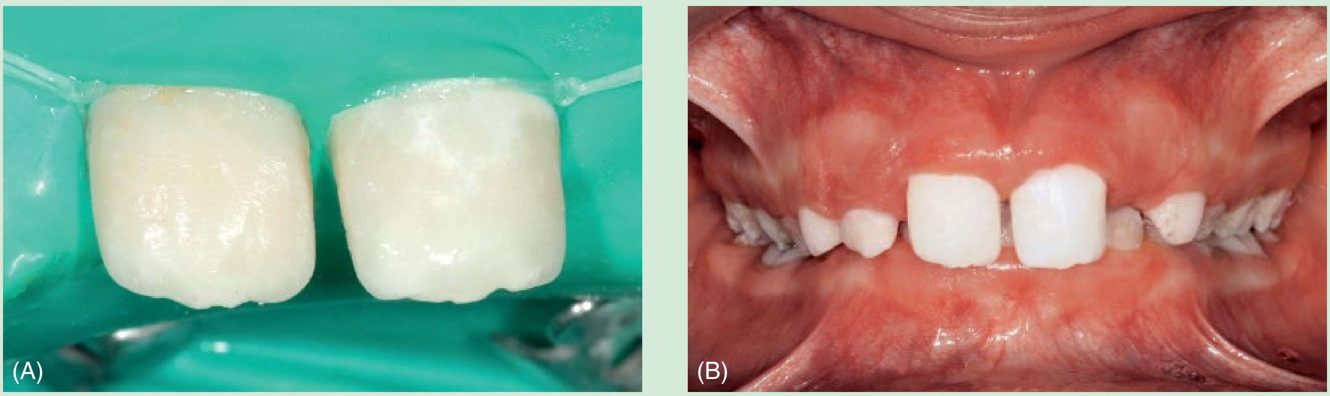

Figure 30.10 After application of the dentin bonding system, a thin layer of flow resin composite is applied **(A)**. Color and morphology are restored by the anatomical layering technique **(B)**.

Nursing bottle syndrome and/or tooth loss due to caries and/or to dental trauma

Early childhood caries

Early childhood caries (ECC), also known as baby/nursing bottle syndrome, is a particularly severe and rapidly destructive manifestation of dental caries whose main cause is the excessive and prolonged use of infant feeding bottles containing sugary drinks or even unsweetened milk, especially during nighttime when the flow of saliva is greatly reduced.

The clinical signs of ECC range from initial enamel demineralization to complete destruction of the crowns. The area usually affected is the vestibular surface of the anterior teeth, from where it rapidly spreads to the rest of the teeth.[21,22] According to the literature, the prevalence of the condition ranges from 1% to 12% in the industrialized world to more than 70% in developing countries and in the weaker sections of the population, even in wealthy countries. Given the risk of loss of one or more anterior teeth due to these deep caries lesions, this disease can have serious consequences. The most critical teeth are the maxillary incisors and, in relation to the dental eruption sequence, the first primary molars.

When children present with chronic and recurrent fistulas and abscesses, tooth function becomes limited. Radiographic investigation and clinical examination frequently show an infectious necrosis of the pulp in an advanced phase. The affected teeth are extracted (if endodontic restoration is not possible), and a pediatric prosthetic appliance is constructed. It is important to be aware that correct space management and maintenance are necessary to ensure normal evolution and eruption of the permanent teeth and improved esthetics and speech.[4]

The possible complications associated with ECC include infectious and systemic pathologies, such as focal disease; locally, there may develop follicular and radicular cysts and hypolasia of the permanent teeth; orthognathodontic complications are related to possible loss of the canine guide, loss of space with dentoalveolar disharmony of the permanent teeth, and also loss of vertical dimension leading to alteration of the profile; functional complications can arise as a result of alterations of the mandibular kinematics, phonetic function, and swallowing; and finally, esthetic problems linked to the loss of teeth can arise, especially at the front.

Figure 30.11 A pedodontic removable prosthesis is placed to restore frontal tooth loss due to ECC.

This form of caries is often treated by extraction of many or all the primary teeth, not only because of the severity of the lesions but also because the very young age of the patients makes them unsuitable candidates for long and complex conservative treatments with uncertain outcomes.

Clinical prevention of ECC includes:

- preventive therapies—behavioral–educational, alimentary and oral hygiene care, fluoride therapies;
- esthetic and functional recovery (tertiary prevention).

Pedodontic prostheses

Pedodontic prostheses (also used in cases of trauma and/or tooth agenesis) are removable appliances that can offer a simple, safe, and efficient therapeutic solution, not least because they can reduce the orthodontic treatment time. Recourse may be had to these prostheses when the child and its parents are collaborative and providing precise clinical conditions are met (relating to the tooth class, available space, and subject's health, both general and oral) (Figure 30.11).

Clinical case 30.5: A 3.9-year-old male with advanced caries and loss of teeth

Problem

Rampant caries, loss of the lower anterior teeth, and advanced caries in the posterior teeth. Tooth T was extracted.

Treatment

Restoration of teeth K and L with composite resins. Replacement of T with a resin tooth. Use of a pedodontic prosthesis to maintain the anterior space, preserve the vertical dimension, and avoid supereruption of the upper anterior teeth (Figure 30.12).

Result

Good functional restoration and achievement of the desired psychological result, with lasting benefits. The patient has undergone periodic (yearly) checkups.

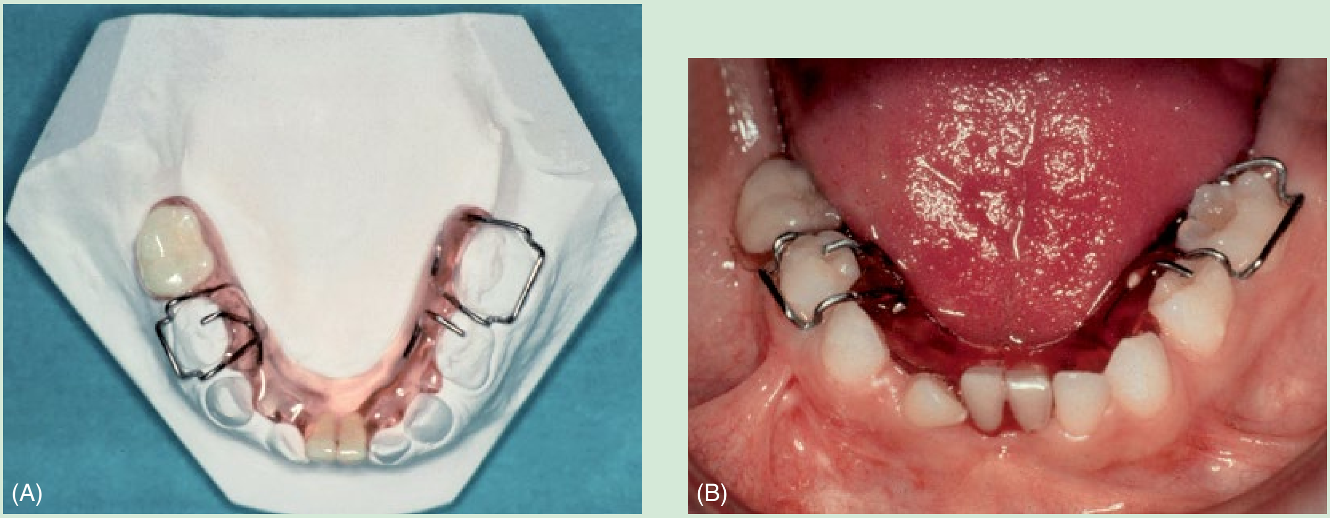

Figure 30.12 Plaster model of a 3.9-year-old patient. A removable space maintainer is designed **(A)** and placed in the lower arch **(B)**.

Clinical case 30.6: Severe trauma and loss of teeth in a 7.4-year-old

Problem

Severe trauma to the anterior region and loss (exarticulation) of teeth #8 and #9. Extrusion and internal root resorption (undiagnosed) due to previous trauma to tooth #25 (Figure 30.13).

Treatment

A complete orthodontic assessment to evaluate criteria for interceptive orthodontics (e.g., direction of growth and skeletal discrepancies).

Use of a function regulator (Bionator) with replacement of the anterior teeth to obtain sagittal correction with restoration of normal neuromuscular function and structure. Application of a lingual arch as a space maintainer (Figures 30.14 and 30.15).

Endodontic treatment of tooth #25 with $Ca(OH)_2$.

Result

Good functional restoration with good esthetic and psychological results. Interceptive orthodontic treatment was performed to improve alveolar growth, preserve vertical dimension, and avoid supereruption of the lower anterior teeth. Over the coming years, different orthodontic and endodontic treatments allow achievement of the final result (Figures 30.16 and 30.17).

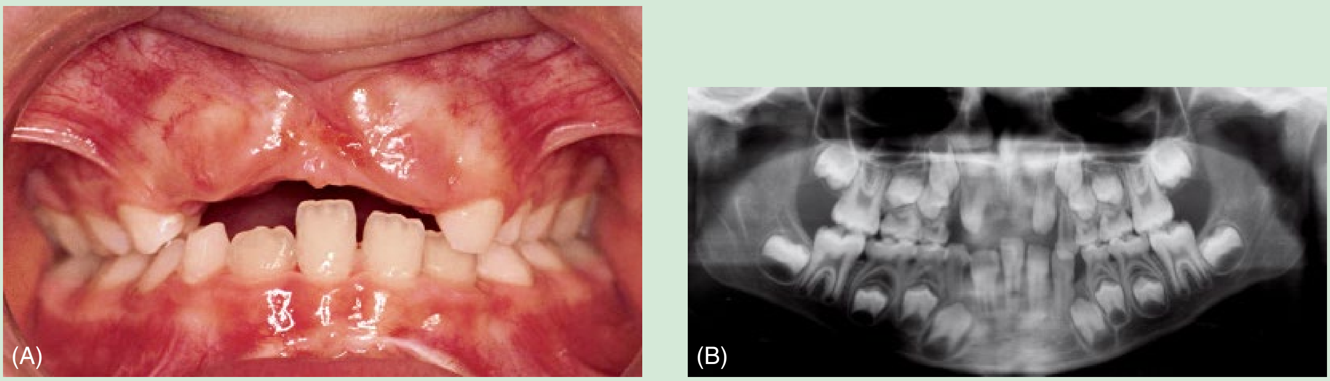

Figure 30.13 Frontal teeth loss due to trauma and extrusion of the lower right central incisor **(A)** Orthopantomograph **(B)**. Note the internal root resorption of tooth #25.

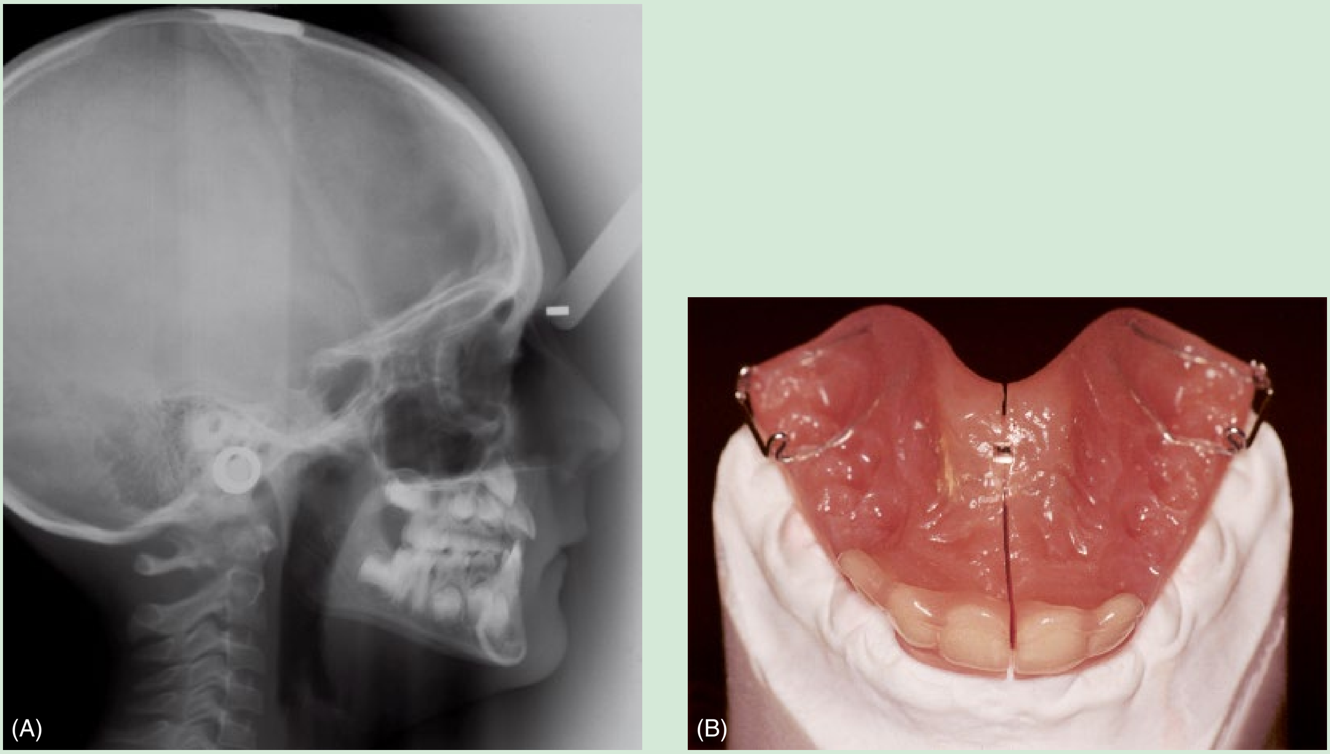

Figure 30.14 Lateral teleradiograph **(A)**. Functional appliance (Bionator) **(B)**.

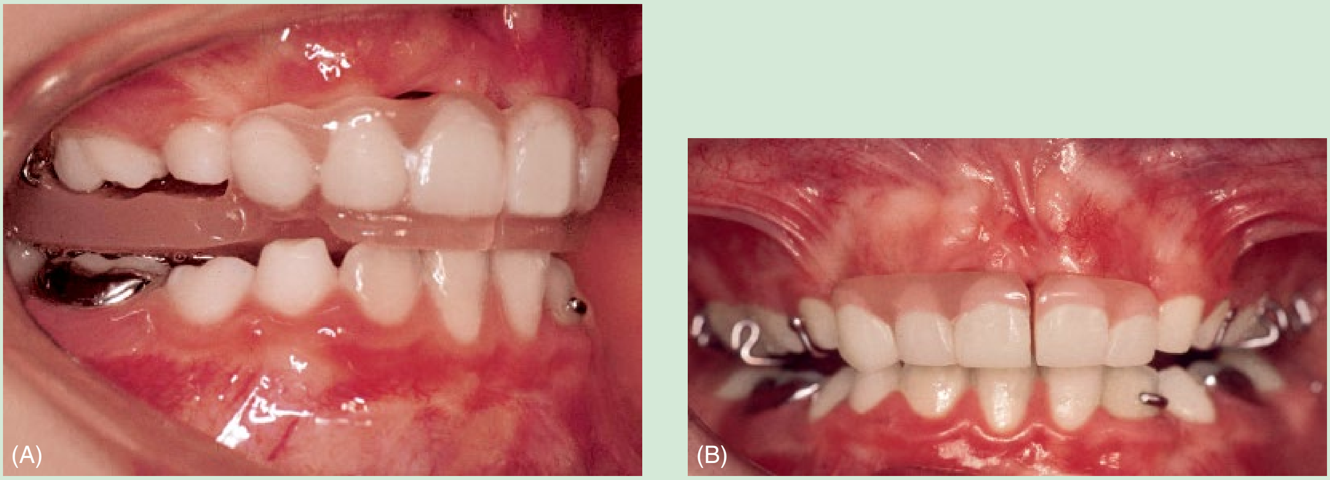

Figure 30.15 Intraoral view of the removable appliance **(A)**. A lingual arch is applied to the lower arch **(B)**.

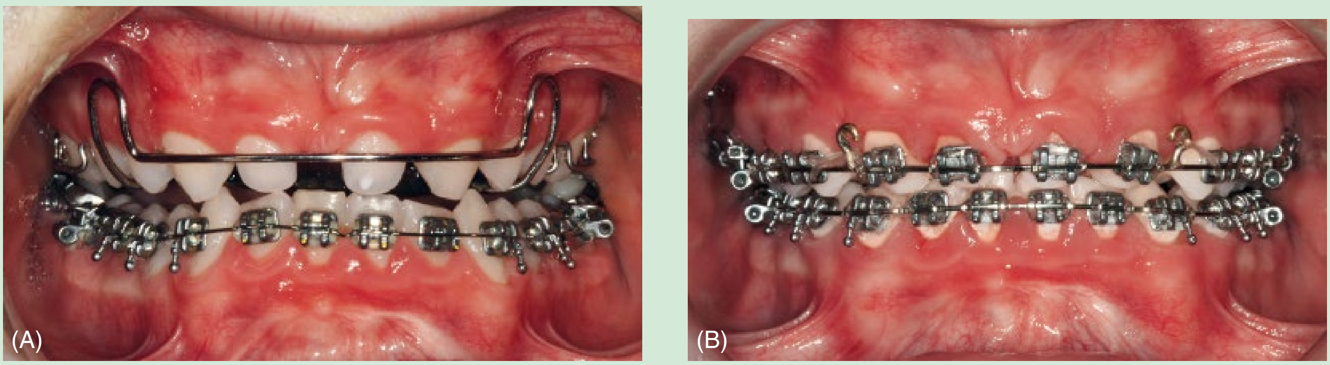

Figure 30.16 **(A, B)** Different orthodontic treatments phases to detail the occlusion.

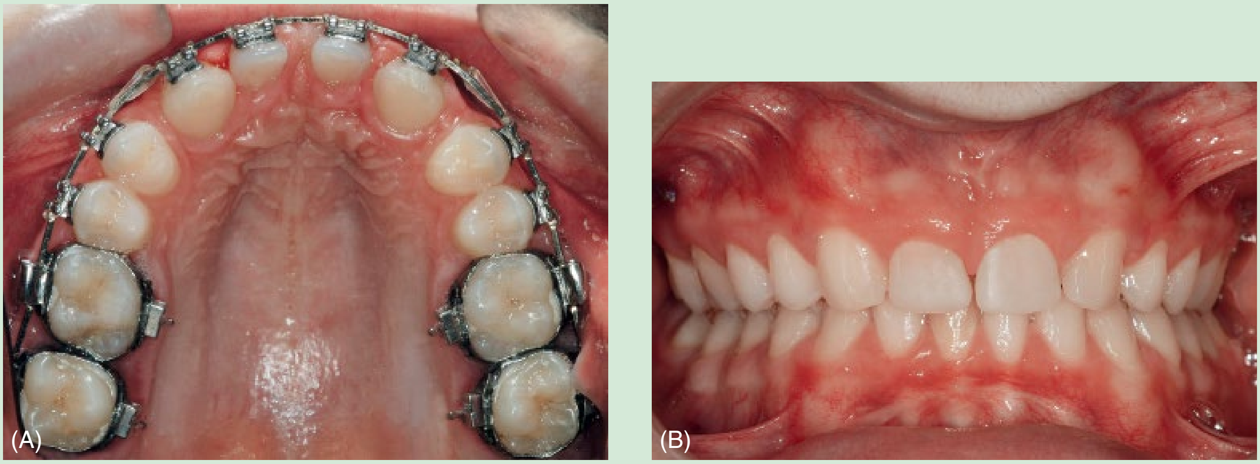

Figure 30.17 Occlusal view before debonding **(A)** and at the end of the treatment with coronoplasty of teeth #7 and #10. Frontal intraoral view: the patient at 14 years of age **(B)**.

Removable space-maintaining appliances offer considerable advantages: they can determine orthodontic movements and can help to prevent orofacial muscle imbalance and/or harmful sucking habits, such as finger, thumb, or lip sucking. Furthermore, they can be modified as the patient grows, improving the esthetics and thus reducing psychological problems. On the downside, their volume can make them uncomfortable for the young patient; they also need periodic checks and high patient and parental cooperation. In addition, they may be more prone to breakage than fixed appliances.[23]

Patient with multiple agenesis: ectodermal dysplasia

Congenital absence of teeth is common, occurring sporadically or with a hereditary component. The presence of conical teeth is frequently associated with absence of the corresponding teeth on the opposite side of the arch. There exist over 120 syndromes of the head and neck manifesting with missing teeth. In these conditions, the important aspect is not so much the number of missing teeth but which teeth are absent.

Clinical case 30.7: Ectodermal dysplasia

Problem

A 5.2-year-old made with ectodermal dysplasia characterized by multiple agenesis, fine, sparse hair with shaft abnormalities, dry skin, frontal bossing, maxillary hypoplasia, and lips showing little of the vermilion margin (Figure 30.18A and B).

Ectodermal dysplasia refers to a group of inherited disorders involving the ectodermally derived structures (hair, teeth, nails, skin, and sweat glands). The most common expression is the hypohidrotic X-linked form.

Treatment

Treatment of this condition aims to provide adequate function, maintain the vertical dimension, and improve esthetics. Ideally, treatment should begin as early as possible, depending on

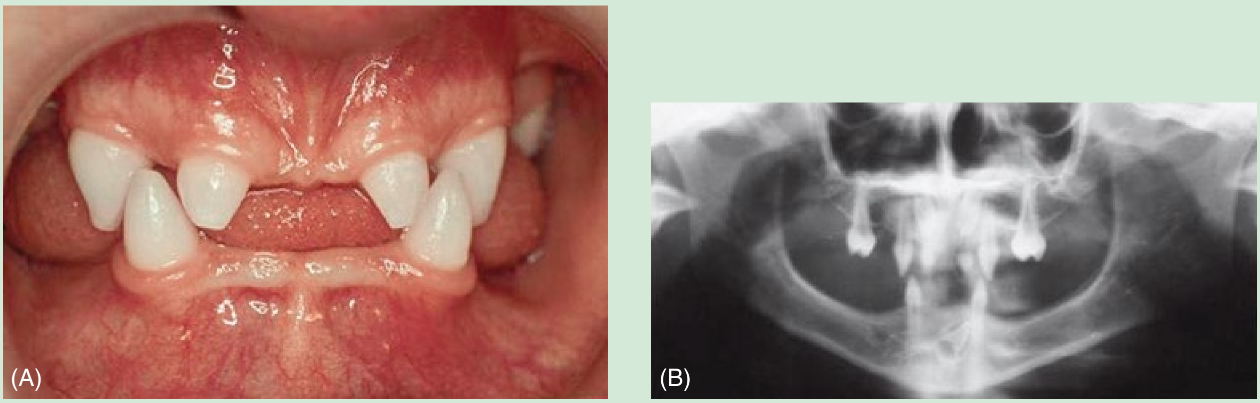

Figure 30.18 Typical appearance of the dentition of a child with ectodermal dysplasia **(A)**. Panoramic radiograph; note the conical-shaped teeth and also the large number of missing teeth **(B)**.

the child's compliance. Partial dentures can be applied; acid-etch composite buildups of conical teeth can be performed, similar to surgical exposure of impacted teeth; orthodontic adjustment of spaces can be carried out over the following years (Figure 30.19).

Result

Achievement of normal speech development and increased self-acceptance thanks to treatment with removable prostheses, modified during the child's growth to improve his smile (Figure 30.20).

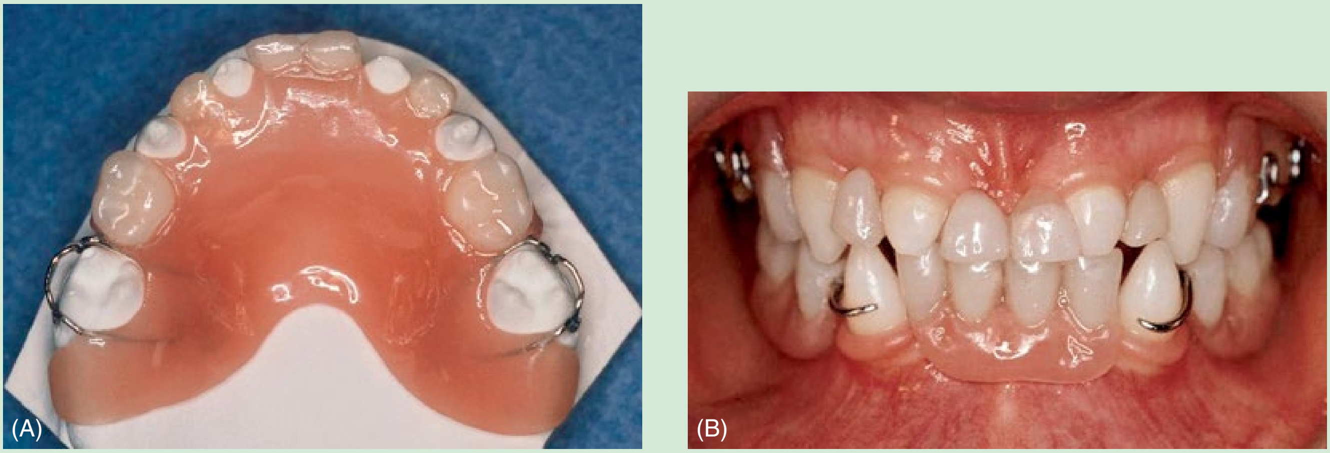

Figure 30.19 **(A, B)** Young children tolerate dentures with Adam's cribs (and/or ball retainers), which provide ideal retention around primary molars.

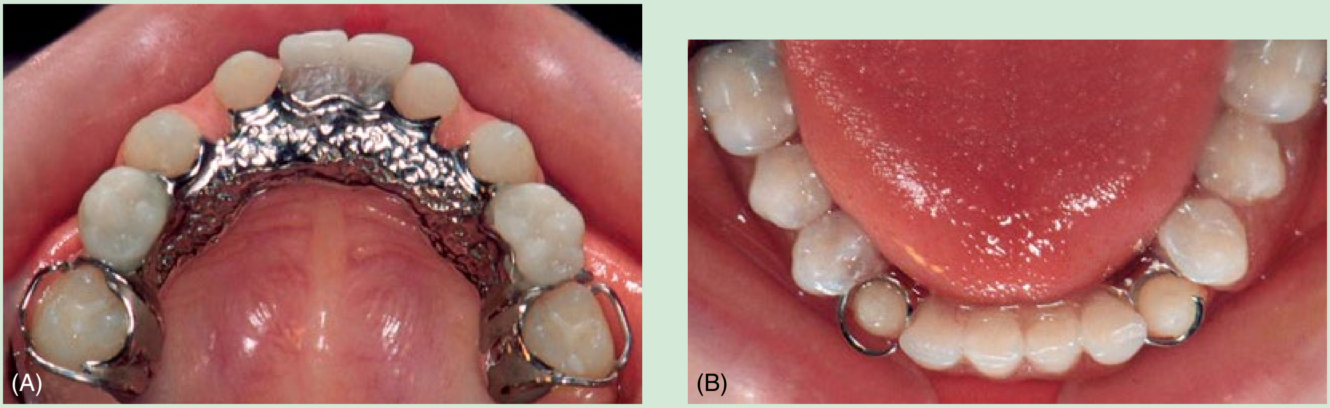

Figure 30.20 **(A, B)** Removable space maintainers in a growing patient.

The major conditions associated with oligodontia include ectodermal dysplasia, clefting, Down's syndrome, chondroectodermal dysplasia (Ellis–van Creveld syndrome), Reiger syndrome, incontinentia pigmenti, and orofacial–digital syndrome (types I and II).

Trauma management in primary dentition and in the first phase of mixed dentition

Trauma is a frequent event seen in pediatric dentistry. Furthermore, it is often very difficult to establish accurately the extent and severity of the traumatic injury, manage the initial treatment of the acute phase, and plan the long-term follow-up. Dental traumas, like dental caries, are true emergencies and demand an accurate diagnosis to save teeth, restore the function of the dental arches, improve the oral esthetics, and avoid complications.

As dental trauma is a high-incidence pathology, effective preventive measures need to be taken to reduce its effects and also the complications that can arise in young patients. Thus, it is crucial to develop and implement effective prevention and information campaigns targeting the general public. The aims of such campaigns should be to reduce trauma-related functional, esthetic, and biological damage to the orofacial area and to raise awareness of the problem among patients and practitioners, thereby making it possible to reduce sequelae, avoid unnecessary treatment procedures, and provide the biological basis for healing after injury.[24]

In particular, the most effective preventive measures include timely orthodontic correction to reduce increased overjet; early correction of habits such as finger, thumb, and lip sucking, and abnormal swallowing; use of a mouthguard to protect permanent teeth during sporting activities; and accurate initial diagnoses and timely treatments, both of which are essential in guaranteeing a correct initial therapeutic approach, avoiding overtreatment, and preventing long-term sequelae.

Application of lasers in dental traumatology

Careful dental history taking and a thorough clinical examination are the basis of an accurate diagnosis. The use of specific standardized charts is recommended to save time and ensure an exhaustive assessment. Every phase, both pre- and posttreatment, must be fully documented through radiographic and photographic examinations and pulp vitality tests, as this will make it easier and quicker to monitor the evolution of the clinical case at subsequent visits and to compile a full medico-legal report, which is often required during and at the end of dental trauma treatment.

Pulp testing in dental trauma is a controversial issue, and different tests have been proposed. Laser Doppler flowmetry is a promising new method of diagnosing the state of pulp revascularization; however, it is still in the experimental phase and not yet available for general use.

Thanks to their characteristic versatility, the Er:YAG and Er,Cr:YSGG lasers can be applied to both hard and soft tissues and are thus indicated in the treatment of dental traumas. Other technologies indicated for the treatment of these injuries are the KTP, Nd:YAG, diode, and CO_2 lasers (Table 30.1).

In the absence of randomized clinical studies of traumatic dental injuries and laser-assisted therapy, we here describe our own clinical experience and aim to stimulate more extensive scientific research in this field.

Traumatic injuries to hard dental tissue and pulp

Uncomplicated and complicated crown fractures

Crown fractures involve the enamel and dentin; complicated crown fractures also expose the pulp. The examination should start with cleansing of the injured area and a careful examination to detect any pulp exposure. An X-ray and vitality tests should be performed; sometimes there is accompanying damage to the soft tissue, in which case it is necessary to look for tooth fragments in tongue, lips, and oral mucosa.

Table 30.1 Classification of Lasers

Hard and soft tissues	Er:YAG 2940 Er,Cr:YSGG 2780
Soft tissues	KTP 532 Argon Diode 810,940,980 Nd:YAG 1064 CO_2 10600
Low-level lasers	Helium neon 635 Diode 810 KTP 532

The availability of modern bonding agents and laser technology has revolutionized our clinical practice.

Treatment with erbium lasers

Erbium lasers can give good results, reducing postoperative discomfort and sensitivity as well as allowing minimally invasive dentistry.[15] Laser cavity preparation is closely related to a series of different variables. Fluence, power density, and pulse length, as well as the laser beam angle, focus mode, and amount of air–water jet delivered, are all factors that can cause substructural damage to the dentin. A final conditioning at low wattage on both dentin and enamel is advisable. Acid etching on lased dentin and enamel produces uniform results, eliminating the thin layer of substructural damage, exposing the collagen fibers, and creating a substrate for the formation of the hybrid layer; acid etching turns Silverstone class 2 and 3 enamel into class 1 enamel, allowing better composite adaptation.[25] The action of erbium lasers on hard tissues and pulp is extremely precise and leaves the treated surfaces cleansed and sterilized. The temperature increases during treatment, already minimal, can be decreased by water-spray cooling. Thanks to the various effects of these lasers, they exert a bactericidal action, do not produce a smear layer, open the dentinal tubules, and promote the formation of a hybrid layer; they can be used to perform the whole therapeutic procedure: excavation, coagulation of the exposed pulp (if necessary), pulpotomy, or pulpectomy. Another feature is their very superficial thermal effect, as a result of which the necrotic zone is likely to be very small.

In crown fractures, many dentinal tubules are exposed: between 20,000 and 45,000 in just 1 mm^2 of dentin. These open tubules are a pathway for bacteria and thermal and chemical irritants, which can cause pulp inflammation; erbium lasers are effective for removing organic material, smear layer, and can achieve a bactericidal effect, but the Nd:YAG and diode lasers also exert an effective decontaminating action. The capacity of the erbium laser to fuse and seal the dentinal tubules (to depths of up to 4 pm) can result in a reduction of the tissues' permeability to fluids, and thus of dentinal hypersensitivity.

Another structural change induced by these lasers is vitrification. This phenomenon can be very useful because it increases dental hardness and thus hard tissue resistance to acid remineralization and to dental abrasion.

Treatment with Nd:YAG and diode lasers

The Nd:YAG and the diode lasers exert a beneficial therapeutic action in direct traumas. These lasers, exploiting their photothermal effect, can be used to treat both pulp and dentin. They can be applied:

- to treat dentinal hypersensitivity;
- to perform indirect or direct pulp capping;
- to remove endodontic material;
- to treat infected root canals.

The CO_2 laser, instead, has a purely thermal effect on the tissue: 90–95% of the energy it delivers is absorbed by a fine tissue layer and transformed into heat. It is indicated for:

- pulp capping (following dentin fracture);
- pulpotomy (following crown or root-crown fractures);
- surgical cutting (e.g., to remove a tooth fragment embedded in the lip or oral mucosa).

Lasers have been proposed for pulpotomy, and one study favorably compared CO_2 laser treatment to formocresol for pulpotomy in primary teeth, recording a survival rate ranging from 91% to 98%. Other studies reported that the superpulsed mode produced markedly higher success rates than the continuous-wave mode. During this procedure, attention must be paid to the energy applied. Low energy delivered in defocused and pulsed or superpulsed mode guarantees good superficial coagulation and good decontamination, thereby helping to maintain the vitality of the residual pulp in pulp capping applications.

In view of the characteristic anatomy of the dental root apex and the penetration depths of near-infrared lasers, particular care must be taken when applying laser energy in primary root canals for root canal cleaning and disinfecting procedures.[26]

Crown fracture and root fracture

Crown fractures, unlike root fractures where the fracture is located entirely within the alveolus, cannot be expected to heal. In these cases, the coronal fragment is usually removed and the subsequent treatment should focus primarily on the possibility of using the remaining fragment. In the case of a superficial fracture without pulp exposure, it is recommended to remove loose fragments, smoothing the rough subgingival fracture surface and covering the exposed dentin. When the residual coronal fragment comprises one-third or less of the clinical root, pulpectomy and root canal filling are advocated, again after the removal of any loose fragments. The fracture surface must be exposed using a gingivectomy or osteotomy procedure, and this is followed by prosthetic restoration.

Laser-assisted therapy can be useful not only in coronal fragment restoration but also in supporting tissue surgery and endodontic therapy (gingivoplasy, gingivectomy, crown lengthening).[27] Lasers work effectively in these soft-tissue procedures as they easily incise, cut, ablate, and reshape soft tissue with no or minimal bleeding; furthermore, they are less painful and have a bactericidal effect. Lasers with deeply penetrating wavelengths (Nd:YAG and diode) produce a thicker coagulation layer than those with superficially absorbed ones (CO_2–erbium). With the former, the technique is similar to electrosurgical tissue removal.

Treatment factors such as optimal repositioning and flexible splinting have a positive influence on healing, as do immature root formation, lower age, and less displacement of the coronal fragment. If a splint is used, which may even be an esthetic orthodontic splint (ceramic brackets), it must be kept in situ for several weeks at least.

It is also worth noting that the use of an Nd:YAG laser can make bracket removal procedures atraumatic; furthermore, the intrapulp temperature increases induced by this laser are lower than those generated when using conventional high-speed instruments. Therefore, the laser-assisted procedure is safer, quicker, and more comfortable than the traditional approach.[28]

Traumatic injuries to the periodontal tissues

Nd:YAG and diode lasers uses are as follows:

- decontamination of the alveolus following a traumatic avulsion;
- treatment of a periodontal defect following a dental luxation or subluxation;
- microgingival surgery for the treatment of a traumatic dental injury;
- gingivectomy and gingivoplasty;
- surgical cutting (e.g., to remove a tooth fragment).[19]

Indirect dental traumas are lesions to the dental supporting structures, in particular, the alveolar bone, the periodontium, frenum, and lips. The Nd:YAG and diode lasers have a beneficial therapeutic action in such injuries. Indeed, these lasers have a decontaminating as well as a biostimulating and a reparative effect; they eliminate the need for sutures, allow good and rapid healing by second intention, and reduce patient discomfort. Finally, they also exert an appreciable analgesic effect on both hard and soft tissues.

Both the diode laser and the Nd:YAG laser are used in oral surgery, the former in continuous or pulsed mode and the latter always in pulsed mode but with different pulse amplitudes. The increase in temperature generated by these lasers has an excellent thermostatic effect. Furthermore, in all luxation injuries, the bactericidal and detoxifying action of lasers (Er:YAG, Nd:YAG, diode, and argon) makes it possible to achieve favorable conditions for the attachment of periodontal tissue. Laser decontamination and/or photobiomodulation (cutaneous and subcutaneous tissue irradiation) can be exploited for tissue repair and for pain relief.

Even though helium–neon lasers were initially used ($\lambda = 632.8$ nm), the ones in use today are the semiconductor diode type ($\lambda = 830$ or 635 nm).

The water absorption coefficient of the wavelengths used in low-level laser therapy (LLLT) is reduced, and the beams are able to penetrate both soft and hard tissues from a distance of 3–15 mm.

LLLT has a number of applications in dentistry, both on soft tissues (biostimulation of lesions, aphthous stomatitis, herpetic lesions, mucositis, pulpotomy) and at the neural level (analgesia, neural regeneration, temporomandibular pain, postsurgical pain, dental pain during orthodontic treatment).

In short, LLLT stimulates tissue repair processes and, influencing a large number of cell systems, can also produce a series of benefits on inflammatory mechanisms (antalgic, biostimulating, anti-inflammatory effects).[29–31]

The use of LLLT, or soft laser therapy, can ensure a nontraumatic introduction to dentistry. There is a large body of literature on this topic even though, methodologically and in terms of doses, there is still considerable difference of opinion.

Nd:YAG, diode, and KTP lasers can also be used as an alternative approach in nonvital bleaching.[32] Lasers are being used increasingly in gingival and dental surgery, where they are taking the place of electrosurgical techniques. The CO_2 laser, in particular, is used for surgical cutting (e.g., to remove tooth fragments from lips or oral mucosa).

Injuries to developing teeth

Disorders of permanent teeth caused by traumatic injuries to primary teeth can be divided into two groups according to the type of dental trauma (direct or indirect). The prevalence of these disorders ranges from 12% to 69%, depending on the study; avulsion and intrusive luxations are injuries associated with very high rates of developmental complications.[24]

Laser-assisted therapy can be useful in:

- enamel discoloration—treatable with the erbium laser;
- circular enamel hypoplasia—treatable with the erbium laser;
- ectopic eruption—treatable with surgical exposure or soft-tissue laser surgeries (all the wavelengths of the near–medium and far infrared spectrum).

Case studies of trauma

Although we acknowledge the importance of guidelines, the need for information and prevention programs, the following case studies do not include reference to classifications, clinical examinations, medical history, or special investigations, although these are absolutely essential for comprehensive treatment planning. For the sake of brevity, our goal is to describe several clinical trauma cases in which cooperation between the pedodontist and the orthodontist led to a good esthetic and functional outcomes.

Clinical case 30.8: Fracture of anterior teeth in an 8.3-year-old

Problem

Uncomplicated enamel–dentin crown fracture of the left upper central incisor with an immature apex. The tooth fragment was not available. The tooth had been protected with $Ca(OH)_2$ (Figure 30.21).

Treatment

Following routine clinical, instrumental, and radiographic examinations, treatment of the surface was with an Er:YAG laser without anesthesia. Decontamination of the dentin.

After etching and rinsing, definitive composite restoration at a low operating temperature and with minimum tissue loss (Figure 30.22).

Result

Restoration of the anterior guide and correct reproduction of the biting edge in a single-sitting, minimally invasive procedure. Minimal discomfort for the patient during treatment, thanks to reduced sensitivity (Figure 30.23).

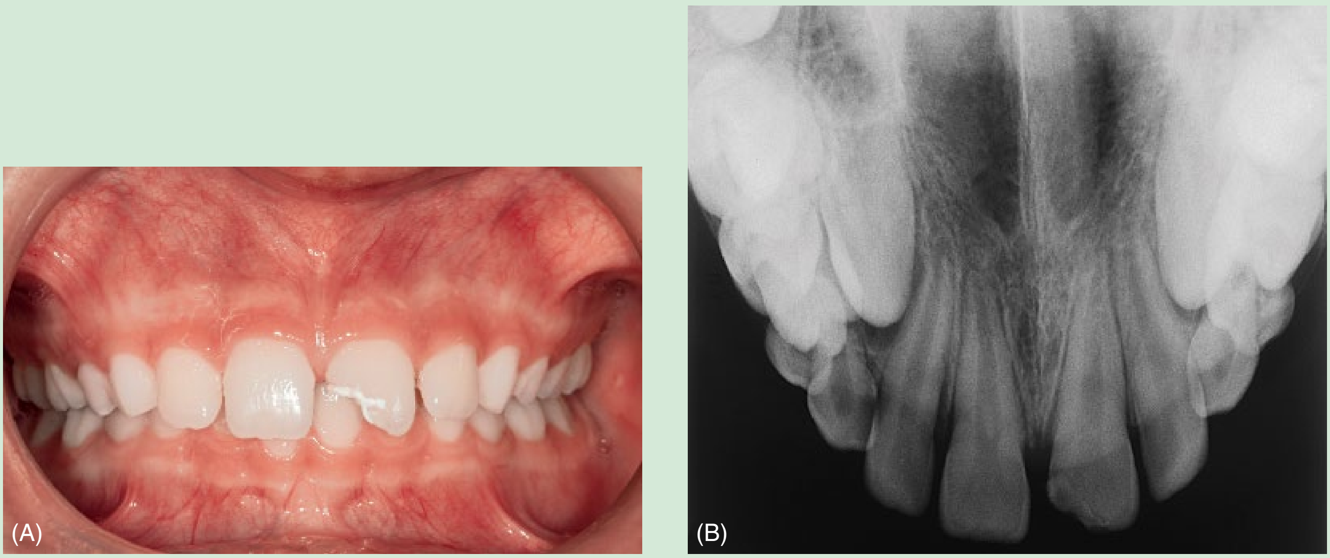

Figure 30.21 Deep but uncomplicated crown fracture of tooth #9 **(A)** and control X-ray **(B)**. The tooth had previously been protected with $Ca(OH)_2$.

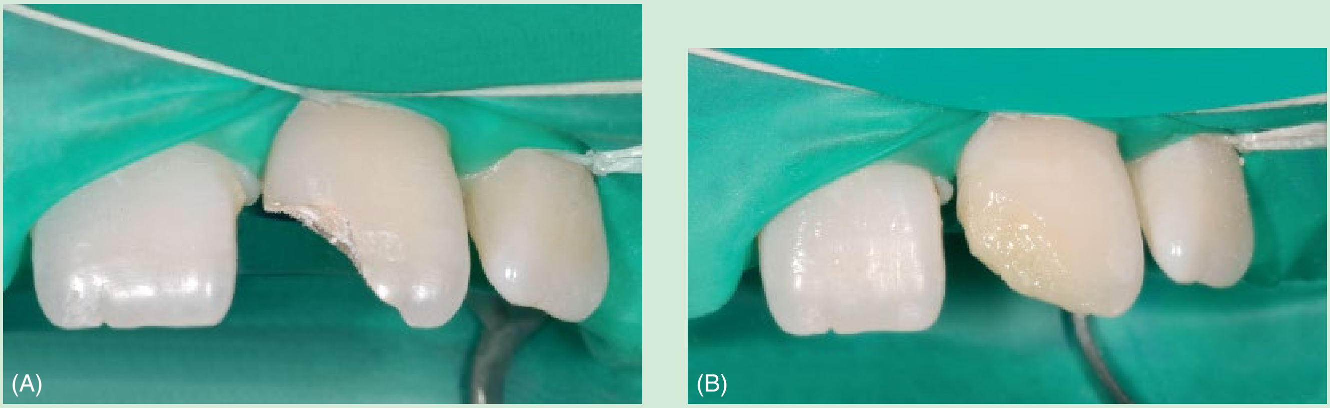

Figure 30.22 Rubber dam isolation and a minimally invasive treatment, performed with an erbium laser **(A)**. Application of enamel–dentin system **(B)**.

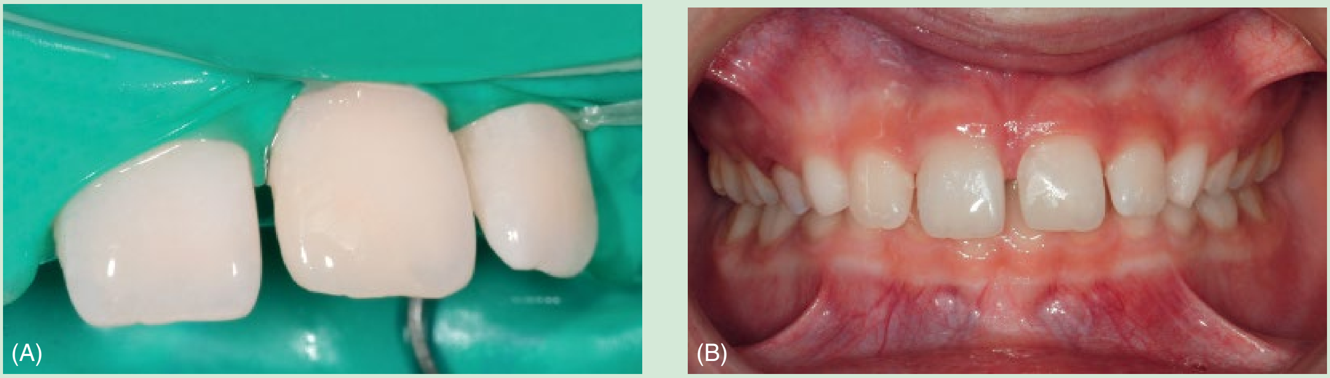

Figure 30.23 Building up the incisal edge; this part is covered with a thin layer of enamel material **(A)**. Finishing the restoration with abrasive disks and rubber polishers. Final appearance after rubber dam removal **(B)**.

Clinical case 30.9: Unacceptable result of treatment in trauma injury in a 19-year-old

Problem

Unacceptable result (incorrect morphology and lack of color) 11 years after treatment for traumatic dental injury with crown fracture of tooth #8. No retreatment between baseline and 11 years (Figure 30.24).

Treatment

Minimally invasive laser preparation of tooth surface using an Er:YAG laser after isolation with a rubber dam. Treatment with the anatomical layering technique; to imitate the facial dentin surface, an opaque dental material is

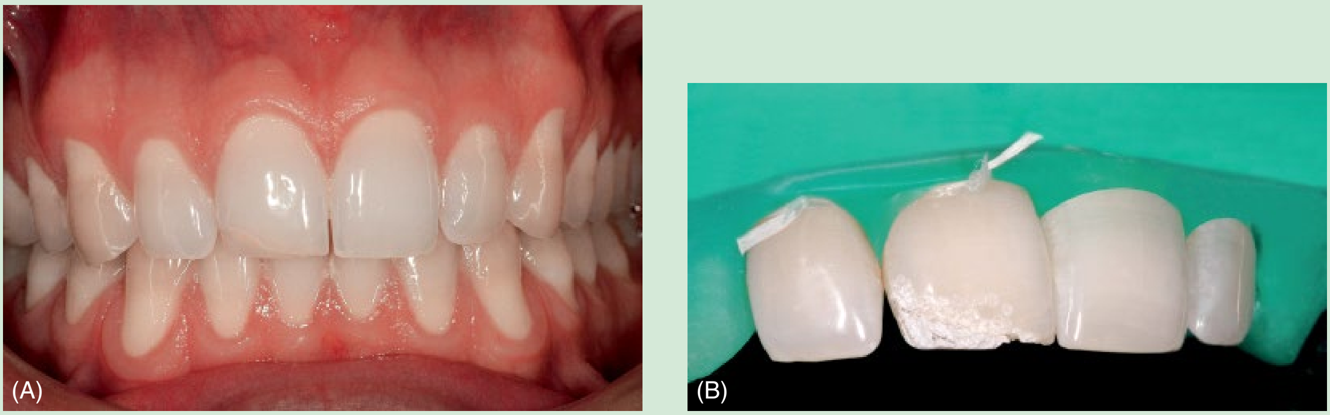

Figure 30.24 Preoperative view **(A)**. Enamel and the previous resin restoration are treated with an Er:YAG laser **(B)**.

applied (first layer) and then a thin layer of enamel material (translucent) (Figure 30.25).

Result

Perfect restoration of morphology and color.

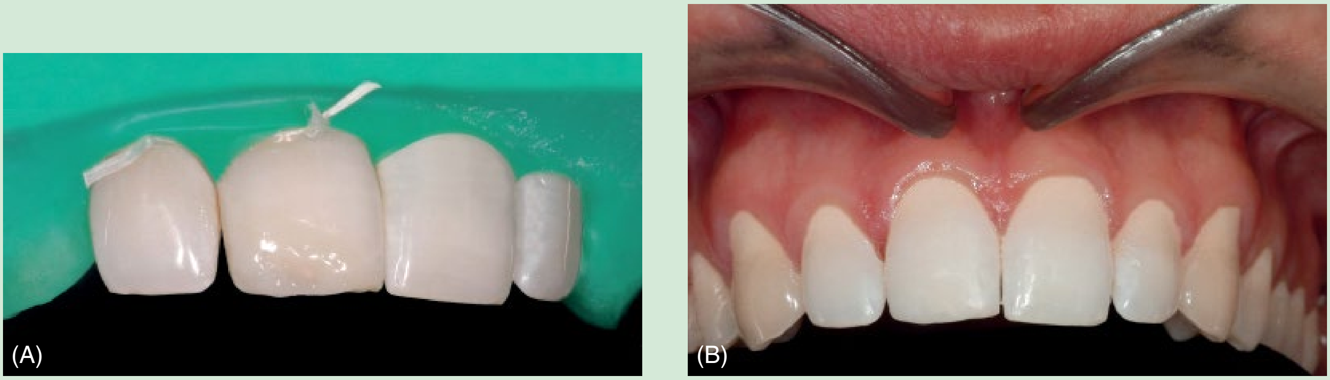

Figure 30.25 To reproduce the facial dentin surface an opaque material is added **(A)**. Final appearance after rubber dam removal **(B)**.

Clinical case 30.10: Discoloration of tooth due to previous subluxation injury in a 20-year-old

Problem

Discoloration of tooth #9, due to a previous subluxation injury. Almost complete obliteration of the root canal (Figure 30.26).

Treatment

Nonvital dental bleaching using the KTP laser (λ= 532 nm) with a red gel as source of activation. After prophylaxis with paste

Figure 30.26 Discoloration of tooth #9 **(A)** and obliteration of the root canal due to a previous subluxation injury. Control X-ray **(B)**.

and water, photographs are taken to record the initial color. Application of a gingival barrier on gingiva and the interproximal area. Several cycles (bleaching procedure repeated two or three times) during a single sitting. Orange protection goggles were needed (Figure 30.27).

Result

Very effective outcome of laser-assisted dental bleaching with no morphological or chemical effects on the enamel, and no thermal effects on the pulp (Figure 30.28).

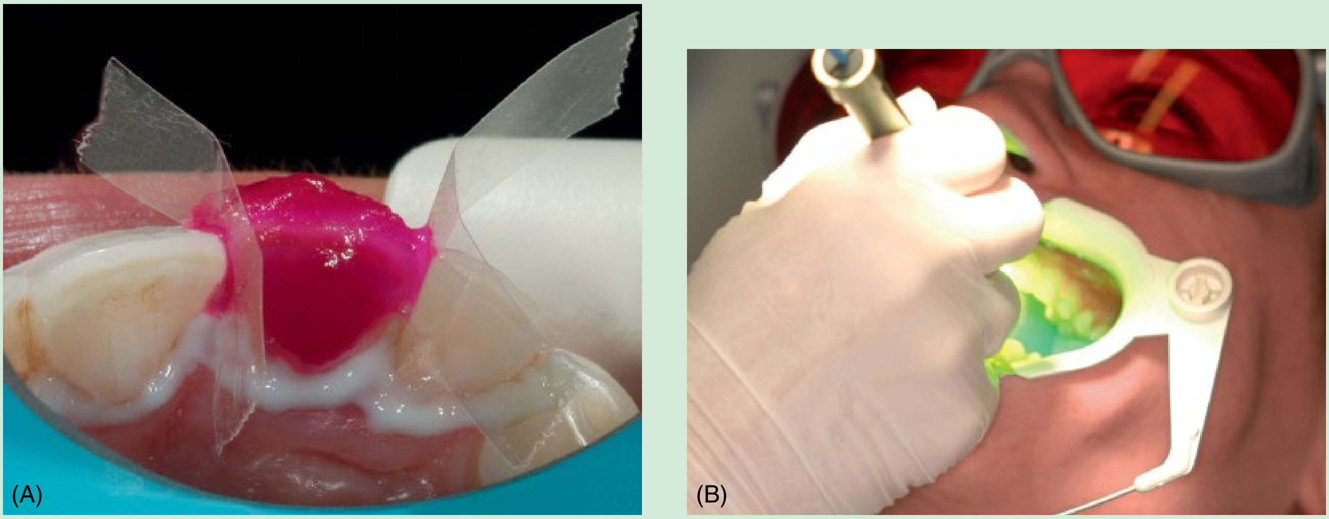

Figure 30.27 A gingival barrier is applied prior to bleaching with a KTP laser. Red gel is applied on the buccal and palatal surfaces **(A)**. KTP irradiation **(B)**.

Figure 30.28 Final result.

Clinical case 30.11: Severe intrusive luxation with complicated crown fracture in an 8.2-year-old

Problem

Abscess and pain 30 days after trauma. Severe intrusive luxation with complicated crown fracture of immature tooth #8 that had not been treated. Uncomplicated fracture of tooth #9 that, instead, had been reconstructed. Class II malocclusion with mandibular retrusion. The patient came to our attention after 30 days (Figures 30.29 and 30.30A).

Treatment:

Endodontic treatment of tooth #8 using $Ca(OH)_2$ (Figure 30.30B). Soft-tissue treatment with an Nd:YAG laser. Application of an orthodontic splint to align the upper frontal group and the incisor. Follow up until the end of mixed dentition (Figures 30.31, 30.32, and 30.33). Subsequently, orthodontic treatment of both arches to obtain good alignment and correct tipping (Figures 30.33 and 30.34). Endodontic treatment of tooth # 9 (Figure 30.35B and C).

Result

Dyschromia of the two upper frontal teeth at the end of the orthodontic therapy (Figure 30.35A). Therefore, to improve the patient's smile, nonvital laser-assisted dental bleaching with a KTP laser was performed, and both upper incisors were restored with composite resin to achieve better esthetics (Figure 30.36).

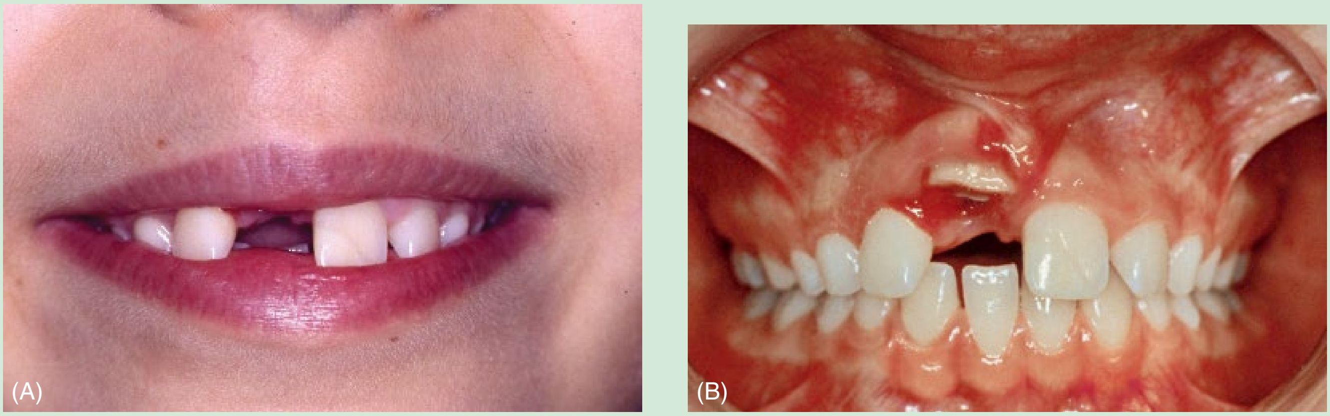

Figure 30.29 A very young patient **(A)** with a severe luxation injury with a complicated enamel dentin fracture of tooth #8 (not treated) and an uncomplicated crown fracture of tooth #9, which was reconstructed **(B)**.

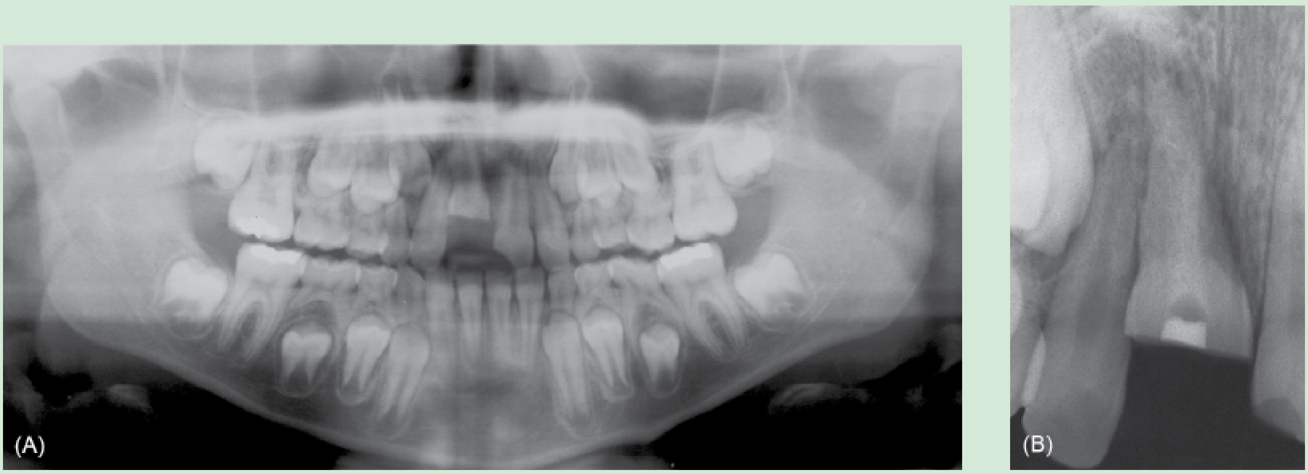

Figure 30.30 Orthopantomograph **(A)** and preliminary endodontic treatment of tooth #8 using $Ca(OH)_2$ **(B)**.

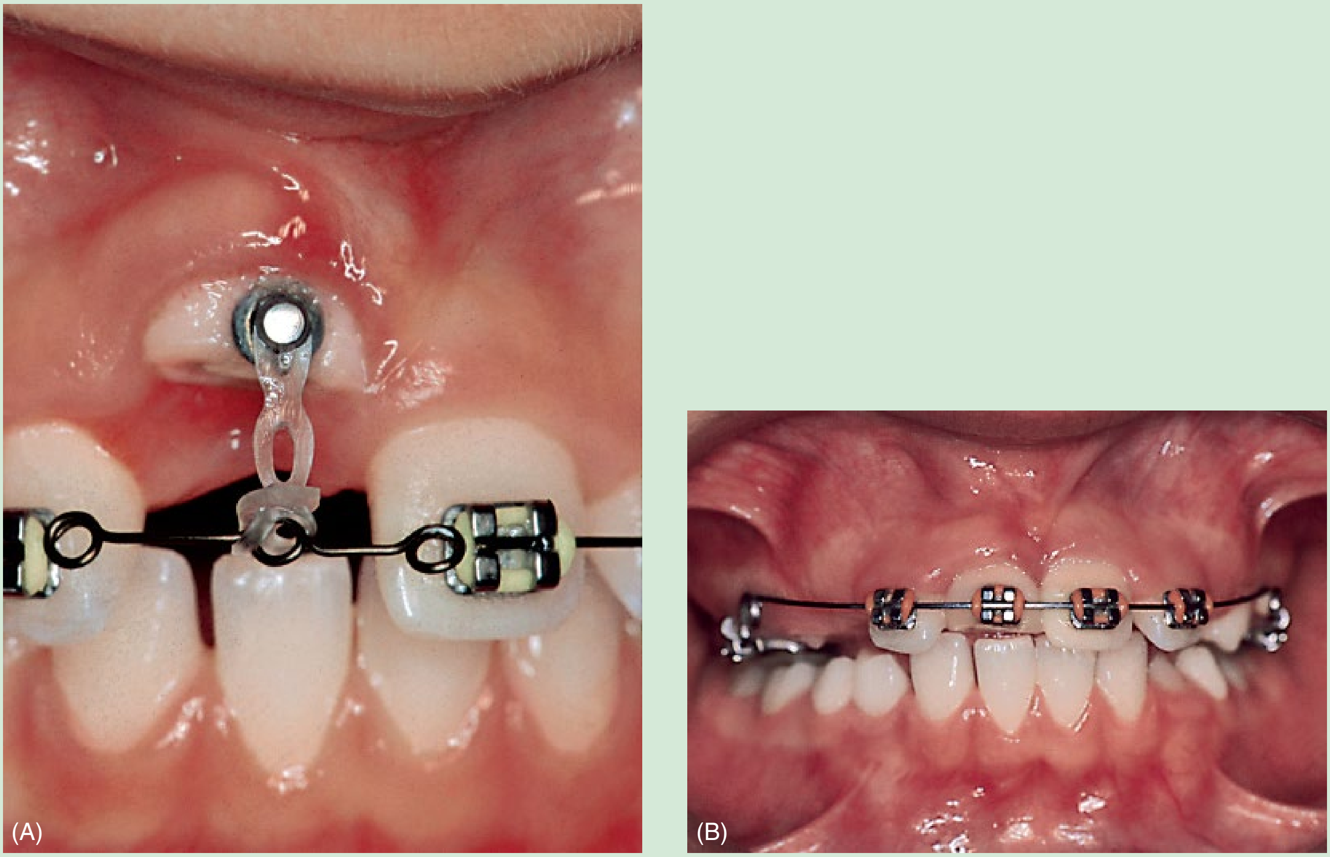

Figure 30.31 Orthodontic splint to extrude the tooth **(A)** and final alignment **(B)**.

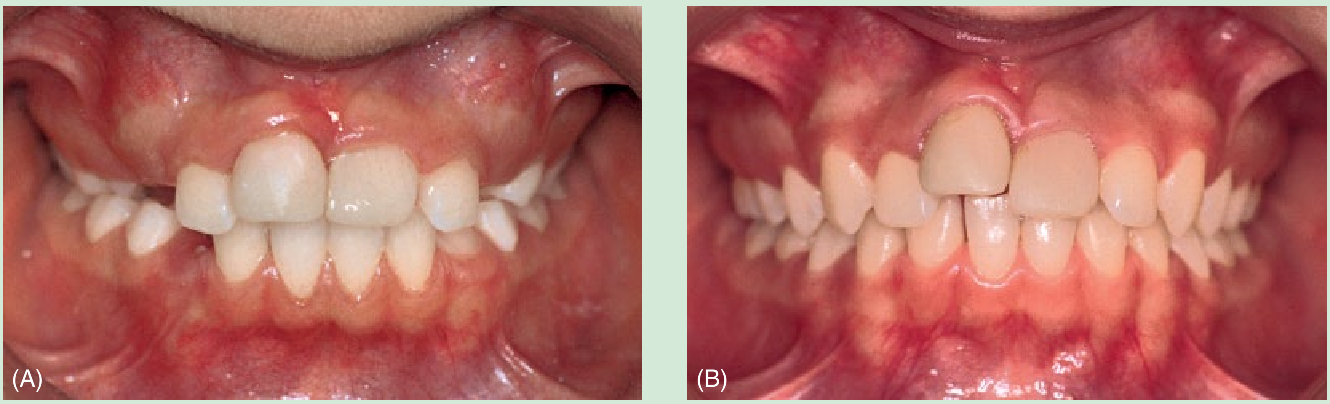

Figure 30.32 A composite restoration was carried out **(A)** and the patient was followed up to the end of the mixed dentition period **(B)**.

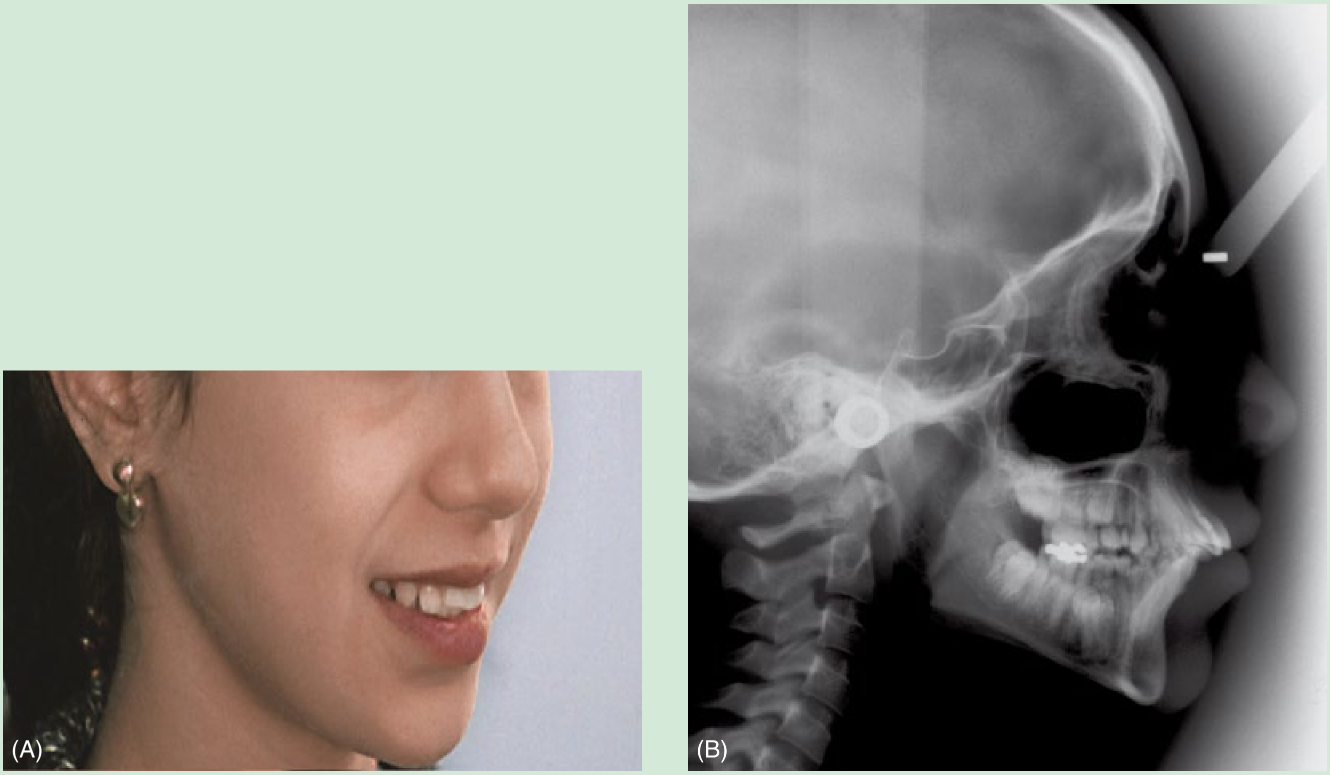

Figure 30.33 The patient at 12.6 years of age **(A)** and a lateral teleradiograph **(B)**.

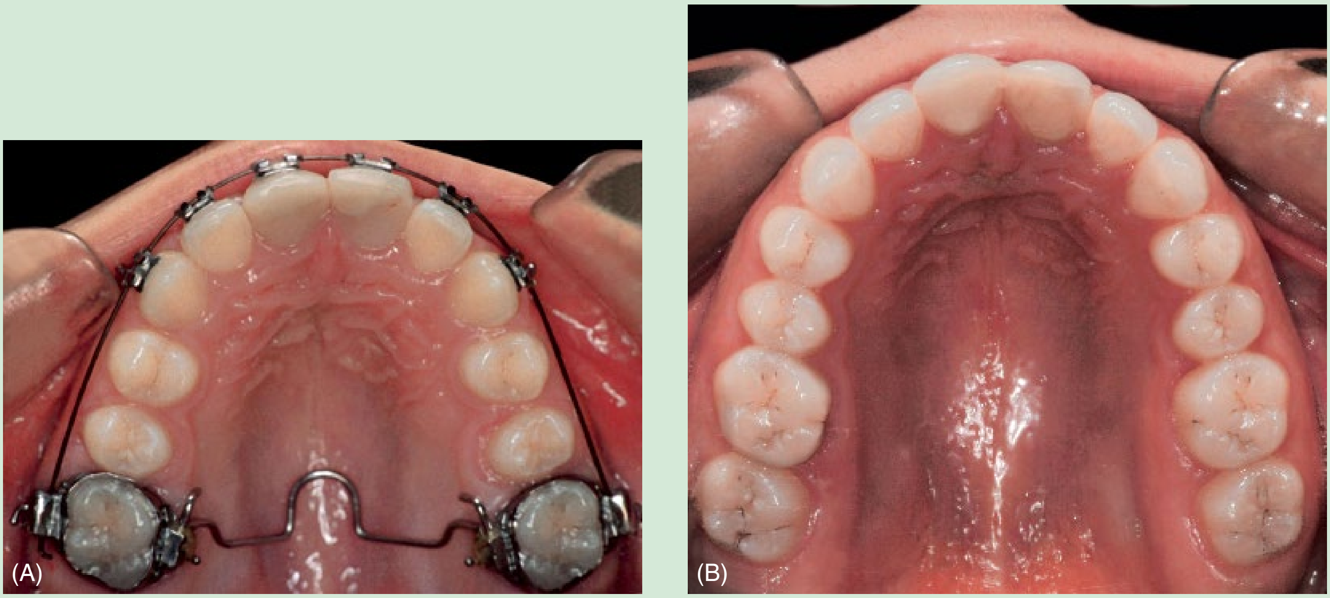

Figure 30.34 Occlusal view of the upper arch during **(A)** and at the end of the orthodontic treatment **(B)**.

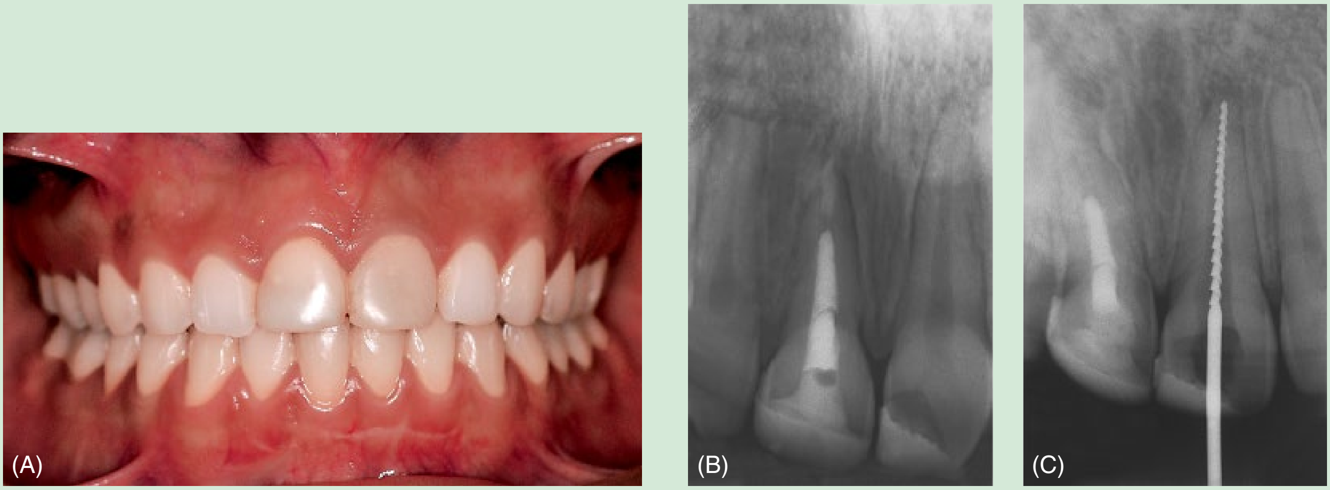

Figure 30.35 Frontal view of occlusion at the end of the therapy; the esthetic result is limited by teeth discoloration **(A)**. Definitive endodontic treatment of both upper central incisors. Control X-rays **(B, C)**.

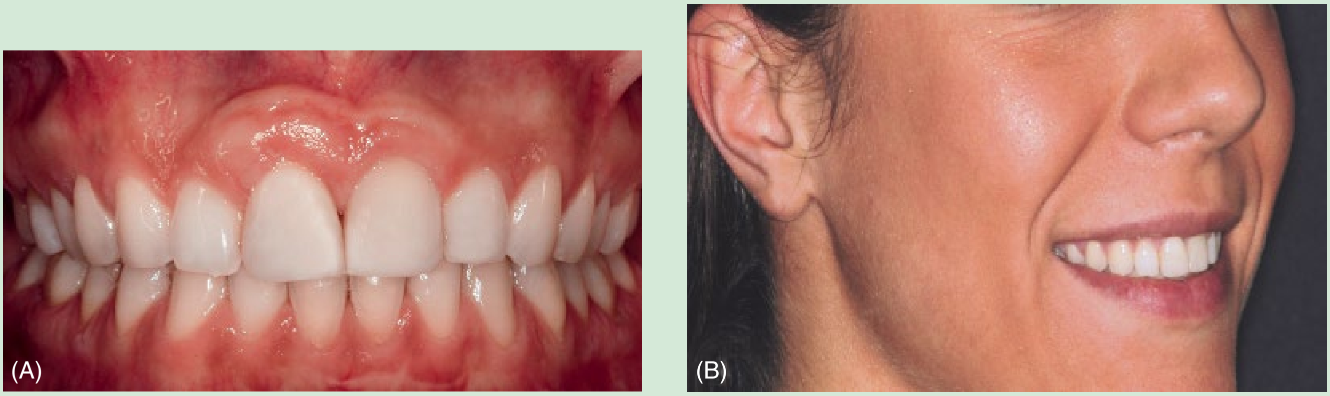

Figure 30.36 A KTP laser bleaching and definitive composite restorations were carried out to improve esthetics **(A)**. The patient's smile 15 years after the traumatic injury **(B)**.

Clinical case 30.12: Luxation injury in a 7.8-year-old female

Problem

Luxation injury of teeth #8 and #9, with lip pain and edema and bleeding (Figure 30.37A and B).

Treatment

Soft diet and oral hygiene instructions. LLLT (at a dose of 3–4 J) within 4 days to treat pain, swelling, and inflammation and to promote tissue repair with deep tissue penetration.

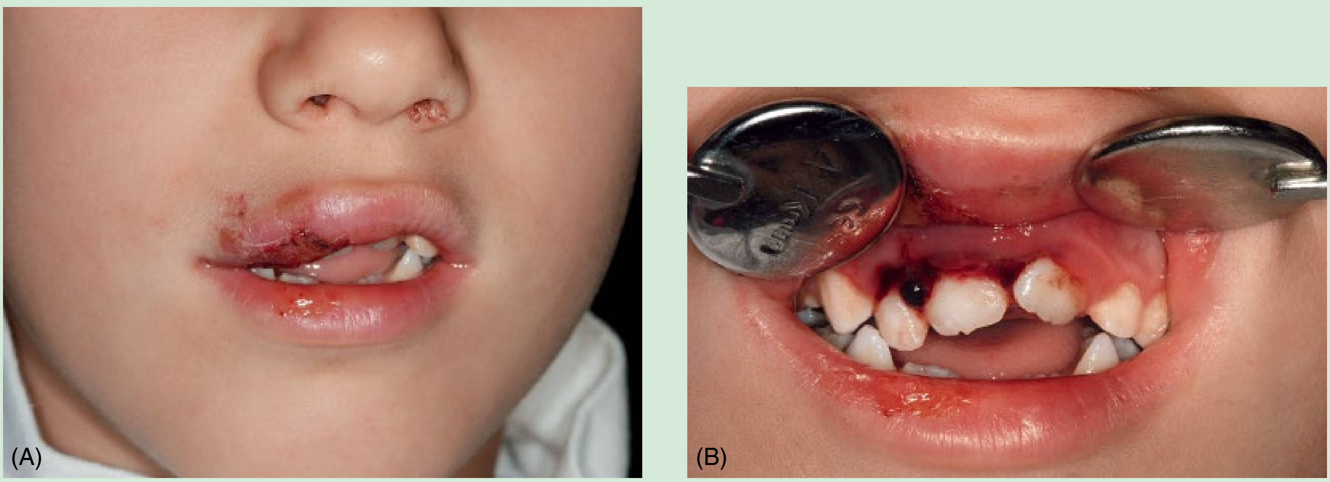

Figure 30.37 **(A, B)** An injury to supporting tissues: bleeding and pain are present.

Result

Biostimulation of soft tissues and lips led to greatly improved wound healing thanks to faster epithelization and collagen deposition (Figure 30.38).

Figure 30.38 **(A, B)** A KTP laser is used to decontaminate the inflamed area and to exploit the laser's antalgic and biostimulating action, thereby improving positive outcome and reducing complications.

Clinical case 30.13: Discolored frontal upper incisor due to previous trauma in a 19-year-old

Problem

Discolored frontal upper incisor due to a previous trauma and desire to improve esthetics (Figure 30.39).

Treatment

Careful diagnostic wax-up (it is recalled that a well-planned and well-executed diagnostic wax-up is essential to ensure good communication with both the patient and the laboratory). Preparation of teeth for porcelain laminates. Fabrication of temporary restorations from a matrix formed over the diagnostic wax-up (Figure 30.40A).

Result

Satisfactory color correction using porcelain laminates (Figures 30.40B and 30.41).

Figure 30.39 **(A, B)** Discoloration of teeth #8 and#9 due to a previous traumatic injury.

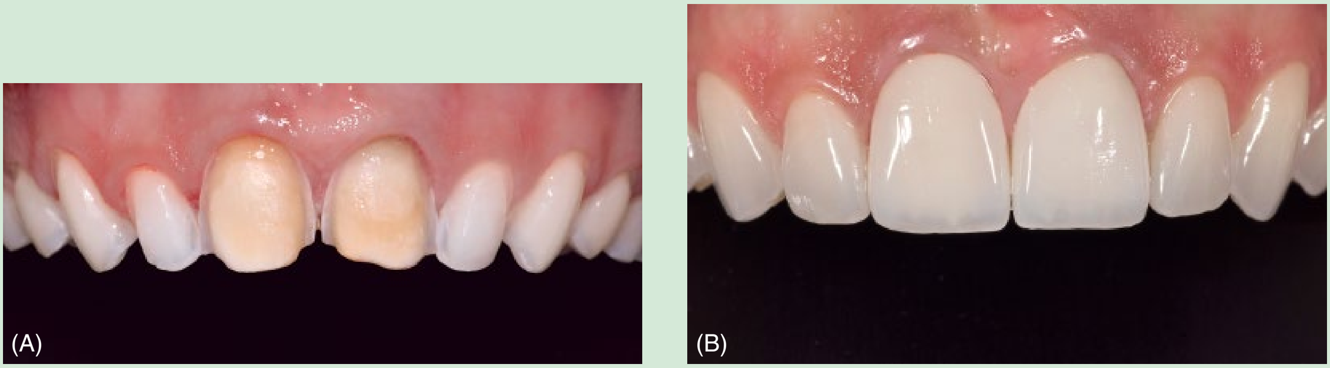

Figure 30.40 Teeth are prepared **(A)** and porcelain laminates are placed **(B)**.

Figure 30.41 Post-treatment smile.

Taking into account several fundamental concepts as well as new therapeutic trends that focus on shape resetting for improved esthetics and harmony of the dental arches, the approach used is to balance the arch symmetrically and monitor the eruption of the first permanent molar (tipping, uprighting) to prevent mesialization of the first lower molars. Next, a correct dentoskeletal analysis, cephalometric study, and careful evaluation of the means and materials must be done before formulating a diagnosis and logical prognostic evaluation. Finally, the application of orthodontic brackets to primary teeth has a number of advantages that must be considered. These include reduced risk of demineralization; the possibility of good anchorage, which decreases the reaction counterforce; and the reduction of acid-etching time and problems associated with the removal of orthodontic brackets.

The dentist can perform several different treatments:

- slicing of the primary cuspids and/or primary second molars;
- placement of a lip bumper on the primary second molars;
- symmetrical balancing of the arches following premature loss or extraction of the primary cuspid;
- uprighting of the first permanent molars.[23]

Particularly prominent among the fundamental concepts of pediatric dentistry is the need to obtain correct evolution of the arches, as well as to treat any irregular condition.[33,34] The first primary molars are the ones that, during eruption, determine the first proprioceptive reflexes on the transverse plane. Compared with the second primary molars, however, their role and maintenance are of secondary importance. Indeed, the second primary molar plays a strategic role, its presence being essential to guide the eruption and articulation of the first permanent molars. The restoration and preservation of the posterior primary teeth are vital to maintaining the arch length and eliminating the risk of mesial drift of the permanent molars.

Arch length and arch anatomy can be modified by:

1. Tooth crowding, or loss of space (unilateral or bilateral). This may be associated with different conditions: premature extractions because of caries, tooth loss in traumatic events, ectopic eruptions, impactions, transpositions, ankylosis, agenesis, microdontia, or supernumerary teeth.
2. Habits such as oral breathing, sleep apnea syndromes, and thumb sucking. Patients with harmful oral habits usually present with a reduction of transverse (cross) diameters, as well as the loss of one or more primary molars, which could lead to a further collapse of the arch.
3. Presence of a malocclusion—Class II with an increased overjet and/or overbite or Class III with an anterior crossbite and/or posterior crossbite and/or open bite.[6,35]

The pedodontist, often working with the orthodontist, must perform a careful analysis of the dentition. The goal is arch harmony and a good balance between function, arch form, and oral tissue conditions.

Optimal space maintenance therapy is based on preservation of the primary molars until natural exfoliation. Dental education and improved prevention have reduced the number of children who develop malocclusion because of premature loss of primary teeth. This has indeed become one of the most controllable causes of malocclusion. When posterior teeth are damaged or lost, pediatric crowns for grossly damaged teeth, space maintainers (fixed or removable appliances), or esthetic posterior restoration techniques can be used to maintain arch length.

Interproximal caries in primary teeth, due to the different thickness of the enamel and dentin, can more easily extend to the pulp, making endodontic therapy necessary. In this context, compomers and composite resins are the materials of choice on account of their easy handling, reduction of tooth preparation, reasonable wear properties, good esthetics, and fluoride-leaching properties.

Clinical case 30.14: Agenesis of teeth in a 14-year-old male

Problem

Agenesis of teeth #7 and #10. Alignment of dental arches and closure of spaces after treatment with a fixed orthodontic appliance; the cuspids need reshaping to improve esthetics (Figure 30.42).

Treatment

Placement of a rubber dam to maintain isolation during a multiple bonding procedure. Etching of the cuspid surfaces, followed by restoration with composite resin (Figure 30.43).

A diagnostic wax-up and computer imaging may help the patient to appreciate the anticipated result.

Result

The final result can be seen in Figure 30.44. Greatly improved smile (well proportioned and more attractive) after a single-sitting procedure.

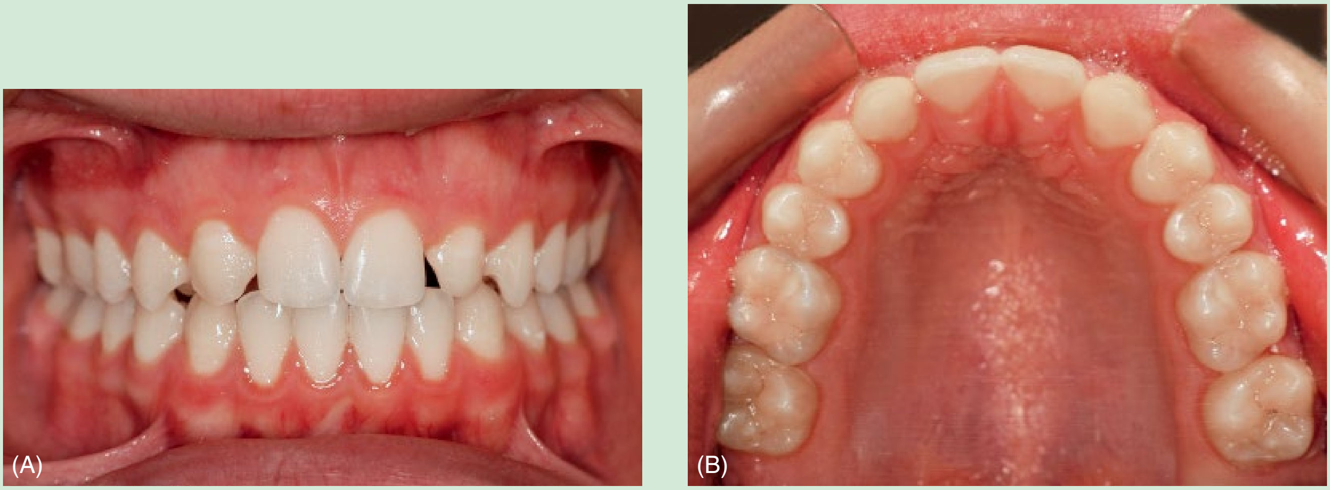

Figure 30.42 The patient after the orthodontic treatment; teeth #7 and #10 are missing. Frontal **(A)** and occlusal **(B)** views.

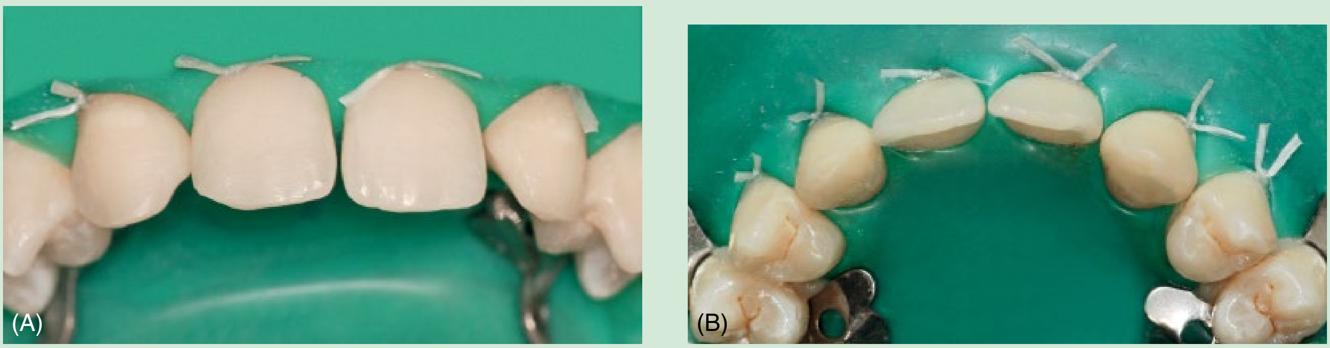

Figure 30.43 **(A, B)** Placement of a rubber dam to maintain isolation during a resin bonding procedure to reshape cuspids as laterals.

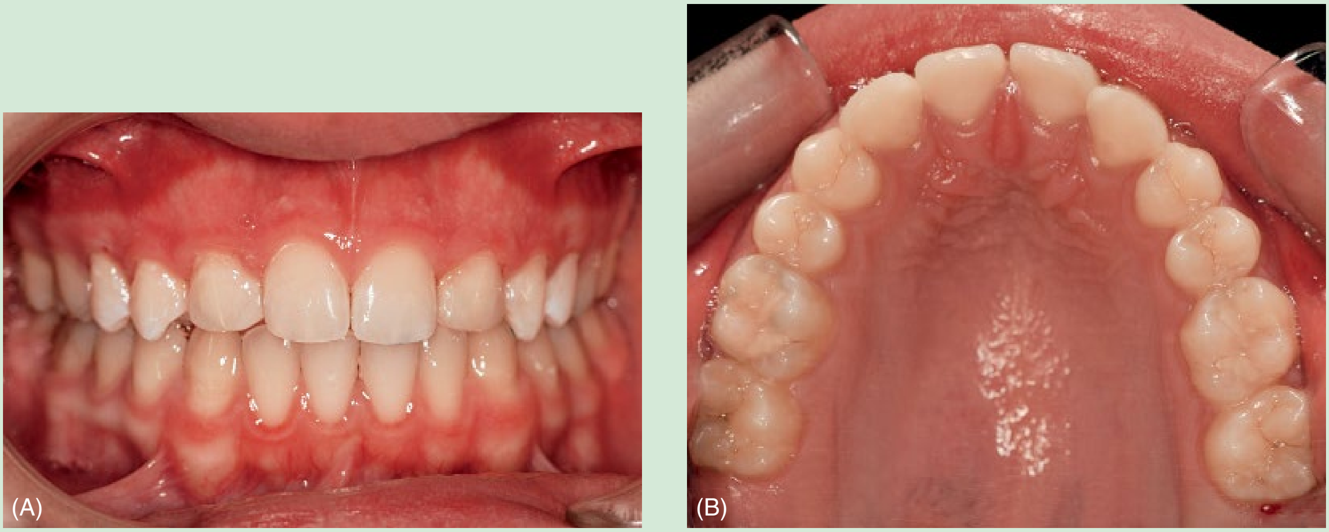

Figure 30.44 The final result after coronoplasty. Frontal **(A)** and occlusal **(B)** views.

Clinical case 30.15: Inclusion of tooth and crowding in a 12.7-year-old female

Problem

Inclusion of tooth #6 and minor crowding of the lower arch after phase 1 interceptive orthodontic treatment. Ortho surgery for guided eruption not indicated due to the tooth position (Figures 30.45 and 30.46).

Treatment

Transplantation of the tooth (vital) after orthodontic space preparation in the upper arch and lower arch alignment. Extraction and immediate repositioning of tooth #6 after avulsion of C and the creation of a new alveolus. Fixation of the cuspid, first by suturing and later by splinting with an orthodontic appliance. Control of tooth vitality by thermal and electrical tests and by X-ray examination during the orthodontic treatment (Figures 30.47, 30.48, 30.49, and 30.50).

Result

Successful esthetic outcome in a patient with a variety of problems (Figures 30.51 and 30.52).

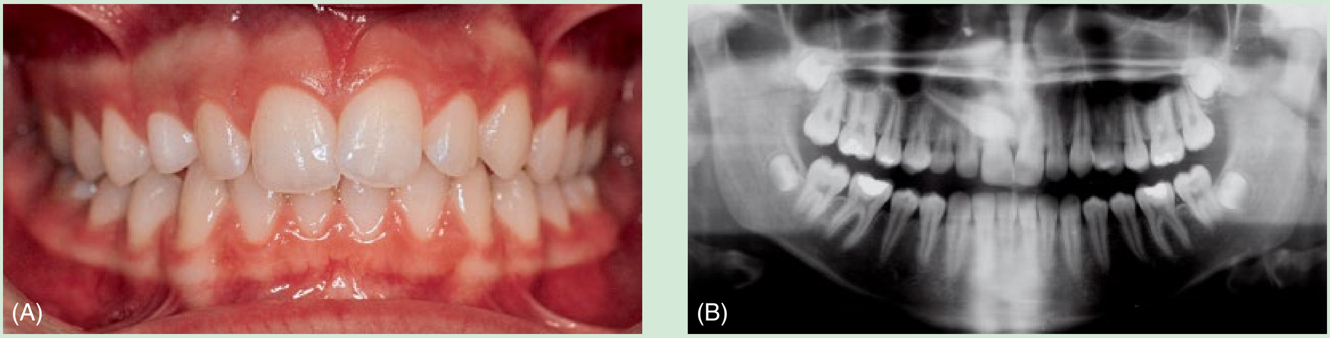

Figure 30.45 Frontal view: note the retention of tooth #6 **(A)** and orthopantomograph **(B)**.

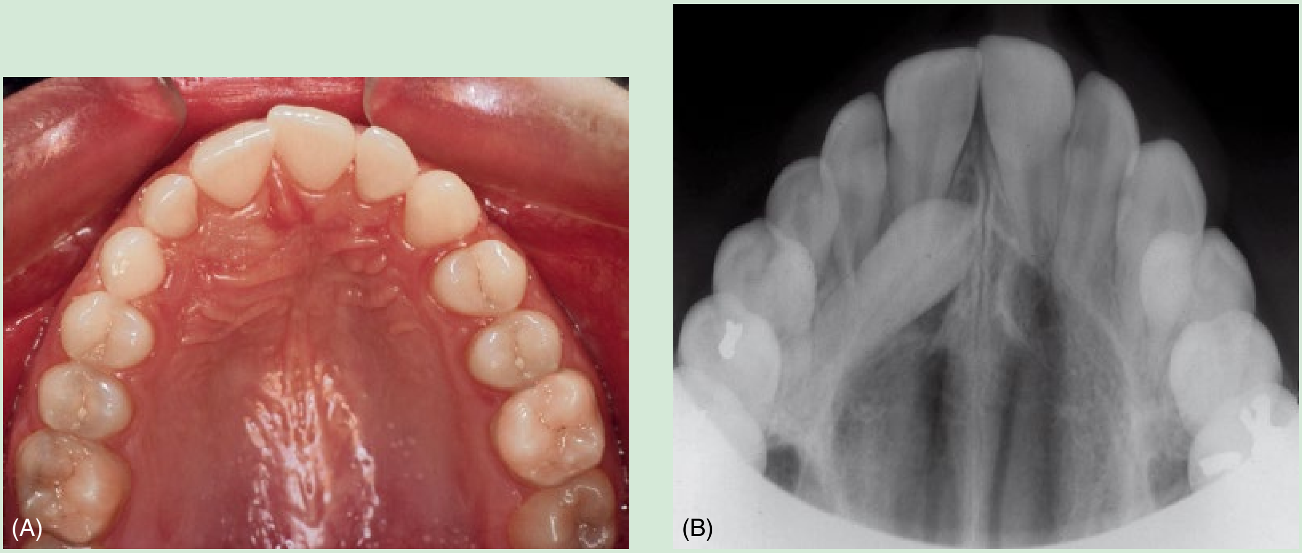

Figure 30.46 Occlusal view **(A)** and occlusal control X-ray **(B)**.

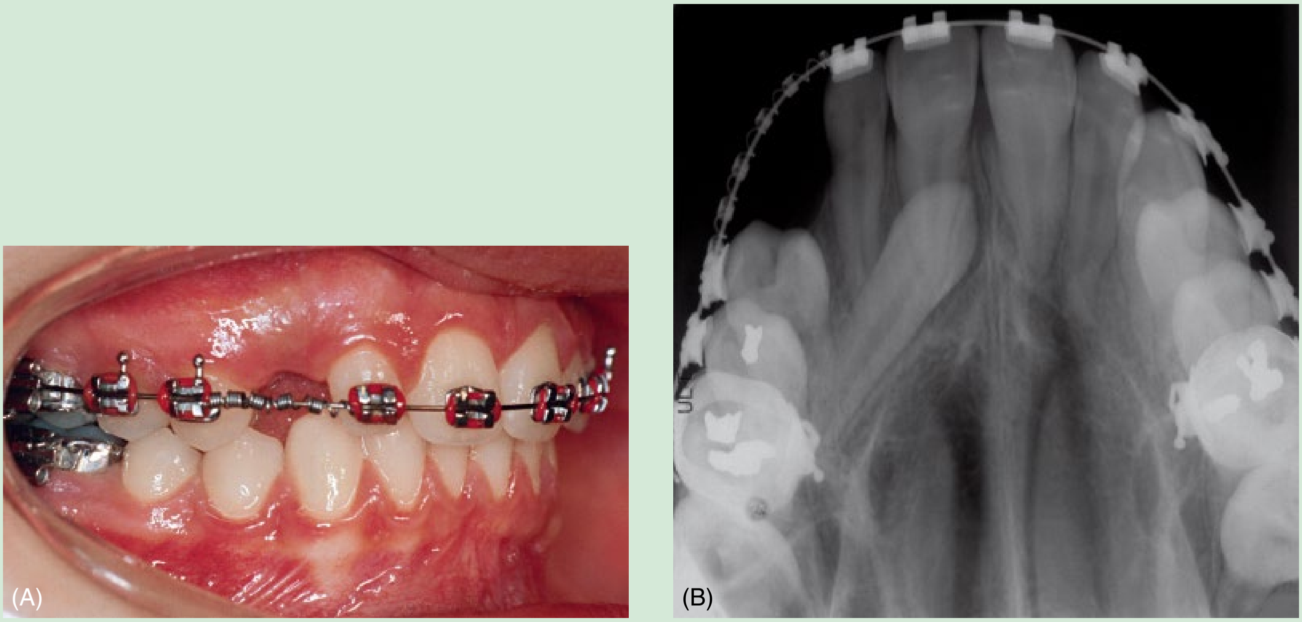

Figure 30.47 Orthodontic space preparation **(A)** and control X-ray before autotransplantation **(B)**.

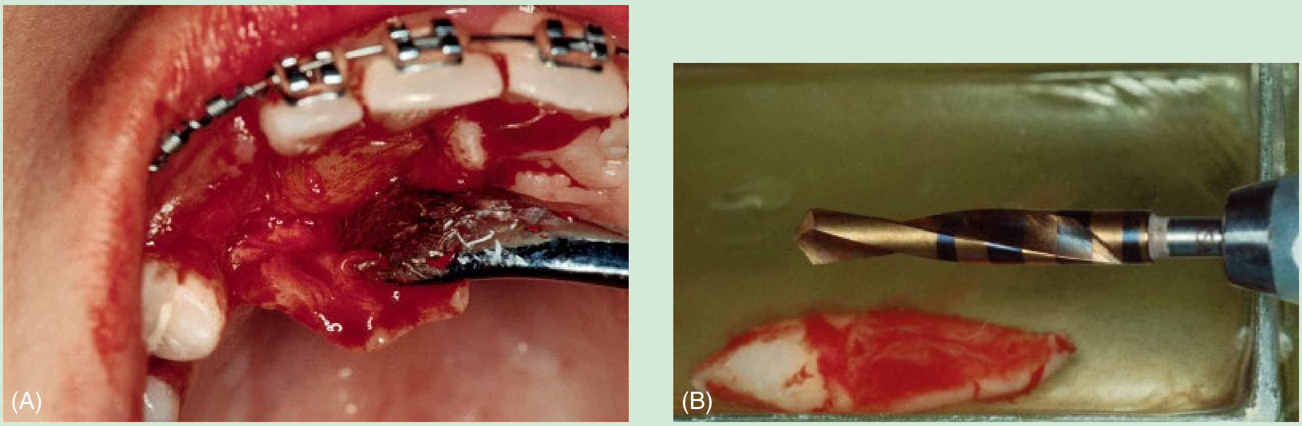

Figure 30.48 Surgical tooth exposure **(A)**. Tooth #7 is extracted and conserved in saline solution until transplantation **(B)**.

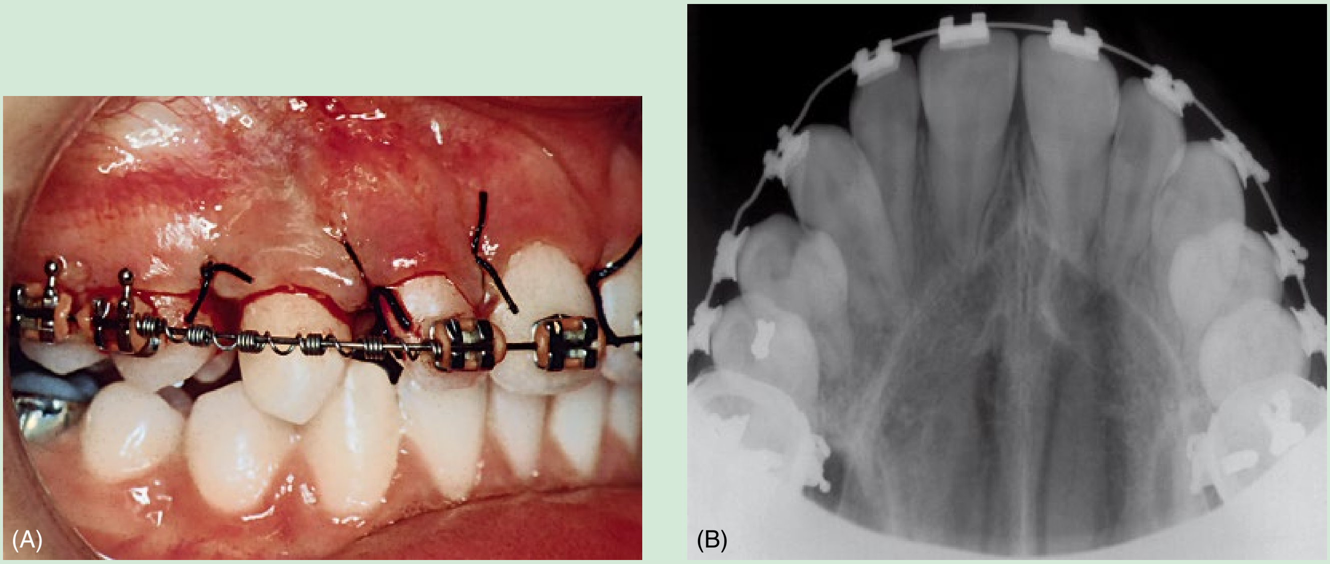

Figure 30.49 The tooth is inserted in the alveolus created **(A)**. Control X-ray **(B)**.

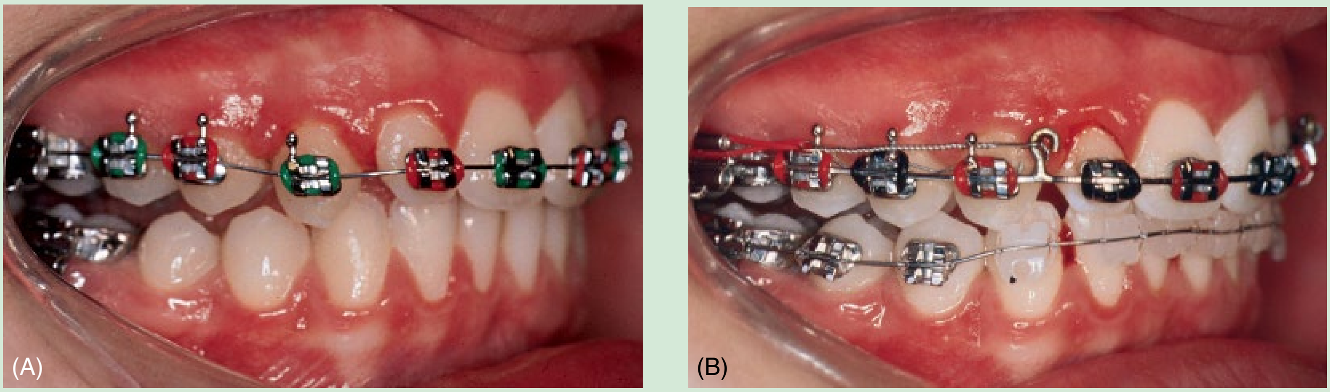

Figure 30.50 **(A, B)** The patient during different orthodontic treatment phases.

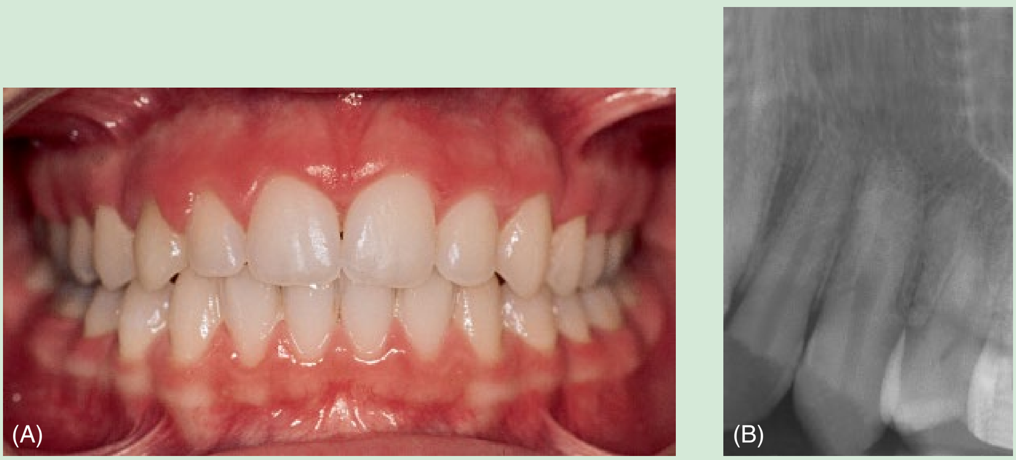

Figure 30.51 The patient at the end of the treatment. The transplanted tooth #6 is vital **(A)**. Control X-ray **(B)**. A very good balance and good esthetics are achieved.

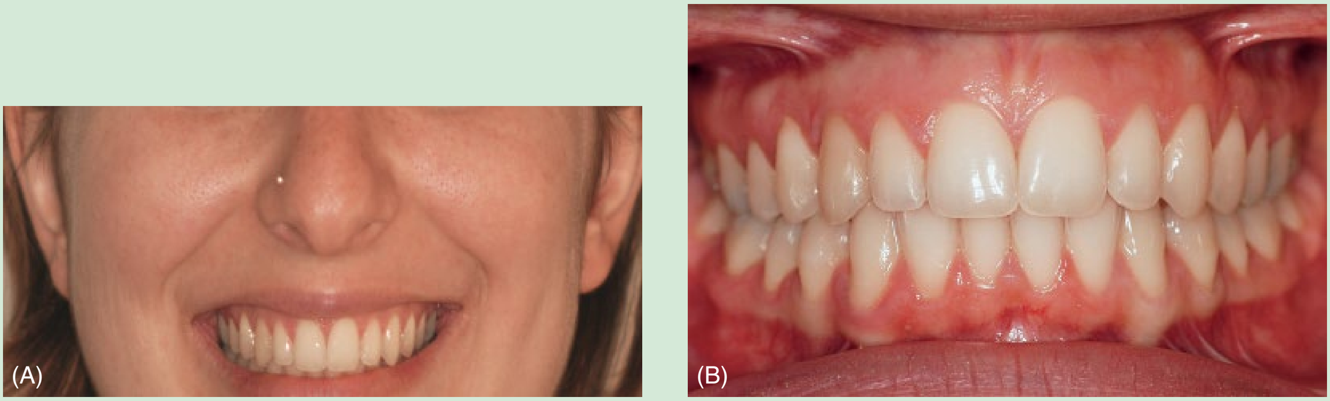

Figure 30.52 The patient's smile **(A)** and frontal intraoral view **(B)** 10 years later.

In such patients who may present, for example, included teeth, drifting, crowding, and malocclusion, the intervention of several dental disciplines is required. As dental professionals, we should try to form groups of practitioners specializing in different areas who can all participate in a patient's diagnostic workup to ensure a successful esthetic outcome.

Clinical case 30.16: Supernumerary (double) tooth in a 9.2-year-old male

Problem

A supernumerary (double) tooth in place of the central upper left incisor (tooth #9) (Figure 30.53). This anomaly manifests itself as a structure resembling two teeth that have been joined together. In the anterior region, the anomalous tooth usually has a groove on the buccal surface and small cut in the incisal edge. X-rays are necessary to determine whether there is a union (fusion) of the pulp chambers. Fusion exists when two teeth are joined at the level of the pulp and dentin. There are usually two root canals, as in this case (Figure 30.54).

Treatment

Surgical separation and extraction of the fused supernumerary tooth; application of a fixed orthodontic appliance to the maxillary arch to align the arch and close the anterior diastema. Subsequently, restoration of the incisal margin and the interproximal area of tooth #9 to improve esthetics and gingivoplasty to improve gingival margins. Monitoring of the tooth by vitality testing and X-ray examinations (Figures 30.55, 30.56, 30.57, and 30.58).

Result

Good morphofunctional recovery and an esthetic result that satisfied the patient, achieved through the teamwork of several specialists (Figures 30.59 and 30.60).

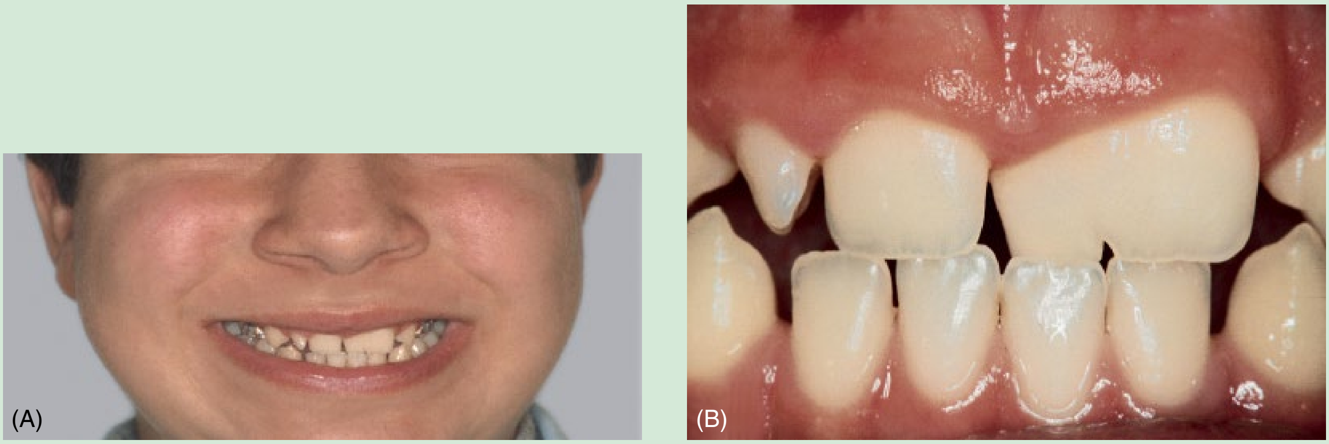

Figure 30.53 A double tooth in place of the central upper left incisor. The patient's smile **(A)** and intraoral frontal view **(B)**.

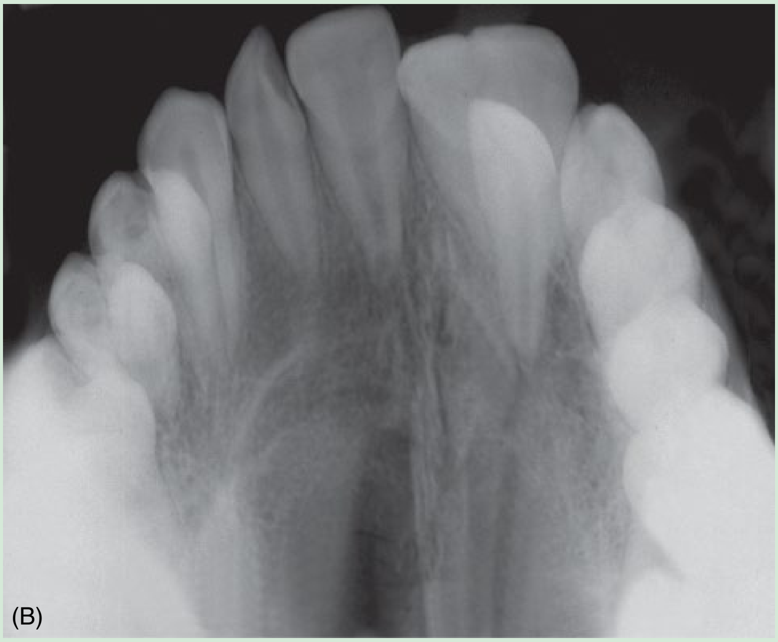

Figure 30.54 Initial orthopantomograph **(A)** and control X-ray **(B)**.

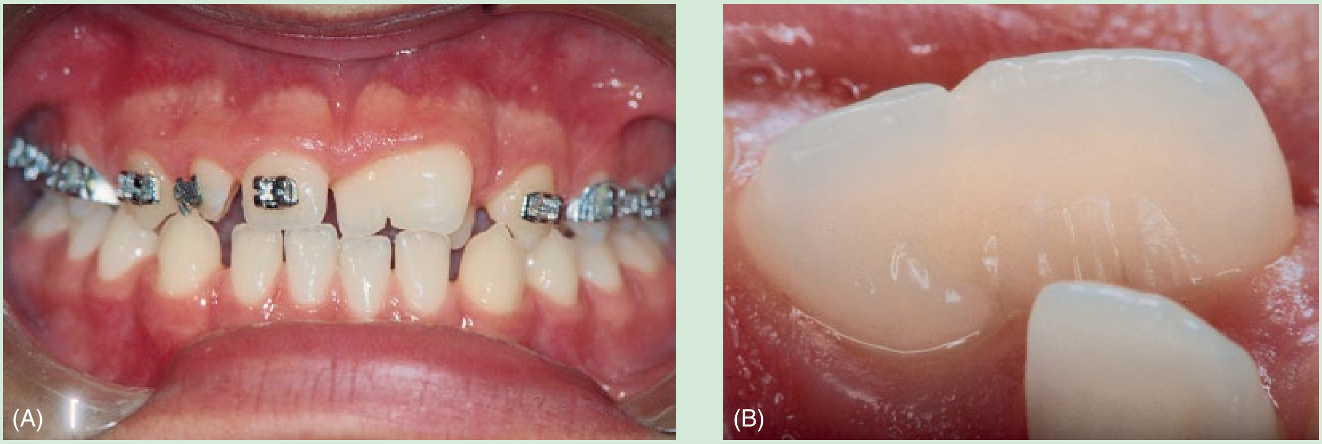

Figure 30.55 Initial orthodontic preparation **(A)** and occlusal view **(B)**.

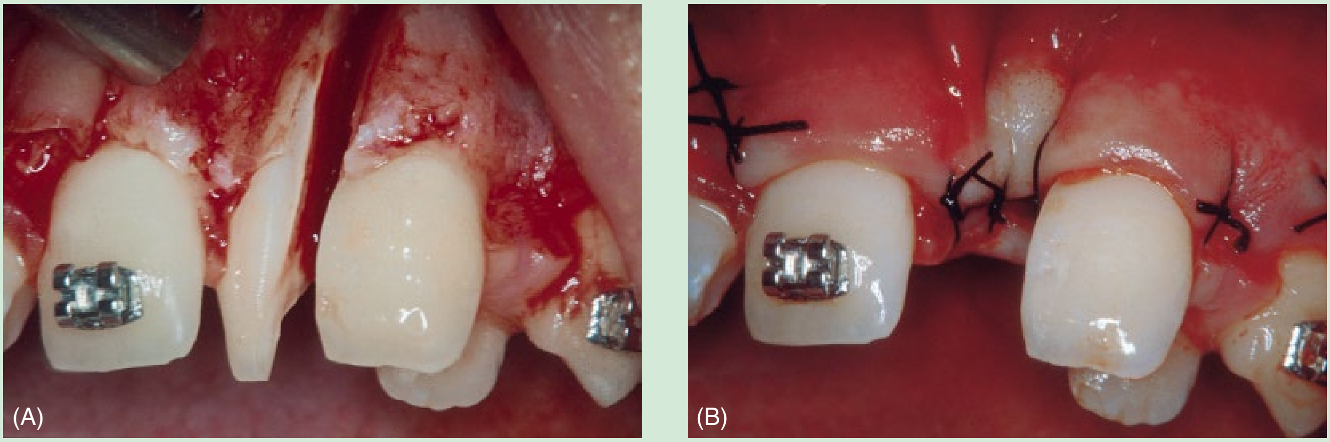

Figure 30.56 The fused supernumerary tooth is surgically separated **(A)** and extracted **(B).**

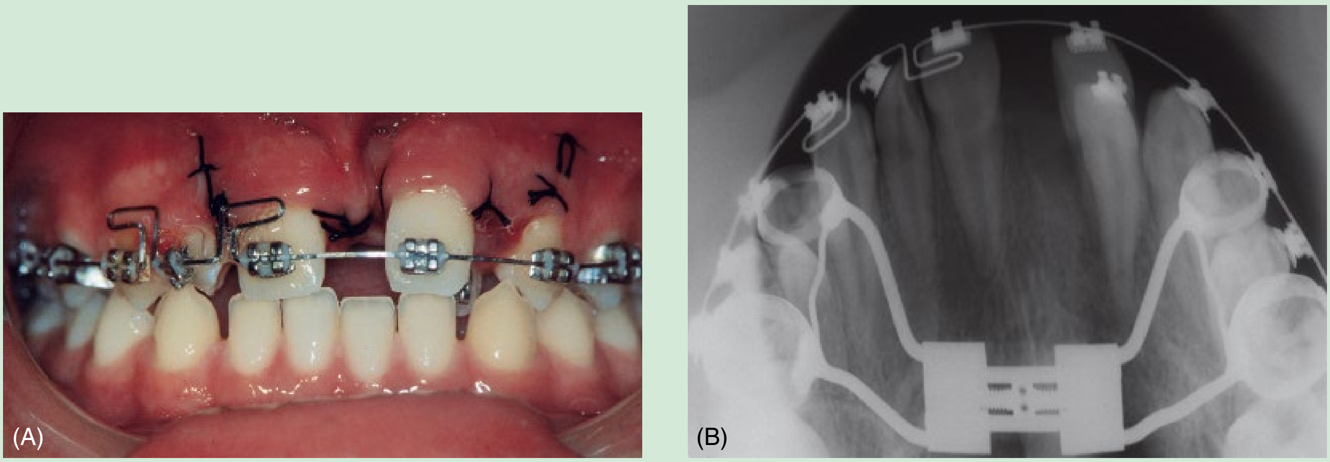

Figure 30.57 Immediately after surgery a rapid palate expander is placed **(A)**. Control X-ray **(B)**.

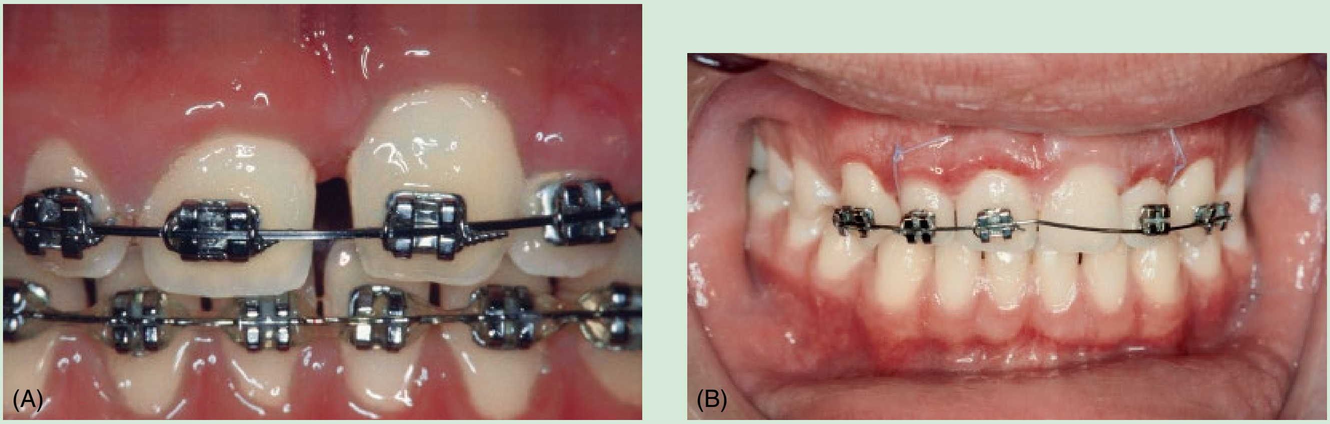

Figure 30.58 Orthodontic treatment phase to align teeth and close the anterior diastema **(A)**. Prior to bracket removal, a gingivoplasty procedure is performed **(B)**.

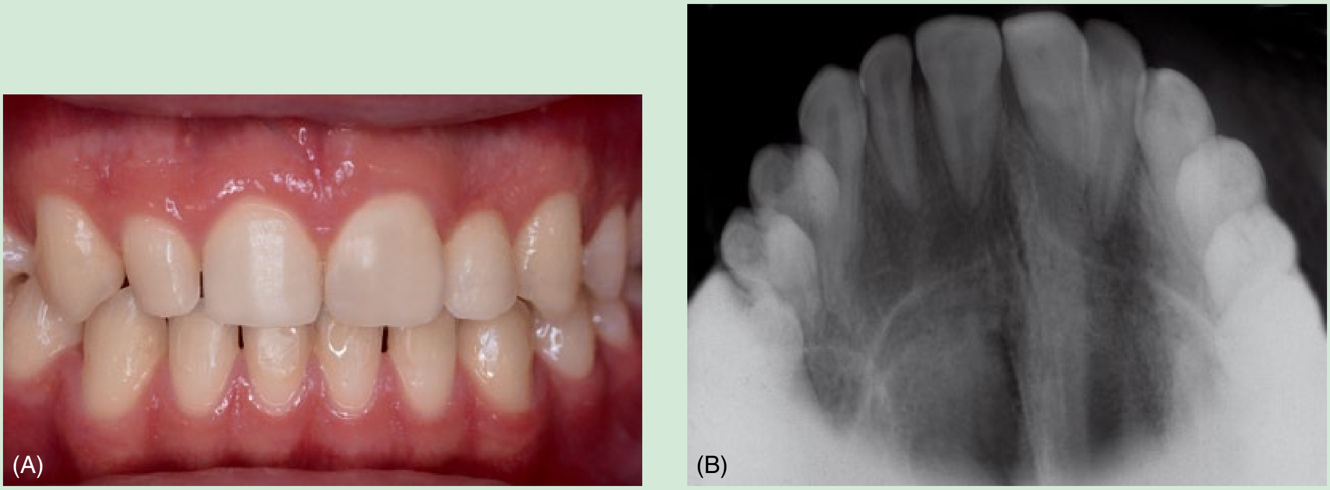

Figure 30.59 The patient's occlusion at the end of the treatment; note that the gingival margins of the central incisors are level **(A)**. Post-treatment control X-ray **(B)**.

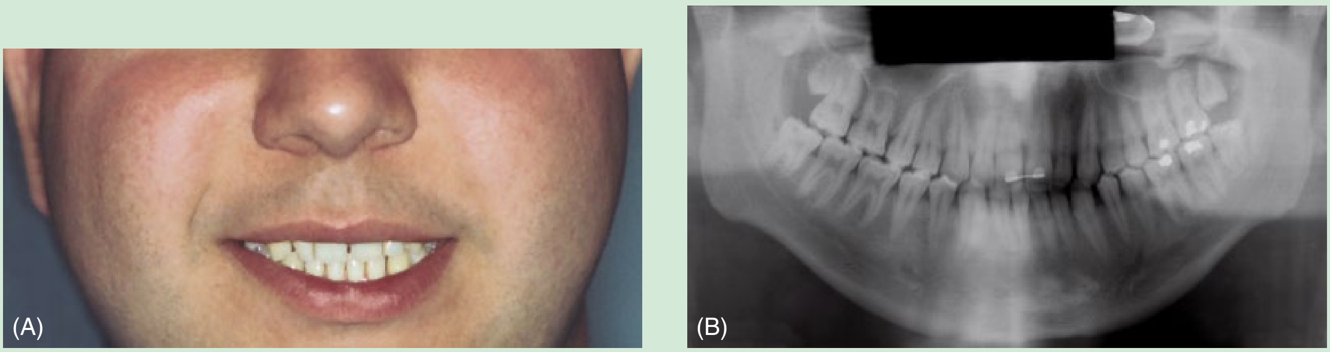

Figure 30.60 The patient 10 years after the end of the treatment **(A)**. Orthopantomograph; notice that tooth #9 is still vital **(B)**.

Clinical case 30.17: Patient with an open bite

Problem

Severe dentoalveolar open bite caused by thumb sucking (Figure 30.61).

Treatment

Two-phase orthodontic treatment: use of a functional appliance to reduce open bite followed by use of a fixed orthodontic device to improve arch morphology and occlusal function (Figures 30.62 and 30.63).

Result

Successful two-phase orthodontic treatment resulting in arch balance and improved esthetics and health of oral tissues. Greater self-confidence and well-being, thanks to the improved smile (Figure 30.64).

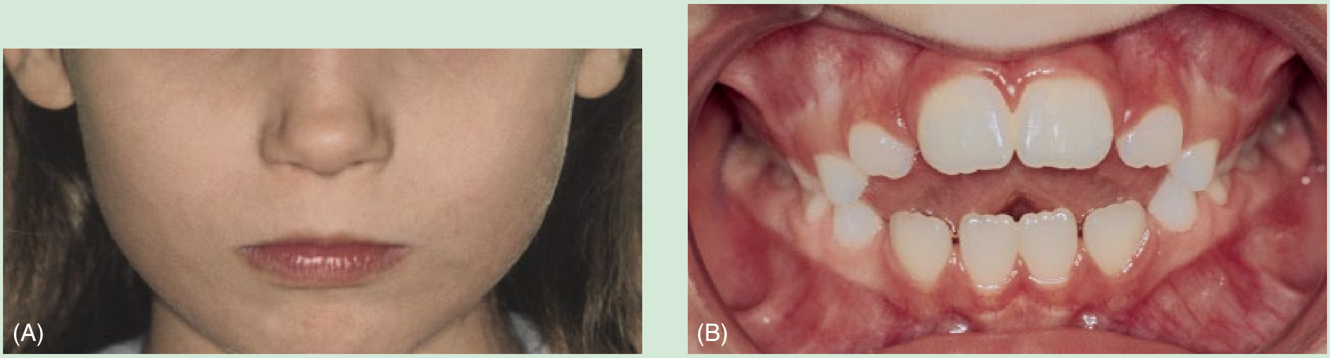

Figure 30.61 A young patient **(A)** with a severe dentoalveolar open bite from thumb sucking **(B)**.

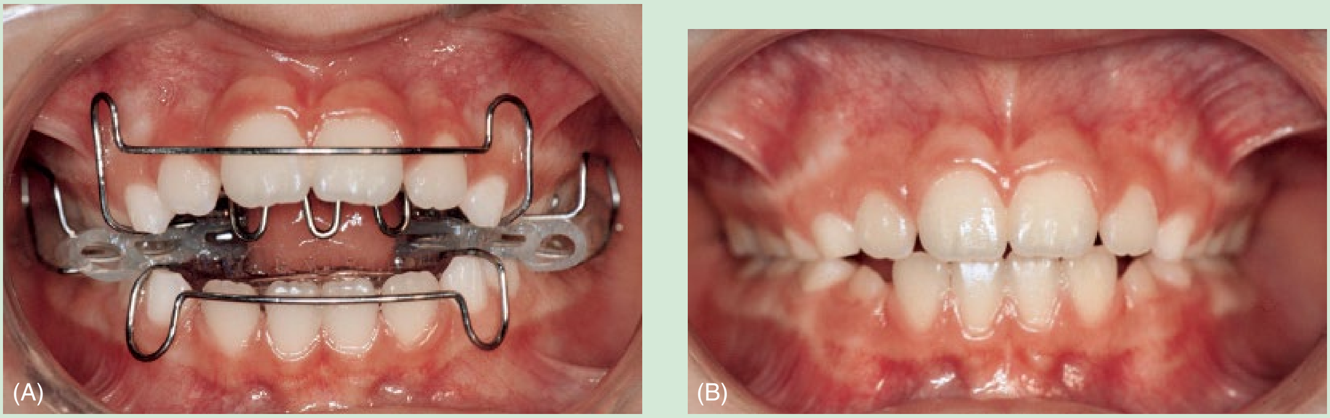

Figure 30.62 The patient was treated with a functional regulator worn for a period of 1 year **(A)**. Frontal view after interceptive orthodontics **(B)**.

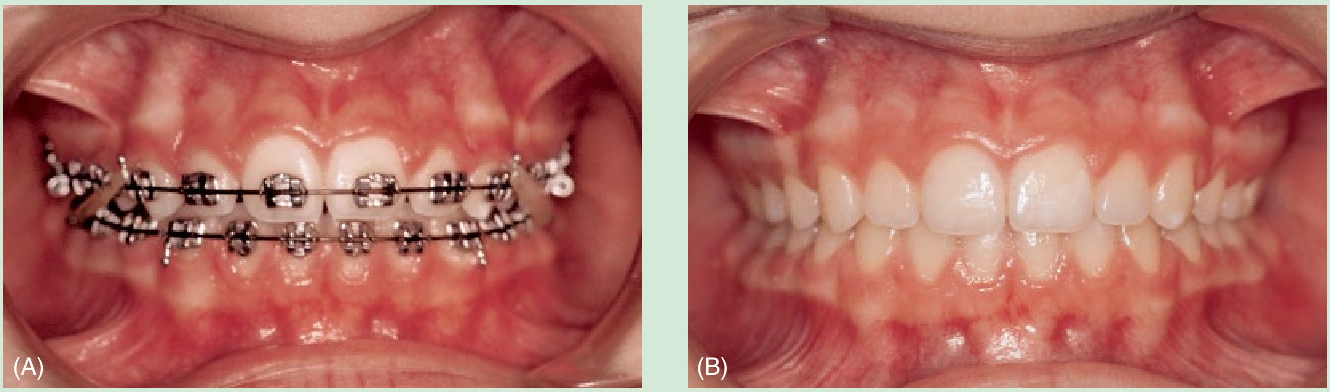

Figure 30.63 The final phase of treatment to correct the relationship of the front teeth in the vertical plane **(A)**. The patient at the end of the treatment **(B)**.

Figure 30.64 The patient's face **(A)** and the frontal view **(B)** after 10 years.

Facial harmony in pediatric dentistry: esthetic keys

The concept of "beauty" has always been subjective. With regard to individual facial esthetics, many attempts have been made over the centuries to establish what constitutes the golden section or divine proportion. In spite of all these efforts at standardization, each age and every century has brought its own esthetic canons, just as each individual may have their own esthetic ideals. However, our society is continuously creating new trends and ideals of beauty to which people aspire. Over the past few decades in the Western world, an individual's appearance has assumed much more importance and become essential in establishing self-image. Ultimately, it contributes to success in all aspects of professional and social life. For this reason, many branches of medicine that have an esthetic component are continuing to research and improve their techniques. One such discipline is orthognathodontics, which is extending its field of activity from the smile to the entire face of the patient. As Goldstein says, "The way you see yourself and think others see you has a great deal to do with the way you feel about yourself. A charming smile can open doors; our own self-image is the key to our happiness."[6,36]

Cephalometrics and soft-tissue analysis

Several authors have shown that orthodontic treatment, including orthognathic surgery, can improve facial harmony. Traditional cephalometrics, based on angular and linear measurements of the patient's soft and hard tissues, have proven to be less than reliable for achieving correct diagnoses and satisfactory esthetic results. It suffices to say that no cephalometric analysis has universal appeal. Most cephalometric analyses use intracranial skeletal plans as a reference. On the basis of the assumption that facial esthetics, harmony, and facial balance are achieved through the achievement of specific dental and bone parameters, diagnosis and proposed treatments are based on these plans. However, many authors now agree that a careful analysis of the soft tissue is needed as well. Thus, cephalometrics now includes studies and measurements also involving soft tissues using the usual teleradiographies of the skull in norma lateralis or the photographic records of the patient in lateral view or, more rarely, in frontal view.

Good functional occlusion that complies with the usual skeletal parameters does not always correspond to an esthetically pleasing facial balance. The soft tissues covering the skeleton of the face can make dentoskeletal analysis an unreliable means of assessing facial harmony. (In other words, if the lips are not well balanced and closed at rest, facial dysmorphosis can be present even in the absence of dentoskeletal alterations.) According to Blanchette et al., the soft tissues have a tendency to mask discrepancies of the bone base (maxilla and mandible); thus, it is suggested that we find thinner soft tissues in subjects with a low-angle facial type and thicker soft tissues in those with a high-angle type.[36] This perhaps explains why Ferrario et al. found significant correlations between skeletal class and soft tissues[37] and why Burnstone et al. argued that no dentoskeletal standard can reliably predict the final esthetics of the face.[38]

The goal of an orthodontic treatment should be the achievement of good functional occlusion along with appealing dentofacial esthetics, maintaining the integrity of the dentoperiodontal tissues. Now several practitioners have started to focus on study of the face rather than the skeleton of the patient. Therefore, the transition has been from a diagnostic system, which can be defined as "centrifugal"—that is, it starts from the skeleton and goes outward—to a "centripetal" system, which instead begins with an analysis of the soft tissues to establish the corrections that are needed at the level of the hard tissues. Arnett and Bergman[39] and Ayala's[40] cephalometric analyses visually evaluated the facial contour of patients' soft tissue exclusively in a natural position, both frontal and lateral views, to arrive at a diagnosis and treatment plan.

Esthetic reference parameters in children

All the existing diagnostic systems based on the analysis of soft tissues are designed for use in adults, particularly candidates for orthognathic surgery. The purpose of this section is to propose a method of analysis for determining esthetic reference parameters reliable for the face of the child (in the different stages of their growth), which may, in turn, be useful for creating a clinical alternative to cephalometric analysis of the soft tissues. Moreover, this method could integrate and complement the usual cephalometric analysis, allowing the clinician to achieve not only esthetic facial harmony but also a good balance.

Holdaway, after analyzing the different methodologies used in different studies to evaluate the harmony of soft tissues in adults, selected reference parameters and data that should be useful and

Figure 30.65 **(A, B)** These children's faces appear to be in perfect symmetry.

reliable when evaluating growing patients.[41,42] These parameters and data were subsequently modified to take into account patterns of craniofacial growth. At birth, for example, the splanchnocranium is considerably underdeveloped compared with the neurocranium. Furthermore, the mandible is the least developed part of the lower third of the face and, compared with the rest of the face, tends to grow more and for a longer period of time. Moreover, a precise growth sequence exists in both the maxilla and the mandible. This has been defined as the completion of growth in the three planes of space: growth is completed first in width, then in length, and then in height. The transverse growth of both bones (including the width of the dental arches) tends to be complete before the pubertal growth peak and is influenced little by growth variations occurring during adolescence.[37,43]

Sagittal growth of the two maxillae continues into puberty. In girls, it stops almost immediately, on average between 14 and 15 years of age. In boys, it does not usually stop before 18 years of age. In both sexes, vertical growth of the maxillae and face continues for longer than growth in length. In view of these considerations, canons of esthetic evaluation have been adapted to growing patients. The selected reference parameters are not able to predict linear measures as the growing patient, unlike the adult, cannot have fixed values.[27,43]

Frontal view: symmetry between different parts of the face

As in adults, the child's face (Figure 30.65) must show perfect symmetry, with the eyes, ears, and mandibular angles placed at the same height.

Correct distance between the eyes, nose, and lips

The 1 : 1 ratio between the width of the lips and the distance between the inside margins of the irises (Figure 30.66) remains valid. However, the child's nose base should be smaller than the intercanthal distance, as it will grow considerably.

Middle to lower facial third ratio

The parameters that are reliable in adults cannot be the same as those that are reliable in children (Figure 30.67). As previously stated, the neurocranium grows earlier than the splanchnocranium; therefore, the middle third of the face develops before the lower third. Accordingly, the lower third should be smaller than the middle and upper thirds. Indeed, when the lower third of the face develops earlier, it is a matter of particular concern, being indicative of excessive growth in a vertical direction. These considerations are inversely proportional to the patient's age.

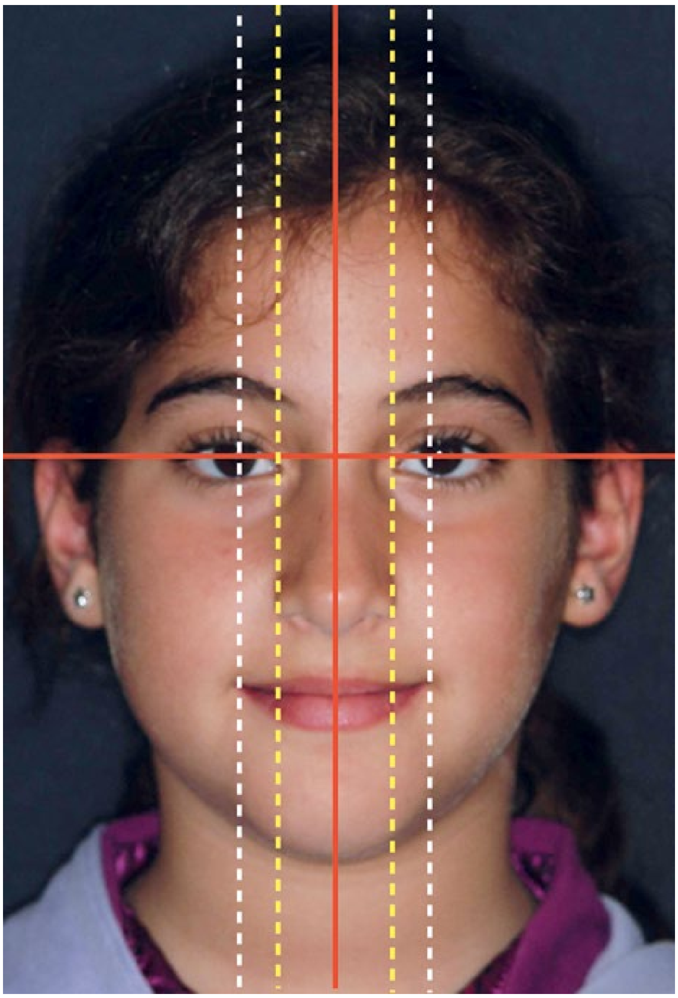

Figure 30.66 Correct distances between the eyes, nose, and lips.

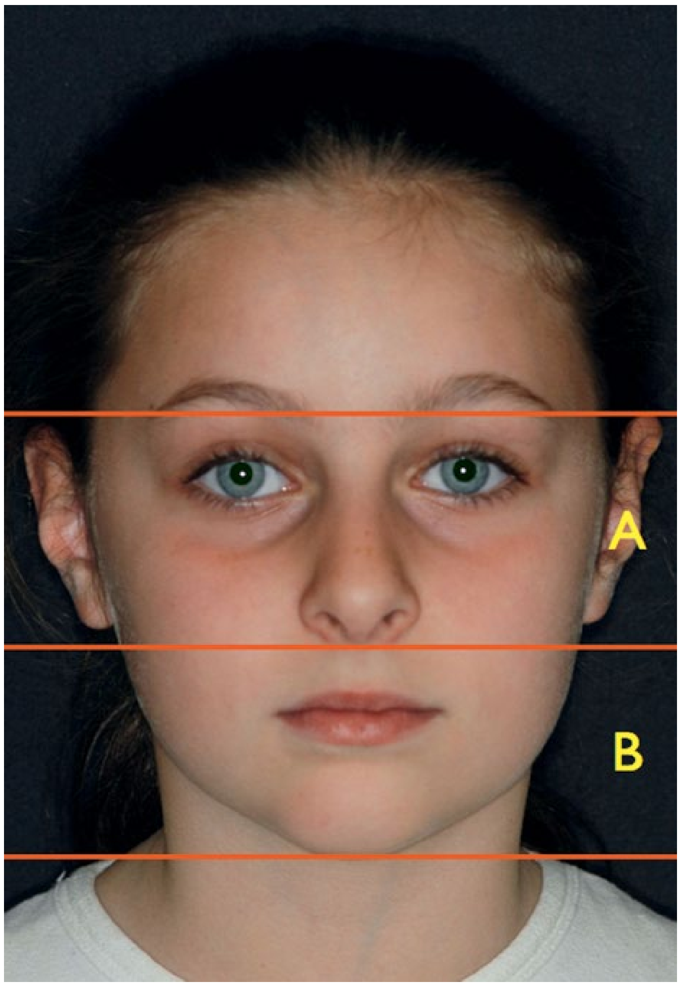

Figure 30.67 The middle third of the face develops before the lower third.

Ratio for esthetic balance

This is the division of the face by a symmetry line passing through the glabella, nasal tip, midpoint of the upper lip, midpoint of the chin, and suborbital line. The ideal trichion (Tr)–menton (Me)/zygion angle (ZA), the ZA ratio, which is 1.35 in the adult male and 1.3 in the adult female, should be lower in the adolescent, who will grow more vertically than widthwise (Figure 30.68). Therefore, the value will start from about 1 in younger subjects, increase gradually during growth, and ultimately reach normal (adult) reference values.

- Tr: the point of the hairline in the midline of the forehead. In early childhood, this landmark may be difficult to identify because of an irregular or indistinguishable hairline.
- ZA: the most lateral point of each zygomatic arch. It is identical to the bony zygion of the malar bone.
- Me (chin): the lowest median landmark on the lower border of the mandible.

Sclera exposure

Excessive exposure of sclera, the firm white fibrous membrane that forms the outer covering of the eyeball, implies a developmental deficit of the middle third of the face. If this sign is present and accompanied by other symptoms, such as oral breathing with a narrow pointed nose, reduced transverse diameters of the upper maxilla with crossbite, and, dentally, upper arch crowding with a tendency to cuspal inclusion, a skeletal Class III with maxillary hypoplasia is present.

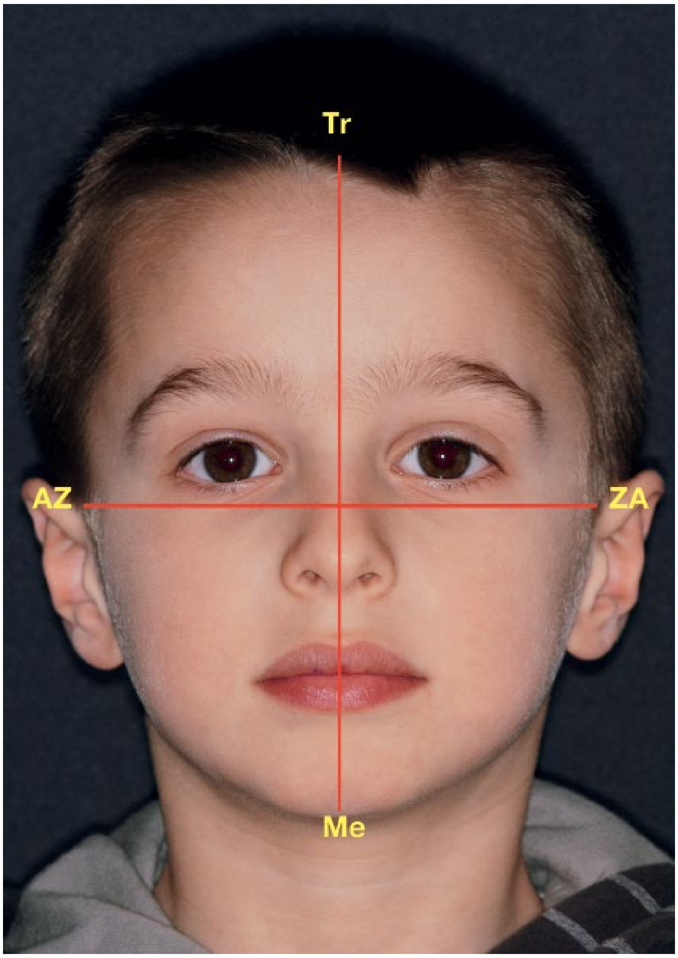

Figure 30.68 The ratio for esthetic balance.

Incisal exposure

In children, when teeth can be exfoliating or erupting, there are no reliable reference points for this parameter. However, if, when smiling, a considerable quantity of marginal gingiva is exposed, then excessive facial anterior vertical growth or excessive maxillary protrusion could be present.

Lip closure without tissue strain

Over time, all soft tissues tend to relax; therefore, it is acceptable for a young subject, compared with an adult, to have a slightly shorter upper lip and, hence, moderate lip incompetence. However, this should not persist beyond the age of 7–8 years.

Profile view considerations

Skeletal convexity from the zygomatic area to the interlabial gap

Because in children the lower facial third develops ahead of the middle third, children can be expected to have a more convex cheek profile than an adult (Figure 30.69).

It is to be noted that, in a child, a curve indicating a trend to high-angle mandibular growth is alarming.

Figure 30.69 In children, the cheek profile is more convex than in adults.

Nose prominence

This is measured from the subnasal to the pronasal parts of the nose (i.e., from the point at which the columella merges with the upper lip in the midsagittal plane to the most prominent anterior point of the nose). This distance, which normally ranges from 16 to 20 mm in adults, will obviously be smaller in children (Figure 30.70). It is important to note that a prominent nose is generally a contraindication to extractive treatment.

The shape of the nose must also be considered. Indeed, the tip of the nose tends to move down and forward with growth. Therefore, it is obvious that a convex nose shape in a child will worsen considerably as they grow. Conversely, the prognosis is better in children with a concave or flat nose shape. In these cases, it is also very useful to observe the parents. In fact, the eyes and nose are the somatic features of the face that show the highest level of heredity.

An increased nasolabial angle must not be considered an absolute contraindication to a protocol of serial extractions, but only as one of the clinical factors to be taken into account when evaluating the case.

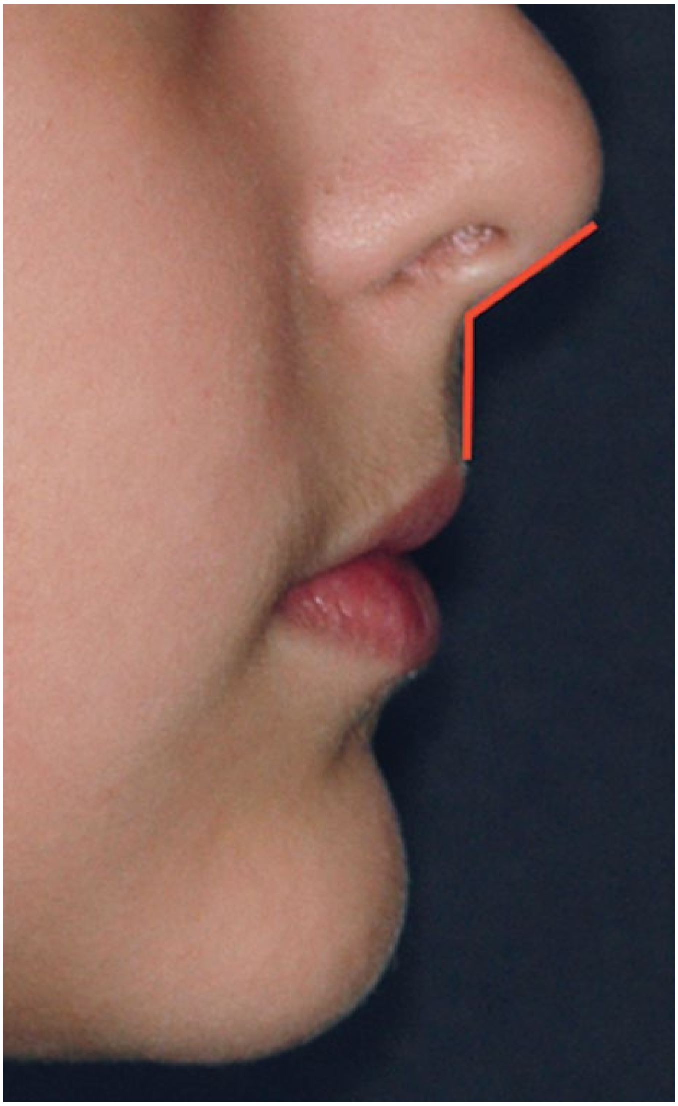

Figure 30.70 The nose prominence (subnasal–pronasal).

Lip curvature

Both the upper and lower lips must show a slight curvature, with concavity pushing forward. A very marked labiomental sulcus in a child may indicate a sagittal mandibular and maxillary vertical deficit, and thus that the child will have a low-angle facial type (Figure 30.71). Alternatively, the total absence or disappearance of this sulcus may indicate sagittal and vertical mandibular development involving both planes and, therefore, a high-angle facial type. High-angle subjects are able to camouflage dentoskeletal Class III components and low-angle subjects Class II components, improving the dental compensations that are present in such cases.

Nasolabial angle

The nasolabial angle can be more open in the child because the tip of the nose grows lower. Generally, in adults, soft tissues generally tend to relax and become less toned. For this reason, it is acceptable for a young patient to have a slightly short strained upper lip and a smile with up 3–4 mm of gingival exposure.

Figure 30.71 In a child, a very marked labiomental sulcus may indicate a sagittal mandibular and maxillary vertical deficit.

Correct ratio between the submental area and the lower facial third

This ratio, NTP–Gn/Sn–Gn, whose normal value in adults is about 0.8, will be higher in children even though the mandible still has to develop in length. There are two reasons for this: the lower third of the face will continue to develop in height and the chin–neck contour is modest in children. Therefore, the usual value in the young patient ranges between 1 and 1.2. Lower values indicate a hypomandible; conversely, higher values indicate a hypermandible.

- NTP, nose tip point.
- Gn, gnathion: a point corresponding to the midpoint between the anterior (pogonion) and inferior (menton) points of the bony chin.
- Sn: subnasal.

The skeletal type of the patient is also a factor to take into consideration. For example, a decrease in the normal value of this ratio in an obese child and an increase in an athletic, long-limbed child are to be expected.

The future

The esthetic measurements and treatments that are available and deemed reliable for adults cannot be considered so for children. There is a real need for new and reliable data that may provide the basis for reviewing and modifying the well-worn cliché of the ideal face (facial proportions) of the Caucasian population during growth. Existing esthetic analyses need to be adapted to growing patients in a way that takes into account the predictable craniofacial growth stages and processes.

Once we are familiar with the craniofacial growth mechanism and the different factors determining it, then it will be possible to reduce the need for orthopedic–orthodontic treatments. True esthetic orthodontics may, in combination with effective pediatric esthetic dentistry, become a protocol for obtaining true facial esthetics and balance.

As Goldstein proposed in the previous edition of *Esthetics in Dentistry*, esthetics is the fourth dimension of dentistry, along with biological, physiological, and mechanical dimensions. Esthetic balance is increasing in importance because, in the 21st century, there is greater cultural awareness of the keys to attractiveness of the face and smile and, in general, of physical appeal. Esthetic harmony is synonymous with skeletal, dental, and neuromuscular harmony and temporomandibular joint harmony.

The fundamental concept is that esthetics in pediatric dentistry lay the foundations of esthetics in adulthood and will thus become an area attracting growing interest in the decades ahead. In the setting of clinical pediatric dentistry, esthetic considerations are increasing in frequency and importance. The pedodontist must work in close cooperation with the orthodontist to apply correct preventive or early interceptive orthodontic and esthetic principles.[44] This close cooperation can reduce treatment times and costs and increase long-term stability because space management will also reduce the need for extractions. It is imperative to appreciate that esthetic harmony can boost psychological health and self-confidence, thereby improving an individual's interpersonal relationships.

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Chapter 31 Geresthetics: Esthetic Dentistry for Older Adults

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How old would you be, if you didn't know how old you are?

(Satche Paige)

In 2011, the world's population reached 7 billion. While the world's population has exploded in the past 50 years, birthrates are not up, longevity is. As life expectancy increases, a global aging boom is occurring. This aging trend is transforming patient populations in dental offices throughout the world. Older adults, like their middle-age children, want to look and feel their best. More and more are recognizing that they are not healthy without good oral health and they want to benefit from all the advances dentistry has to offer. This chapter discusses the esthetic oral health needs of older adults. It reviews the demographics of a global aging society and the expectations they bring to the dental office. It discusses the effects of systemic illnesses on oral health, the importance of prevention at any age, and the diagnosis and treatment planning when providing esthetic dental services to older adults.

Demographics: an aging population

The world is aging. Today, the population ≥60 years old is estimated to be 680 million, or 11% of the world's population. By 2050, this number is expected to grow to 2 billion, or 22% of the world's population.[1] The populations of both Europe and Japan are predicted to remain the oldest populations in the world. Although China and India have a lower percentage of their population over age 60, the size of their older population is growing

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rapidly and reflects more older adults than in the United States. Table 31.1 lists a sample of countries and the percentage of their populations over age 65.[1] Germany and Japan lead the world, with over 20% of their population over age 65 years, compared with only 13% in the United States (or 35 million people). By 2030, this percentage is expected to increase to 20% in the United States. South America and Africa have a far lower percentage of older adults, but these countries are seeing their populations age as well.

In 1900, the average life expectancy in the United States was 47.3 years. By the year 2010, the average life expectancy at birth had increased to 78 years.[2] The increasing life expectancy at birth has resulted from improved infection control, public health advances, and improvements in medical and surgical treatment. Healthier lifestyles and improved medical care are enabling those reaching age 65 to live even longer. Table 31.2 lists the remaining life expectancies for United States' adults aged 65 and older by gender and race.[2] For each age group until 85 years old, women outlive men and white Americans outlive African Americans. For the groups ages 85 and older, the trends reverse and African American men and women live longer than their white counterparts. At age 65, American adults can expect to live on average 19.3 years, or about 20% of their lives, in the retirement years. Regardless of age, adults want to make the most of their remaining years.

Goldstein demonstrated the benefits of esthetic dentistry as an important health service in a paper over two decades ago.[3] Goldstein and Niessen later expanded that concept to identify important benefits and issues to consider when providing esthetic dentistry for older adults.[4] Since that time, esthetic dentistry has become a well-accepted part of dental care. Adults of all ages have experienced the benefits that esthetic dental services can provide to their overall health. The older adult in Figure 31.1A–O benefited from extensive esthetic dental treatment, including orthodontia.

Table 31.1 Aging Throughout the World

Country	Estimated Population >65 Years in 2017 (%)
Australia	16.1
Canada	18.3
China	10.8
Costa Rica	7.8
Germany	22.1
India	6.2
Japan	27.9
Mexico	7.0
Peru	7.4
Russia	14.3
Sweden	20.1
Ukraine	16.3
United Kingdom	18.0
United States	15.6
Uruguay	14.3

Source: Adapted from *CIA World Factbook*.[1]

From baby boomers to baby zoomers

Individuals born between 1946 and 1964 (known as the baby boomers in the United States) are fueling concern about aging in the United States. This group, comprised of 76 million people in the United States, represents almost 30% of the US population.[5] In 2011, the first of the baby boomers reached age 65. These baby boomers are redefining what it means to be old. If you frequent a health club, spa, or ski resort these days you are likely to be a part of this group, causing some to rename them from the "baby boomers" to the "baby zoomers." Perhaps more significant than their sheer numbers, is their educational

Table 31.2 Remaining Life Expectancies: Adults Aged 65 Years and Older in the United States

Age in 2012 (Years)	Total (Years)	White (Years)		African American (Years)	
		Male	Female	Male	Female
65	19.3	17.9	20.5	16.2	19.5
70	15.6	14.4	16.5	13.2	15.9
75	12.2	11.2	12.9	10.4	12.6
80	9.1	8.3	9.7	8.0	9.3
85	6.6	5.9	6.9	6.0	7.2
90	4.6	4.1	4.8	4.5	5.2
95	3.2	2.8	3.3	3.5	3.8
100	2.3	2.0	2.3	2.6	2.8

Source: US National Center of Health Statistics.[2]

Figure 31.1 **(A–C)** This 76-year-old lady presented for treatment after a lifetime of dissatisfaction with her crowded teeth.

attainment. Twenty-five percent of this group has a college education. They are demanding, service-oriented, and expect high quality in their goods and services. In addition, they expect to look their best and are working hard to defy the aging process.

From a dental perspective, the baby boom generation represents the first to have benefited from widespread community water fluoridation and preventive dentistry programs. As adults, they are the first group to benefit from widespread workplace dental insurance. This combination of preventive services as children and dental care as adults is resulting in their being the first generation to reach 65 years old with a virtually intact natural dentition.[6] Unfortunately, most are not aware that their health insurance coverage will shift to Medicare when they retire, and they will likely lose their dental insurance benefits. Only select Medicare Advantage programs provide dental care as part of their insurance coverage. Recently, the American Association of Retired Persons has begun to sell an individual dental insurance policy, available when an employee retires or loses workplace dental insurance.

The mature esthetic dental consumer

Today's baby boomers and their parents have experienced the benefits of esthetic dentistry in their lives. They have straightened, whitened, and bonded their teeth as adults. It is anticipated that they will continue to invest in themselves. Their oral health goals will include keeping their teeth healthy, attractive, and functioning. Additionally, they will want to erase the effects of aging on their dentitions to improve their appearance.

Our colleagues in the marketing arena have described baby boomers as "the new health care consumers." These new health care consumers are characterized as more aggressive, demanding, and self-directed in their health care. They use the internet for health information, and are rapidly becoming consumers of social media, joining Facebook and Twitter to stay informed as well as connected with friends and family. The internet has leveled the information playing field, so to speak, between health professionals and consumers. With virtually all professional journals now online, health professionals and consumers can

Figure 31.1 **(D–F)** Tooth-colored brackets were applied because their esthetic appearance gave the patient the confidence to smile during treatment.

be informed about new scientific advances simultaneously. In addition to online health journals, new internet health sites are added every day that serve as a source of health information, treatment options, and clinical trial sites. Chat rooms and blogs with consumers having various health conditions have developed and provide general information and support. Websites are now evaluating dentists or offering coupons for dental services. The internet will continue to expand its role as an intermediary between patients and health professionals for information and access to care, including dental care. While the internet is expanding access to health information, research continues to demonstrate the linkages between oral diseases and systemic

Figure 31.1 **(G)** After the removal of the orthodontic appliances, the teeth are much straighter but still discolored.

Figure 31.1 **(H)** After restorative treatment featuring tooth-colored restorations and bleaching, the patient has the smile she has always wanted.

Figure 31.1 **(I, J)** Note that the formally eroded cervical areas have better contour and will deflect food particles better.

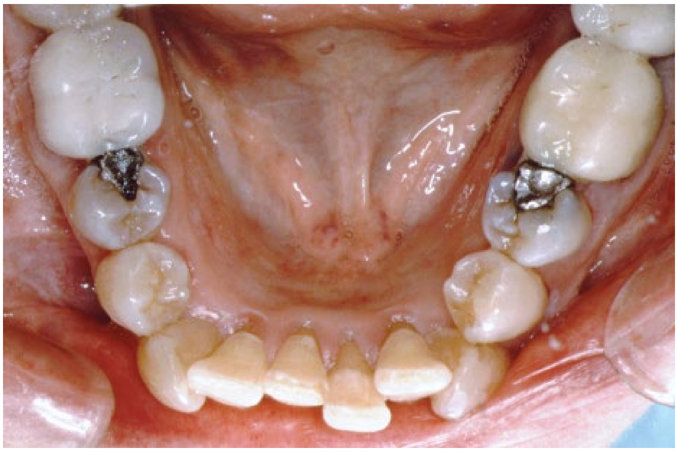

Figure 31.1 **(K)** Note the crowding of the mandibular anterior teeth.

Figure 31.1 **(L)** The teeth are less crowded, and the new tooth-colored restorations have been placed.

illnesses, most notably the link between periodontal disease and cardiovascular disease and stroke.[7,8] The Surgeon General's Report on Oral Health, *Oral Health in America*, reinforces the message that general health and oral health are related.[6]

Older adults understand better than younger adults that dental health is more than just healthy teeth. It is also the ability to speak, smile, chew, and swallow comfortably. Dental health has become oral health. Patients who receive esthetic dental services readily appreciate this concept of oral health. The ability to smile confidently and the improved self-esteem will continue to drive the demand for esthetic dental services by older adults, particularly as baby boomers age.

Figure 31.1 **(M)** The maxillary arch shows anterior crowding and defective amalgam restorations.

Figure 31.1 **(N)** Following 12 months of orthodontic treatment, the patient's amalgam restorations were replaced with posterior composite resin.

Figure 31.1 **(O)** Interdisciplinary therapy including orthodontics, periodontics, and restorative dentistry combined to produce this attractive result 2 years following the initiation of treatment in this now younger looking 78-year-old lady.

Data in the United States show an increased use of esthetic services by older adults.[10] Plastic surgery has become less expensive and more readily available for adults of all ages, and dental treatment has become a routine part of facial plastic surgery. Individuals who may be contemplating plastic surgery, such as facelifts, liposuction, or laser skin resurfacing, are also contemplating a smile makeover (tooth whitening to eliminate darkened teeth, crowns or veneers to correct shortened clinical crowns, and/or orthodontics to correct malpositioned teeth) as part of their plastic surgery options. This smile makeover, or "instant facelift" as it is being called, may last 20–25 years, unlike the plastic surgery changes that may last for only 5–10 years.

Chronic illness and esthetic dental care

With aging comes an increase in chronic diseases. Middle-age adults, nicknamed the "sandwich generation," are finding themselves caring for their adolescent children and aging parents. As one reaches the eighth and ninth decades of life, maintaining

Clinical case 31.1: A 57-year-old patient with "ugly smile" receives orthodontics and composite resin bonding

This 57-year-old patient's chief complaint was she had an "ugly smile." Her bruxing had worn away the enamel, shortened her teeth, and decreased her vertical dimension, resulting in an aging appearance. Her treatment plan consisted of full mouth reconstruction to restore her vertical dimension with posterior maxillary and mandibular crowns. Conservative composite resin bonding restored the anterior teeth. As a result of her exceptional home care, she maintained her dental health for 24 years until she died at 80 (Figure 31.2A–H).


(A)


(B)

Figure 31.2 **(A, B)** This 57-year-old woman had worn down her posterior teeth so much that she was traumatizing the anterior teeth, which had also worn considerably.

Figure 31.2 **(C)** Treatment crowns to restore vertical dimension were constructed for the patient to wear to determine if she would tolerate the new occlusal position.

Figure 31.2 **(D)** After three comfortable months of wearing temporary crowns with an increased vertical dimension, final metal-ceramic crowns were constructed for the posterior teeth.

Figure 31.2 **(E)** Artus strips (5/10,000 inch thick) were used to make sure the occlusion was perfect. Note sufficient open space for composite resin bonding to be able to lengthen the maxillary anterior teeth.

Figure 31.2 **(F)** The maxillary anterior teeth were next bonded with a hybrid composite resin. Note the increased length.

Figure 31.2 **(G)** The final smile helped to create a younger-looking smile line, which lasted for 24 years due in part to the exceptional home care performed by the patient.

Figure 31.2 **(H)** The combined approach of posterior crowns and anterior bonding greatly improved this patient's smile, her appearance, and self-confidence. Reproduced with permission from Quintessence Publishers.[9]

Table 31.3 Most Common Chronic Conditions in Older Adults

All Ages	Age ≥75 Years
Sinusitis	Arthritis or other musculoskeletal
Arthritis	Heart or circulatory
Orthopedic	Diabetes
Impairments	Vision
Hypertension	Lung
Hay fever	Hearing impairments

Source: Adapted from Centers for Disease Control, National Center for Health Statistics[11] and Summer[12] (based on National Academy on an Aging Society analysis).

oral health in the face of multiple chronic diseases and declining health may become a greater challenge.

Table 31.3 lists the common chronic conditions for individuals of all ages and for those age 75 and older.[11,12] Whereas arthritis affects 28% of 45–74-year-olds, it affects over 50% of adults over age 65.[13] Although these chronic conditions may occur in middle age, they may not cause disability or limitation of activities until over age 65. Data from the National Health Interview Survey in the United States found that 34% of 65–74-year-olds and 45% of those 75 and over reported some limitation in activities because of chronic conditions.[11,12]

Older adults who visit their dentist may be taking a variety of medications for these various chronic conditions. Thus, the recording and interpreting of the medical history and medication history will often require more time in older adults. These chronic illnesses may also necessitate more frequent consultations with the patient's physicians. Patients with cardiac conditions, orthopedic problems, or on anticoagulation therapy are just a few of the examples of systemic illness for which a physician consultation may be warranted. These systemic conditions may make maintaining any esthetic dentistry more difficult. Patients should be advised that their systemic conditions could affect their oral health.

Even the best dentistry can break down quickly in the absence of oral hygiene self-care and the presence of multiple risk factors, such as dry mouth (xerostomia) and a highly refined carbohydrate diet. Patients undergoing esthetic dental services who are about to enter a nursing home or assisted-living facility should be assessed for factors that will increase their risk of oral diseases, such as dementia, stroke (which may cause the loss of ability to use the dominant hand), or medications that cause dry mouth. Once these risk factors are identified, aggressive preventive therapies must be initiated to avoid dental diseases and breakdown of previous dental work.

Medical/dental history and oral examination

The history and physical examination for older adults will clearly require more time and result in more positive findings than for younger adults. In addition to the routine esthetic questions, it is important to ask each patient what their personal goals are for oral health. Does the patient expect to lose any teeth to caries or periodontal disease? Is the patient willing to implement preventive measures to avoid tooth loss? These questions will assist the dental team in understanding the patient's plans and expectations for oral health and whether such plans and expectations are realistic. Clearly, the patient with 7–8 mm of probing depths on posterior teeth that are mobile and who would be devastated to lose any teeth may not have realistic expectations given the current level of oral disease present. The sooner this situation is identified, the sooner the dental team can assist the patient in understanding and accepting what goals are realistic. Questions about the importance of esthetics and the patient's smile will help the patient and dental team understand the patient's self-concept and how esthetic services may affect it. This line of questioning, although not traditional, can result in greater patient understanding and, ultimately, in obtaining the patient's consent for an esthetic procedure.

Esthetic oral health services are not contraindicated for patients with chronic diseases. However, both the dentist and patient must fully understand the effects that one's systemic diseases and medications will have on dental care and subsequent home care. A patient taking nifedipine for hypertension is still a candidate for porcelain veneers but must understand that the medication will increase the susceptibility to plaque-induced marginal gingivitis.

The medical history plays an increasing role in the treatment planning of older adults. The most common chronic diseases seen in older adults include heart disease, arthritis, diabetes, osteoporosis, and senile dementia. Medical conditions must be identified, and the stability of the patient's health status assessed. A patient who has had their hip joint replaced within the past 6 months will require greater assessment and perhaps a consultation with their orthopedic surgeon compared with a patient who had a hip replacement over five 5 years ago and has no other comorbidity.[14] Medical history forms should provide an area for comments on the stability of a patient's medical condition. A medical history form that asks "Do you have heart disease?" with a yes or no answer will not provide the dental team with sufficient information to gauge the status and the stability of the patient's health. The medical history must include an assessment of both the patient's prescription and over-the-counter medications. Studies have shown that salivary flow does not decrease naturally with age; however, the absence of saliva does put a patient at much greater risk for both coronal and root caries.[15]

As part of the oral examination, a patient's salivary flow should be assessed.[16] Salivary flow is much more likely to decrease as a result of multiple medication use. Over 400 medications are estimated to decrease salivary flow.[17] Other medications have been shown to affect oral tissues; for example, nonsteroidal anti-inflammatory medications can cause oral ulcerations, and antihypertensive and antiseizure medications can induce gingival overgrowth. Tests are currently available to assess salivary flow, pH, and buffering capability of saliva.

Providing esthetic dental services for healthy 65-year-olds should not prove difficult for dental practitioners. Rather, the challenge will come when that 65-year-old becomes an 85-year-old with heart disease, stroke, arthritis, chronic obstructive pulmonary disease, and/or Alzheimer's disease. The patient who has invested significant time and money in one's oral health will find the maintenance of the esthetic dentistry investment more difficult if they become frail and medically, mentally, or physically compromised. This scenario represents an opportunity for dental professionals to take a leadership role in both patient education and the education of nursing home staff, families, caregivers, and other health-care professionals about oral health for compromised patients. Health professionals need to understand that oral health does not have to decline simultaneously with a decline in physical or mental functioning.

The oral examination, like the patient's medical and medication history, may take more time than with younger patients. Older adults will continue to be at risk for caries, both coronal and root caries, periodontal disease, occlusal disorders, and oral soft tissue lesions. A thorough oral examination with complete imaging studies will insure that the correct diagnoses are made prior to the development of the treatment plan.

Prevention and risk assessment

Prevention is not just for kids anymore. Preventive therapies must be an integral part of the treatment planning for esthetic dental care.[18,19] By including a comprehensive preventive plan as part of the overall esthetic treatment plan, the unspoken message the dental team conveys to patients is that the team believes in the patient's future. That future is one of oral health, not oral disease. Patients with diabetes may be at increased risk for periodontal disease.[20] New strategies for at-home or in-office therapies can help patients lower their risk for gingivitis and/or periodontal infections prior to esthetic dental treatment. Antimicrobial rinses should be used for individuals at risk of gingivitis. New bacterial monitoring tests are available and may be necessary for individuals particularly at high risk for caries or periodontal disease.

Oral cancer occurs more commonly in older adults, particularly in those who use tobacco and drink alcohol.[21] However, about 25% of oral cancer cases today demonstrate no risk factors, suggesting that an oral cancer examination in every adult patient is a critical part of their dental care. Older adults should be questioned about their interest in quitting tobacco, and smoking cessation counseling should be provided for patients who are interested in discontinuing tobacco use. Do not assume because a patient has been smoking for ≥50 years that they are unwilling to quit. Studies have shown that dental professionals are as effective as their health professional counterparts in getting their patients to quit tobacco.

Maintaining oral health in older patients

Esthetic dentistry for any patient is not successful if it cannot be maintained. As with any dental treatment, maintenance of the oral cavity with appropriate home care is critical to the success and longevity of the dental treatment. A preventive program serves as an integral part of every treatment plan. It must be based on a patient's oral and medical conditions, risk factors, and, especially, the physical and mental ability to perform adequate home care. Oral health education, particularly regarding self-care, remains a staple in the preventive plan for patients of every age. Family members and caregivers play a critical role in maintaining oral health, particularly in the medically and physically compromised older adult. The dental team should not be shy about inviting family and caregivers to assist in the daily oral care for a patient who has become incapacitated and can no longer perform their own oral care.

Older adults with severe arthritis or neurological illnesses like stroke or dementia, will find that oral self-care is more difficult. They may require assistance from a caregiver to make oral self-care easier. Educating patients, caregivers, and family members how to make daily toothbrushing and interproximal cleaning easier will be time very well spent by your dental hygienist.

Caries management by risk assessment

The medical history and oral examination will provide an insight into the risk factors that will affect the oral health of older adults. Patients with low salivary flow rates, a low oral pH, or whose saliva does not have an adequate buffering capability will be at increased risk of root or coronal caries.[15] Caries management by risk assessment (CAMBRA) provides an approach to prevent dental caries in patients of all ages.[22] CAMBRA forms are downloadable through the American Dental Association website (www.ada.org) and CAMBRA helps patients understand their risk factors for dental caries. Once the risk factors are identified, a preventive plan can be developed to help patients lower their risk for caries, prior to any significant restorative or esthetic dental care. The preventive plan can include topical fluorides, provided as gels or fluoride varnishes, to prevent caries in adults.[23] Higher level fluoride toothpastes (5000 ppm) are available for home use, and new products are available to insure that sufficient calcium and phosphates ions are available to help remineralize the enamel or dentin of teeth. Professional and home-use neutral sodium fluoride gels or rinses to prevent root caries or recurrent caries should be prescribed for patients who are considered at high risk, such as patients with decreased salivary flow or impaired dexterity.[24,25] Salivary substitutes may also assist patients with oral dryness to provide comfort and improve oral tissue cleansing by the tongue.

Treatment planning in the older patient

Treatment plans should be based on the patient's needs and wants, not their age. Do not assume that older adults do not care about their appearance. Even grandmother and grandfather want to look their best for the family wedding photos!

Options for esthetic dental care are readily available for those in their 70s, 80s, and 90s just as they are for those much younger. However, with increasing life expectancies, treatment planning the 40-year-old esthetic dental patient requires a life cycle approach. Patients of all ages should be informed that esthetic dentistry does not last forever and procedures will likely need to be repeated at some point as the dental materials age and wear or the oral tissues change in relation to the face.

Older adults in the United States are seeking orthodontic treatment in record numbers to correct long-standing malocclusions and improve their oral function. It should not be assumed that the 78-year-old woman is not interested in whitening her teeth, replacing her worn amalgam restorations with new tooth-colored filling materials, or investing in her smile. When treatment planning older adults, give them the opportunity to "say yes." Older adults have seen their children and grandchildren benefit from modern techniques and new dental materials, and they are interested in benefiting from these same procedures.

Older patient attitudes will vary considerably. Often during the interview, patients will provide clues about their motivation for seeking dental care, particularly esthetic dental services. For some, function and overall health will be the motivating factors in maintaining good oral health; for example, removing oral infection may be the key determining factor. Others may feel that looking good is important to overall quality of life and will have no problem with spending resources for improving their smile. If a restoration needs replacement or the patient requires a new restoration because of caries, ask the patient if they are interested in an esthetic restoration.

Identifying the chief complaint is important when caring for any patient. For older adults seeking esthetic dentistry, it is important to understand precisely what they like and dislike about their appearance as well as their expectations for such treatment. They have lived many years with their smile and often know exactly what they want to change. It is critical for the dentist to assist the patient in articulating one's goals clearly.

Older adults presenting for esthetic dental care may often arrive at the dental office with an adult "child" as a caregiver. It should not be assumed that the adult child is the decision maker. The treatment plan should be addressed to the older adult, and if the older adult needs assistance with the decision making, allow the older adult to ask advice from the adult child. For the patient who may be medically or physically compromised, the individual's ability to cooperate with the dental treatment must be assessed. The appointments must be timed for the patient's comfort.

Managing other chronic illness and sequencing of procedures

Systemic illnesses can affect oral health, and the dental team must educate patients and their families to recognize these changes. Clearly, chronic medical conditions and medications can affect oral health and increase the risk for oral diseases. Because older adults may be managing chronic diseases, esthetic treatment may be delayed due to an acute exacerbation of a chronic illness. The patient with hypertension who suffers a stroke and requires rehabilitation for 3–6 months will have dental treatment interrupted. When dental treatment resumes there will be additional, special medical considerations; for example, if the patient is now taking anticoagulants, this will require monitoring of the international normalized ratio to ensure that bleeding is not a problem during dental treatment. Similarly, a patient with heart disease may undergo cardiac surgery. delaying dental treatment. In this case, it would be prudent to have a consultation with the cardiologist prior to resuming treatment. This may require more time for you and your team, but the patient will appreciate this concern and effort in communicating with the physician.

Sequencing esthetic dental treatment for older adults will be similar to that for younger and middle-aged adults. Caries control and periodontal therapy may be necessary prior to definitive esthetic treatment. Also, consultations with dental specialists may be required, depending on the nature of the patient's oral diagnoses; consultations with the patient's physicians may be required, depending on the patient's medical diagnoses.

Imaging in decision-making process

An accurate diagnosis is the most important first step in providing any esthetic dental service. In the final analysis, *no* treatment is better than the *wrong* treatment. In the words of Hippocrates, "First, do no harm." For individuals unsure about the decision to pursue esthetic dental treatment, imaging can play an important role in assisting the patient to understand how their smile can be altered. Imaging can assist both the patient and dentist in understanding what can be accomplished with esthetic dentistry. Dentists should be wary of the patient who says "I've hated my dental work all my life. I'll be pleased with whatever you do." It is important to find out the exact specifics of what the patient does not like about their teeth and what they expect. On careful questioning and the use of an intraoral camera and/or imaging, the dental team can usually identify the cause(s) of concern and gain insights for potential treatment options.

Informed consent requires that the patient be presented with treatment options. Imaging can assist the patient in understanding the problems and the potential options for treatment. By demonstrating the overall changes and specific changes on each tooth, the patient will understand the goal of each dental procedure and how it contributes to the overall result. For patients who are having difficulty making a decision to pursue esthetic dentistry, imaging gives them the opportunity to share a photograph of the planned results with friends and family, and get feedback that will help them make a decision.

Financing

Financing esthetic dental services will most frequently be out-of-pocket. Although some patients over age 65 may still have dental insurance as part of their employment retirement package, most dental insurance does not reimburse for elective esthetic services. Dental care provided for the treatment of the teeth and/or supporting tissue is generally not reimbursed under Medicare, although more Medicare Advantage plans are including a dental benefit. In some cases, adult children may be willing to incur the cost for esthetic dental services if their parents are not comfortable or able to spend money on themselves for esthetic dental care.

Esthetic dental consultation and facial plastic surgery

Esthetic dentistry can be a part of an overall appearance makeover. New treatment approaches have made facial plastic surgery more affordable and accessible to patients. For a patient considering facial surgery, the consultation with the dentist regarding smile enhancement should occur prior to the facial surgery to maximize the final facial esthetics. In some cases, interdisciplinary dental care such as orthodontics, periodontics, and prosthodontics may be required to achieve the best result and will take several months to accomplish.

Patients, as well as plastic surgeons, should be educated as to the benefits of consulting with a dentist prior to any esthetic surgery procedures. The reasons for this include the following: (1) creating a younger-looking smile may be sufficient to please the patient so that plastic facial surgery may not be necessary or less surgery may be required; (2) oral pathology, such as caries or severe periodontal disease subsequent to facial surgery, may compromise the esthetic surgical result; (3) esthetic dental services provided after facial surgery may involve the use of lip and cheek retractors, and any excessive stretching of the facial tissue is contraindicated during the initial healing phases. If esthetic dental services are provided after facial surgery, patients may perceive the use of retractors as contributing to "new" wrinkle development that the plastic surgery had removed. Oftentimes, these wrinkles were present prior to the dental treatment, but the patients did not notice them until after the dental procedures. When treating a patient who has had plastic facial surgery, the patient should be photographed in repose and smiling close up and full face without make-up to record any existing facial wrinkling prior to dental treatment.

Esthetic dental procedures for older adults

Vital tooth bleaching

Teeth darken and become more yellow as they age. Teeth also tend to take on stain throughout the enamel and cementum surfaces (characterization, as it is euphemistically called). With the trend toward whiter teeth, it is not at all surprising to find patients of all ages requesting tooth-lightening procedures.

Vital tooth bleaching performed either in the office or at home has been demonstrated to be effective in older adults. Since aging tends to darken teeth in the yellow color range, this color range achieves the best results with vital tooth-whitening procedures. In-office and at-home whitening with trays work equally well. Products containing 10–35% peroxide have been shown to work in mature adults. The main determinant is whether the patient desires the whitening results immediately or can wait longer for the at-home whitening agents to begin to work. In older adults, sensitivity does not appear to occur as frequently as in younger patients. This is thought to be due to the gradual receding of the pulpal tissue with age. If a patient has anterior teeth with prominent microcracks, they should be advised of these cracks and monitored carefully to ensure that there is no streaking in the whitened teeth.

Cosmetic contouring and bonding

The teeth of people over 60 years often exhibit the wearing away of hard tissue by erosion, abrasion, or parafunctional habits such as bruxism. Shortened anterior teeth, particularly in the maxilla, result in less of the teeth being seen when one talks or smiles. This shortening of teeth in the maxilla contributes significantly to an older appearance. As hard tissues wear away, patients will lose vertical dimension, resulting in the mandible becoming more anteriorly positioned. The reverse, the so-called "long-in-tooth" phrase that Shakespeare used to describe the aging process, results from periodontal disease.

With age, one shows less of the maxillary teeth and more of the mandibular teeth. The patient at age 50 who wishes to change only the color or shape of the maxillary teeth by age 60 may be requesting similar changes in the mandibular teeth. Both of these age-related changes can add years to an individual's appearance and inhibit oral function. However, esthetic dental treatment can easily transform the patient's appearance, in effect turning back the clock on the aging process.

Cosmetic contouring provides an excellent introduction to esthetic dentistry for patients who are unsure about making significant changes in their smile. It also provides a lower cost option

Clinical case 31.2: Whitening procedure for a 72-year-old patient

The 72-year-old woman in Figure 31.3A believed that her smile made her look older than she felt. Her teeth were whitened using an in-office 35% hydrogen peroxide solution. The result of whitening on her maxillary teeth is seen in Figure 31.3B. In-office whitening procedures provide a more immediate result when patients do not want to take the time for at-home whitening process and waiting several weeks/months for results or have already tried home whitening but had difficulty complying with the daily regimen. Patients should be advised that they will require touch-up treatments after the initial whitening procedures.

Figure 31.3 **(A)** This 72-year-old woman felt that the color of her teeth aged her smile.

Figure 31.3 **(B)** After an in-office bleaching procedure on her maxillary teeth, the patient was pleased with her lightened color.

Clinical case 31.3: A 74-year old with cosmetic contouring

The 74-year-old woman in Figure 31.4 was dissatisfied with her smile but was not sure if she wanted considerable changes made. Her chief concern was that she did not like the cant in her upper teeth (Figure 31.4A). Cosmetic contouring of the maxillary arch was done to straighten the appearance of the upper right side to be more symmetrical (Figure 31.4B).

Figure 31.4 **(A)** This 74-year-old woman was dissatisfied with the appearance of her teeth.

Figure 31.4 **(B)** Cosmetic Contouring was done on both maxillary and mandibular incisors to make the teeth appear straighter and eliminate the cant.

Clinical case 31.4: Cosmetic resin bonding

The patient in Figure 31.5A and B did not like the appearance of her front teeth and felt that her maxillary central incisors were too dark and too short. Cosmetic resin bonding was chosen as the treatment of choice because of the immediacy of the result. Figure 31.5C and D shows how the teeth were both lightened and lengthened to provide a younger-looking smile line.

Figure 31.5 **(A, B)** This 78-year-old lady had shortened and darkened maxillary central incisors. Reproduced with permission from Quintessence Publishers.[9]

Figure 31.5 **(C, D)** Composite resin bonding was done to lengthen and lighten the central incisors. Reproduced with permission from Quintessence Publishers.[9]

for those patients with limited financial resources. Bonding with composite resin is a particularly useful esthetic technique for the mature adult. With minimal preparation, the tooth or teeth can be altered to achieve an esthetic result. Bonding also enables the dentist to easily repair chipping and fractures that occur in the teeth of older adults. Although manufacturers have made cosmetic shades lighter to reflect the increasing range of whiter shades of bleached teeth, older patients may require darker composite shades to restore erosion or root caries. Currently, when a patient needs a restoration on a tooth darker than existing composite shades, the dentist may need to use modifiers to make the restoration more natural in appearance and blend with the surrounding teeth. An overlay technique or partial veneer can be used when a spot match is not possible.

Clinical case 31.5: Patient's wife motivated 65-year-old husband to pursue esthetic dentistry

A 65-year-old did not care much about his smile, but his wife thought his smile made him look much older. She encouraged him to have esthetic dentistry by telling him that she would not kiss him until his smile improved. Figure 31.6A and B shows the worn and discolored central incisors and the crowded lower anterior incisors. Figure 31.6C shows cosmetic contouring of the lower incisors. Figure 31.6D and E illustrates the completed esthetic improvement following composite resin bonding of the central incisors.

Figure 31.6 **(A)** This 65-year-old man displayed worn, discolored maxillary central incisors with a fractured anterior composite restoration on tooth #9.

Figure 31.6 **(B)** The patient avoided smiling to hide his worn, discolored, and fractured central incisors.

Figure 31.6 **(C)** Cosmetic contouring of mandibular incisors.

Figure 31.6 **(D)** The view after composite resin bonding of his central maxillary incisors.

Figure 31.6 **(E)** Note how much younger looking and happier the patient is following his esthetic dental treatment.

Orthodontics

Research has shown that teeth can be repositioned successfully at any age. Orthodontics should always be considered as an option in cases of facial–dental arch discrepancies. Often, orthodontics is the most conservative treatment option to improve malocclusion. It is a mistake to assume that the older adult would not be willing to invest the time or money in orthodontics as a treatment option. Clear aligners have made tooth movement more desirable in patients of all ages. For adult orthodontic patients with missing teeth or insufficient numbers of teeth for orthodontic anchorage, dental and orthodontic implants are being used to assist with the necessary support. Orthodontically repositioning teeth may prevent the need for more aggressive crown and bridge coverage. In baby boomers who may not have as many restored teeth as the previous generation, preserving the natural enamel through orthodontics may be preferable to removing enamel and dentin for crowns or veneers. The orthodontics may also be less costly in the long run than the prosthodontic procedures.

Periodontal therapy

Esthetic dental procedures require a foundation of good periodontal support. Periodontal tissues frame the teeth and need to be healthy and in harmony with the smile. Age is not a contraindication for periodontal plastic surgery or periodontal surgery of any type. Nonsurgical scaling and root planning often form the basis of periodontal treatment. Antimicrobial therapies provide an adjunct for treating localized periodontal infections. New periodontal regeneration procedures are providing older adults who have lost periodontal bone support with options for retaining teeth.

Esthetic surgery, whether periodontal or oral surgical, should be offered to the older adult if surgery provides the best option for an esthetic result. Frequently, interdisciplinary therapy is necessary to achieve the most esthetic result.

Laser-assisted new attachment procedure

One periodontal procedure that may be useful for geriatric patients is the laser-assisted new attachment procedure (LANAP). This conservative technique can avoid periodontal surgical techniques and can make a significant difference in both bone and tissue health. Figure 31.10A shows significant mesial and distal bone loss on an elderly woman. Dr Peter Rubelman, periodontist in Miami, Florida, reported that the lady was 82 years old and a smoker. The osseous defect on the molar probed to 10 mm, and post-LANAP it was 4 mm (Figure 31.10B). Atlanta periodontist Dr Maurice Salama achieved similar success around anterior implants. Even bone loss around implants may be helped with the LANAP procedure. Figure 31.10C shows extensive bone loss around an implant. Figure 31.10D shows significant bone growth around the implant at 6 months. So, being conservative can make a difference, and it may well be worth trying to save both teeth and implants.

Clinical case 31.6: A 70-year-old received bonding, but retained diastemata

A 70-year-old man was unhappy with his look because of worn enamel on his lower incisors, but felt his maxillary diastemas were an integral part of his personality and look (Figure 31.7A and B). He requested bonding to improve the appearance of his lower teeth, but did not want correction of the diastemata. The result of the composite resin bonding of the mandibular incisors is seen in Figure 31.7C.

Figure 31.7 **(A)** This 70-year-old man was unhappy with the look of the worn enamel on his mandibular incisors but felt that his maxillary diastemas were an integral part of his personality.

Figure 31.7 **(B)** The extent of tooth loss due to bruxism.

Figure 31.7 **(C)** Composite resin bonding and cosmetic contouring helped to improve the appearance of the mandibular anterior incisors.

Prosthodontics, endodontics, and implants

Prosthodontic procedures can restore the function and esthetics of an aging, worn dentition. Prosthodontic treatment may last longer than composite resin bonding. Often, the bonding procedures serve to introduce the patient to how esthetic dentistry can improve their smile at a lower cost. Later, when it needs to be redone, the patient may opt for the long-lasting, more expensive prosthodontic procedures.

Endodontics procedures are also not contraindicated in older adults. However, since dental pulps decrease in size with age, endodontics can be more difficult in older adults than in younger adults with larger pulp chambers. Consultation with an endodontist can assist the dentist in performing these procedures successfully.

Porcelain veneers are by far one of the most effective and yet conservative methods to achieve an esthetic result, especially when eight or more teeth are involved. If the patient's goal is to improve their smile, the dentist should first note how many teeth are involved in this smile improvement. Generally, the patient should smile to their fullest, and then which of the posterior teeth shows at the corner of the mouth can be noted. Sometimes, it may be a second molar. If so, the esthetic result the patient desires will not be achieved if only eight teeth are included in the treatment plan.

Clinical case 31.7: A 56-year-old patient orthodontics and cosmetic resin bonding, and 24 years later

A 56-year-old woman was unhappy with her smile and for health reasons wanted to correct her malocclusion (Figure 31.8A). In addition, she was also dissatisfied with her appearance and opted for tooth-colored brackets (Figure 31.8B). The teeth were repositioned in 18 months. The patient maintained her newly esthetic dentition with regular use of retainers. Figure 31.8C demonstrates the effectiveness of long-term orthodontics in this photo taken 24 years after initial orthodontics and cosmetic resin bonding.

Figure 31.8 **(A)** This 56-year-old woman was unhappy with her malpositioned teeth and was willing to undergo orthodontic treatment. Reproduced with permission from Quintessence Publishers.[9]

Figure 31.8 **(B)** Tooth-colored brackets were applied because of her concerns about her appearance during treatment. Reproduced with permission from Quintessence Publishers.[9]

Figure 31.8 **(C)** Twenty-four years after treatment with orthodontics and composite resin bonding, as well as regular use of retainers, shows effective esthetic treatment. Reproduced with permission from Quintessence Publishers.[9]

Clinical case 31.8: Younger-looking smile achieved with periodontal surgery and porcelain veneers and posterior crowns/inlays

Figure 31.9A shows an older man with discolored and worn teeth and irregular gingival margins that contributed to his unattractive smile. He requested a younger-looking smile. His treatment plan consisted of periodontal surgery to improve the gingival contours and porcelain veneers plus posterior crowns and inlays. Figure 31.9B and C shows the final result with lighter teeth and improved tooth shape and arch alignment.

Figure 31.9 **(A)** This chief executive officer had discolored and worn teeth and irregular-looking gum tissue, resulting in an aged smile. Reproduced with permission from Quintessence Publishers.[9]

Figure 31.9 **(B)** After cosmetic periodontal surgery, during which the gingiva was cosmetically and functionally improved, five porcelain laminates were placed, as well as posterior crowns and inlays.

Figure 31.9 **(C)** The result was lighter teeth and improved tooth shape and arch alignment to help create a younger-looking smile. Reproduced with permission from Quintessence Publishers.[9]

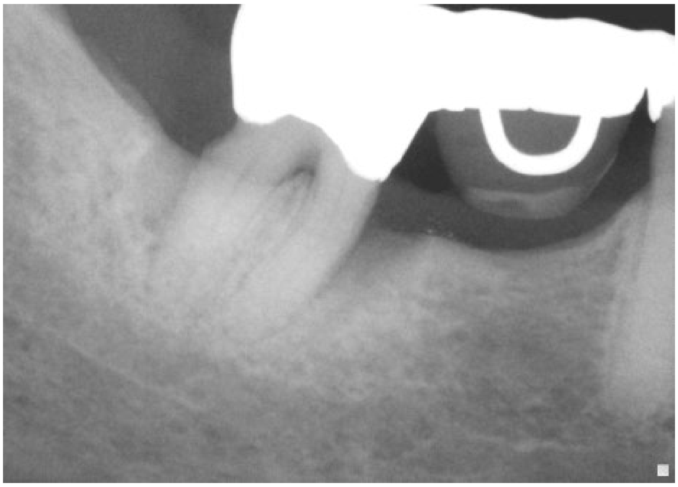

Figure 31.10 **(A)** This X-ray shows significant mesial and distal bone loss in an 82-year-old woman.

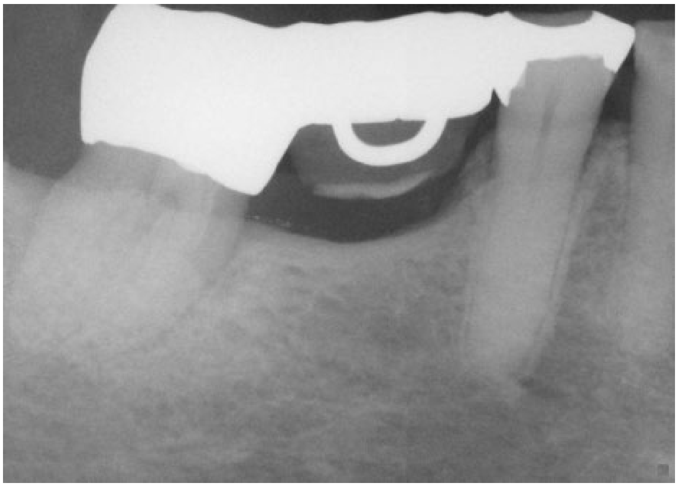

Figure 31.10 **(B)** Following LANAP procedures, this post-op X-ray shows a significant amount of bone growth.

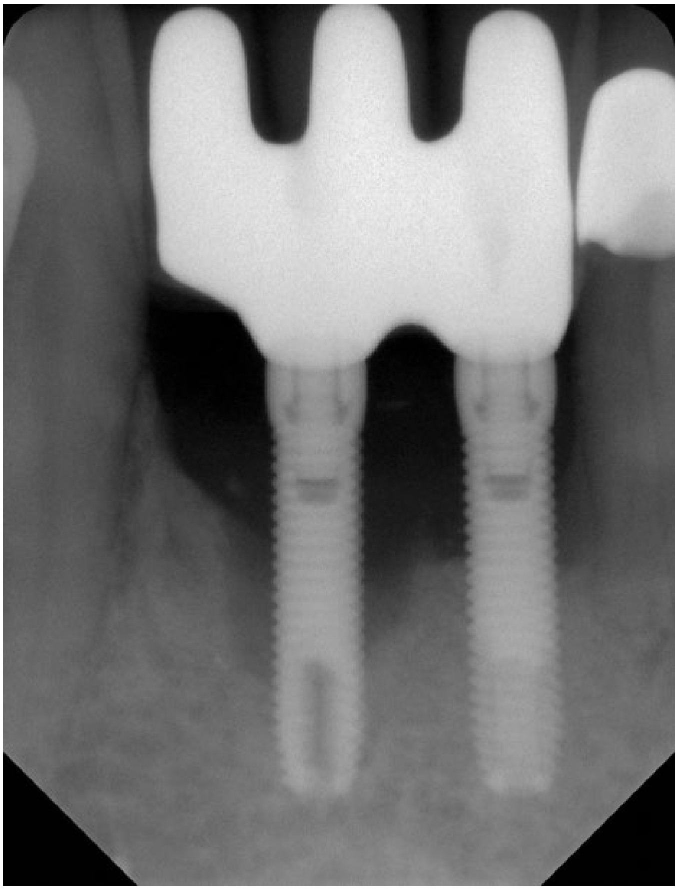

Figure 31.10 **(C)** This X-ray reveals extensive bone loss around an implant.

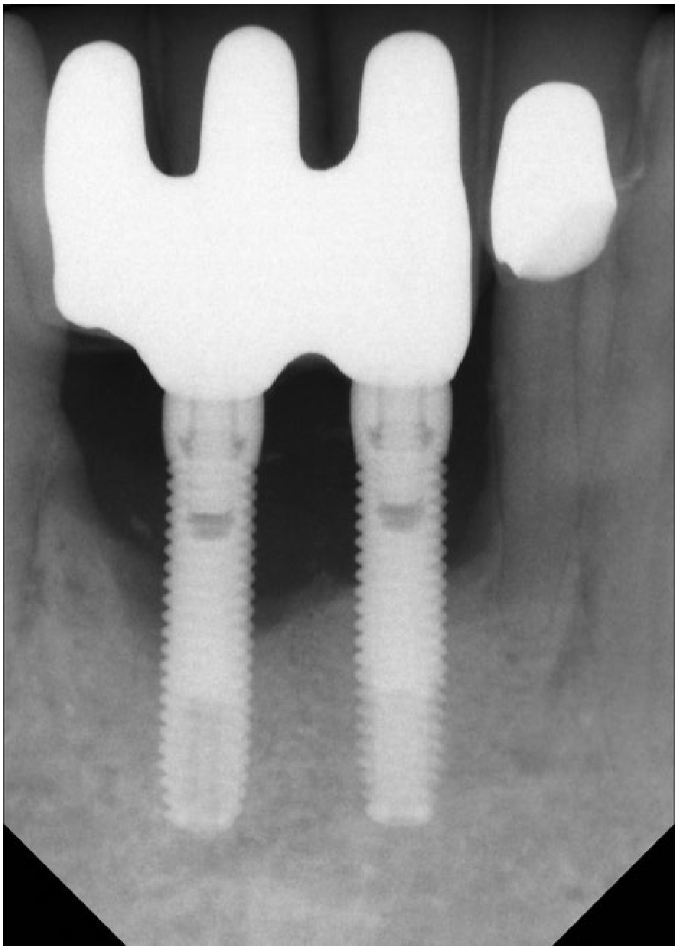

Figure 31.10 **(D)** At 6 months, the X-ray shows significant bone growth around the implant.

Since the upper lip line varies considerably in older adults, this assessment will be critical to achieving an esthetic result pleasing to the patient. The most artificial result occurs when only the six anterior teeth are restored in a lighter shade, with 8 or 10 teeth showing when the patient smiles. The unrestored posterior teeth now appear even darker than before and detract from the anterior teeth. The result is a false-looking smile on the older adult.

If the patient cannot afford to include 10 or 12 teeth in the treatment plan, consider bleaching the posterior teeth first to see if you can avoid laminating all of the teeth. The opposite arch should be whitened so that the entire smile will look as natural as possible.

As patients age, they tend to show more mandibular teeth and less maxillary teeth. Most patients often request the esthetic dental treatment for their maxillary teeth only, feeling that people will not see their lower teeth. However as patients age, mandibular teeth play a greater role in their smile and esthetic appearance. Where possible, it is critical to educate patients who are seeking esthetic dental treatment to include their mandibular teeth in any esthetic dental treatment plan.

Porcelain restorations of all types offer the ability to retain their color over the years and not darken with age as the natural dentition does. Porcelain veneers can also be used to reshape teeth that show loss of interdental papillae. Newer, low-fusing porcelains are showing considerably less wear to opposing teeth than the high-fusing porcelains. This is particularly important for middle-aged patients (e.g., age 50) undergoing esthetic dental treatment with a 30-year remaining life expectancy. When the patient requires complete oral rehabilitation, the full crown remains the restoration of choice. It can be expected to provide a greater functional life than bonding. It can be combined with porcelain veneers to accomplish an esthetic result. In many cases of bite problems that require an esthetic solution, the full crown, rather than porcelain onlays, will offer the most occlusal support against fracture.

Age and dysfunctional habits can contribute to severe wear over the years. Figure 31.11A and B demonstrates evidence of bruxism in an 86-year-old woman who had been advised to wear a bite guard when she was in her mid-50s. She disappeared from the practice and returned 30 years later demonstrating severe wear, loss of vertical dimension, loss of masticatory function, and temporomandibular joint pain and dysfunction. Additionally, she was embarrassed by her smile. Her treatment plan consisted of temporary crowns and bridges to restore vertical dimension and comfort. She was subsequently treated months later with fixed prosthodontics using metal–ceramic restorations (Figure 31.11C). She regained much of her self-confidence, as well as masticatory function, following the esthetic reconstruction of the maxillary arch (Figure 31.11D) and planned to restore the lower arch.

Fixed and removable prosthodontics can be used to improve appearance and function. The 78-year-old patient in Figure 31.12A and B showed severe wear on his upper and lower incisors, which compromised his smile line. He also had

Figure 31.11 **(A)** This lady presented with a severe bruxism habit that resulted in virtually no maxillary anterior teeth showing at rest or when smiling.

Figure 31.11 **(B)** Although she was advised more than 30 years previously to wear a night guard, she chose not to do so.

Figure 31.11 **(C)** Crown lengthening followed by prosthodontic reconstruction helped to recreate her smile. The next step is for her to rebuild the mandibular arch.

Figure 31.11 **(D)** The reconstructed teeth of this 88-year-old lady now enhance her smile.

multiple missing teeth. He was president of a large company and felt that he looked older than his actual years because his smile did not show any teeth. His treatment plan included crowns on his remaining natural teeth and a maxillary precision attachment removable partial denture. The final result shows both improved appearance and function (Figure 31.12C).

Although esthetic dental treatment for older adults may require an interdisciplinary team approach of general dentists and specialists, families may also be involved in helping patients understand the need for dental treatment. Figure 31.13A–C shows a 75-year-old woman who presented with severe root caries and moderate periodontal disease. Her daughter, who disclosed that her mother was difficult to please, referred her. The daughter was very supportive of her mother receiving dental treatment; however, her mother was initially not interested. The mother did not think that the esthetic aspect of dentistry was important. During consultation with the dentist, the mother was informed of the infection in her mouth and the potential effect that this could have on her future health and functionality. The patient consented to have the maxillary arch restored with fixed prosthodontics. She refused to accept treatment for her mandibular teeth, preferring to use her existing partial denture. Figure 31.13D and E shows the final result after periodontal and prosthodontic treatment. Although the patient was not particularly grateful to have the dental treatment, her family was thrilled to have her caries and periodontal disease treated and the esthetic appearance improved. The patient lived with her esthetically improved appearance for an additional 13 years.

Implant treatment is increasing in older adults, and is expected to increase further as implants have become the treatment of choice for replacement of a single missing tooth. Research has shown that outcomes with implant prosthodontics are as successful in older adults as in younger adults.[26] Implants remain a viable option for older adults who wish to replace their missing teeth with a more "tooth-like" approach. Age, in and of itself, is not a contraindication to implant therapy. Dental implants have been placed successfully in patients of all ages, including older adults. Many older adults are trading their complete dentures for implant-supported prostheses. A traditional mandibular complete denture provides considerable more retention and stability when four implants (either traditional or mini-implants) are placed in the mandible. Implant therapy requires a team approach with excellent communication between the surgical and the prosthodontic teams. Contraindications for dental implants relate more to an individual's medical


(A)


(B)

Figure 31.12 **(A, B)** This 78-year-old man had worn down his maxillary and mandibular teeth during the course of his life. This negatively affected his smile line.

Figure 31.12 **(C)** All of the maxillary and mandibular teeth were crowned, and a precision attachment partial denture was made to improve both function and esthetics.

Figure 31.13 **(A–C)** This 75-year-old woman had severe root caries and moderate periodontal disease.

Figure 31.13 **(D)** Although this woman stated that she would "just as soon have her teeth extracted," she was motivated to have both periodontal and prosthodontic treatment.

Figure 31.13 **(E)** The patient's smile after esthetic dental treatment shows how much improved her dental and oral health, as well as her smile are.

condition (e.g., uncontrolled diabetes) than one's age. See the examples in the clinical cases described in Figures 31.14, 31.15, 31.16, 31.17, and 31.18.

The nursing-home or assisted-living resident

The increase in the oldest-old has led gerontologists to define a concept of active life expectancy. Active life expectancy refers to that portion of life in which one can perform the activities of daily living with little or no help. Scientists have estimated that although a 65-year-old man may have an average of 16 years remaining life expectancy, three of those years may be periods of dependency, in which the individual requires some type of care.[2,11] Dependency results from the disabilities caused by long-standing chronic illnesses. Older adults often require more care from their children, family, or unrelated caregivers. Some may also need nursing home care.

In the United States, only 5% of the population over age 65 resides in a nursing home. However, adults over age 65 have a one-in-four chance of spending some time in a nursing home. The most frequent scenario is that of the older woman living alone who falls and fractures a hip. She is hospitalized to have the hip surgically repaired and then may enter a nursing home for months of rehabilitation therapy. More recently, as people age, they consider the concept of assisted living before severe problems arise. Thus, they avoid abrupt change when something adverse does occur. However, good or even adequate home care for them remains a problem.

The probability of residing in a nursing home increases with advancing age and is greatest for those with dementia. In the United States, over 50% of nursing home residents carry a diagnosis of dementia. Data on the oral health needs of nursing home residents in Ohio found that fulfillment of patients' dental needs was declining.[27] The authors hypothesized that patients and their families are delaying entry into the nursing home, opting instead to care for the family member for as long as possible in their home. During this period of home care, dental appointments are often overlooked as the family struggles to meet the care needs of their family member.

Dental care for residents of nursing homes in the United States remains woefully inadequate.[28] Oral health care in most nursing homes is virtually nonexistent. Studies have shown that education of the nursing staff can help improve the daily oral care and the ability to recognize the oral problems of the residents.[29] As baby boomers care for their aging parents and/or make difficult decisions regarding nursing home placement, they may become aware of the lack of essential health care services in nursing homes and demand improvements for the family members. (One can only hope that they demand improved oral hygiene care.)

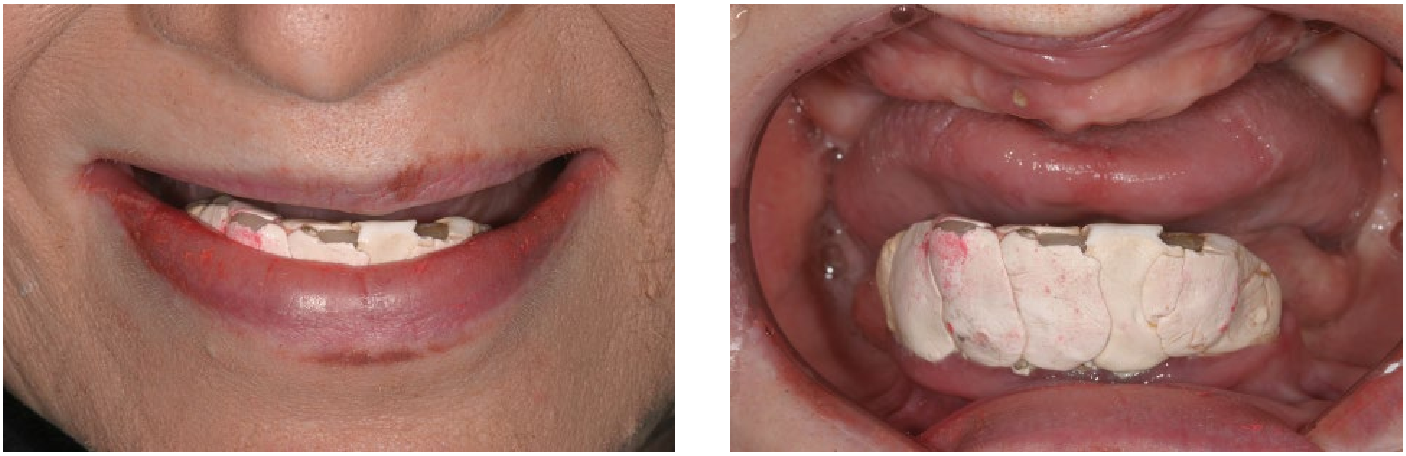

Figure 31.14 **(A, B)** A 72-year-old woman was forced to face her dental problems and fears after years of neglect prior to hip replacement surgery. She had only residual roots in the maxilla, onto which she was balancing an old porcelain-fused-to-metal bridge. Her lower teeth had advanced caries and periodontal disease, which she was covering up with over-the-counter dental temporary filling.

Figure 31.14 **(C–E)** After extracting her nonrestorable remaining dentition, she was transitioned into treatment dentures. Six maxillary and five mandibular implants were placed and prostheses fabricated: maxillary bar overdenture and mandibular screw-retained hybrid prosthesis.

Patients who have spent considerable time and money for esthetic dental services should not enter a nursing home only to have the lifetime of restorative and esthetic dentistry become undermined by root caries or periodontal infection. The opportunity for dentistry lies in advocating for a change in the standard of oral health care for nursing-home residents. If residents can have their sight and hearing needs met, their oral health needs should be accepted as an important part of their health care needs, particularly given the amount of time that residents spend using their oral cavity to swallow, smile, eat, and, especially, to communicate. These are surely important activities in the life of a nursing-home resident.

Figure 31.14 **(F–H)** This patient's functional and esthetic oral health were reestablished after having been severely compromised for many years. The patient is maintained on a strict 2- to 3-month hygiene schedule.

Figure 31.15 **(A, B)** A 65-year-old executive administrative assistant was unhappy with his dental esthetics and function. He had been a maxillary complete denture wearer for several decades. Note the uneven occlusal plane and reverse smile line of the maxillary denture.

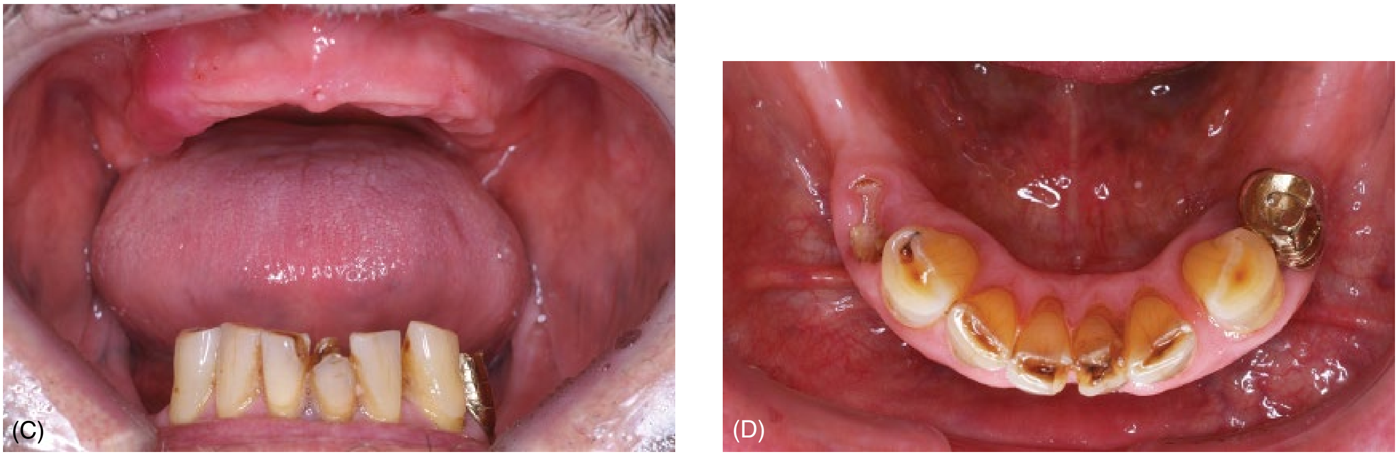

Figure 31.15 **(C, D)** The remaining lower teeth had advanced caries and periodontal problems.

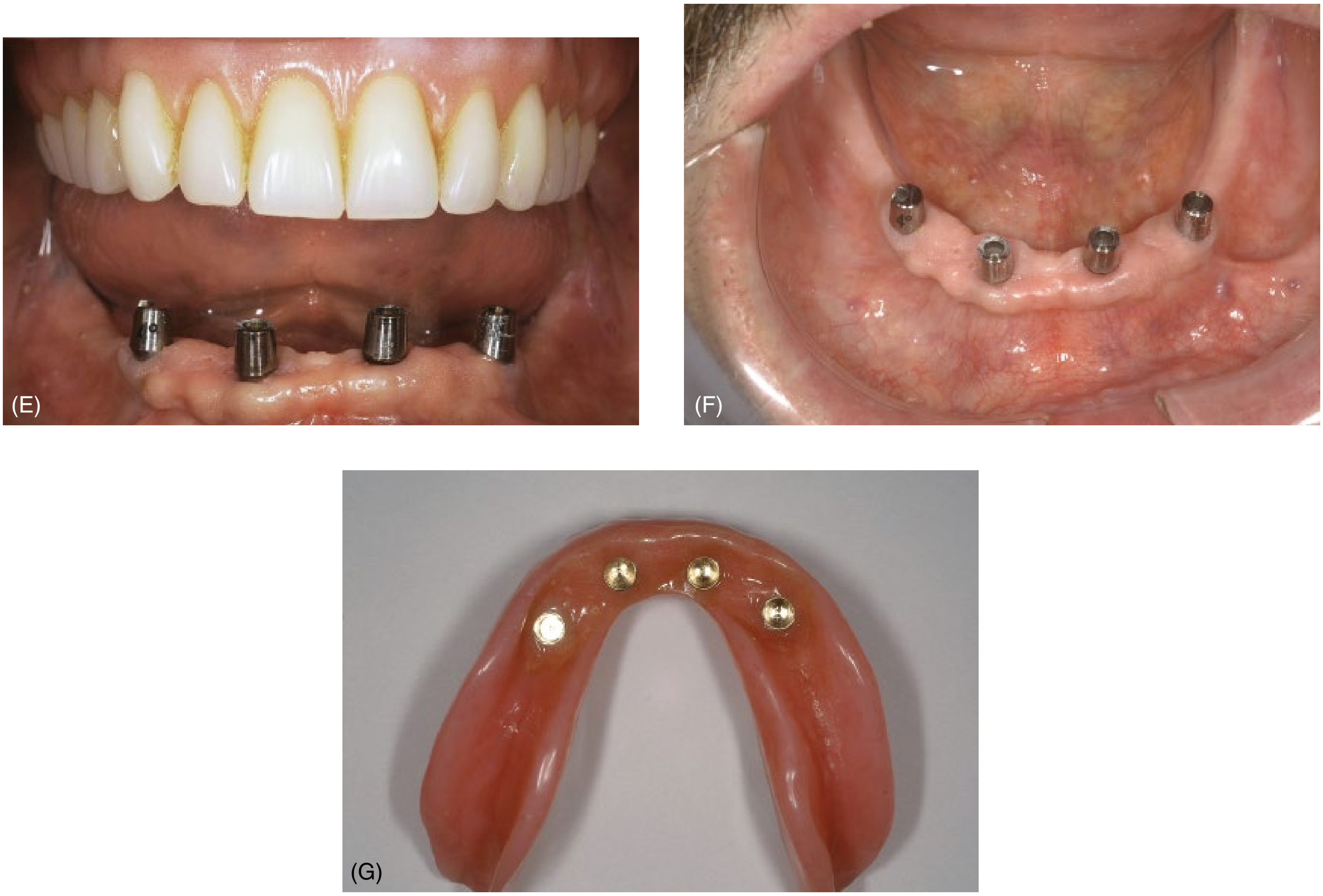

Figure 31.15 **(E–G)** Four Ankylos implants were immediately placed and SynCone abutments connected and four SynCone gold caps were immediately integrated into a previously fabricated immediate lower denture.

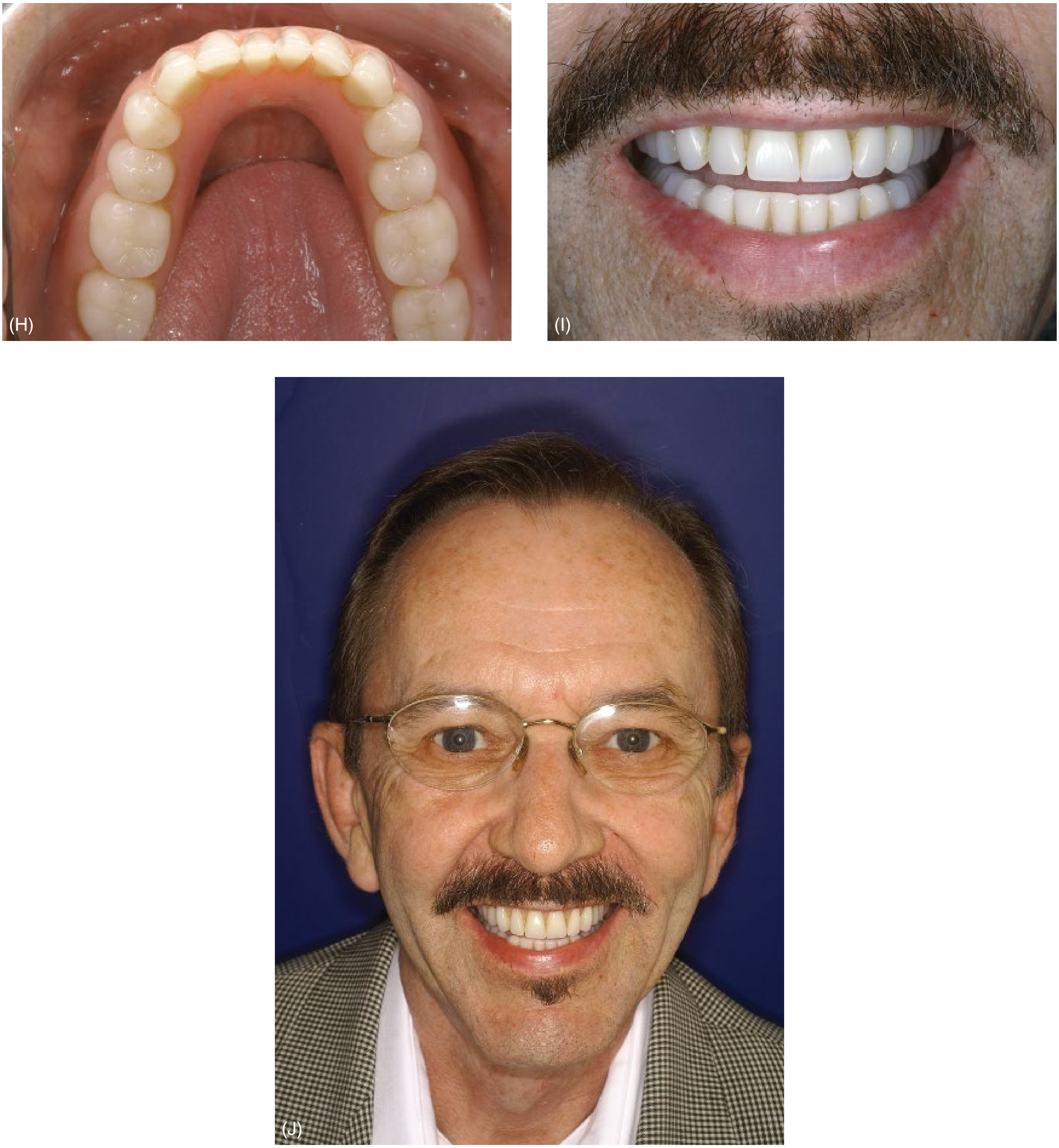

Figure 31.15 **(H–J)** The patient's facial esthetics and dental health and function have been restored with improved fit and retention.

Figure 31.16 **(A–C)** After three decades of being edentulous, this 72-year-old woman wanted to replace her maxillary full denture and lower bridges with implant-retained prostheses in a desire to improve her overall dental esthetics.

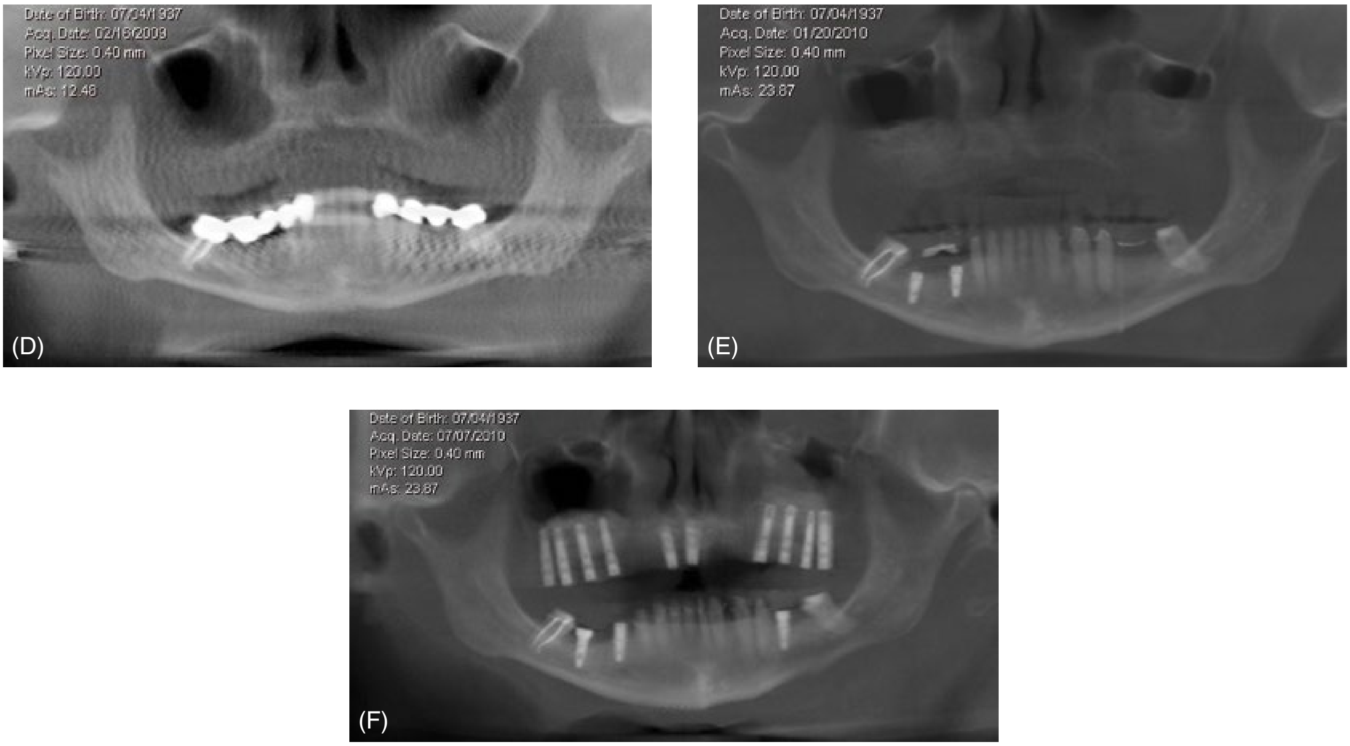

Figure 31.16 **(D–F)** Panoramic CBCTrenderings showing before, during and after surgical treatment. Her initial clinical and radiographic evaluations revealed insufficient bone for maxillary implants without extensive grafting and reconstructive surgeries. There were no health, time, or financial restrictions.

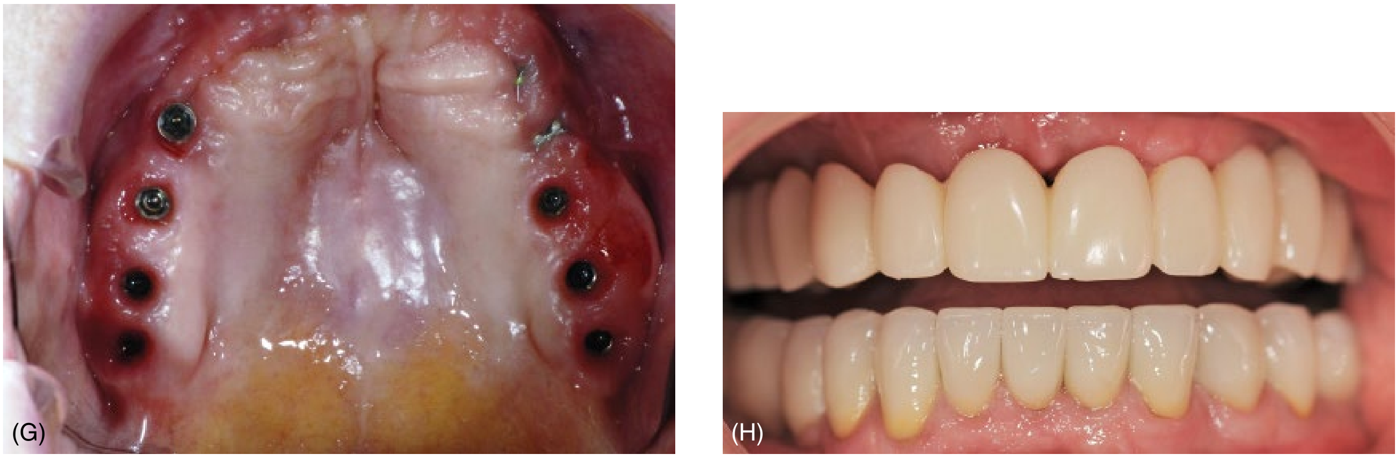

Figure 31.16 **(G, H)** Sequential surgery included bilateral sinus floor augmentation (Figure 30.16E), followed by implant placement in posterior right and left maxilla, and mandibular right and left edentulous spaces. Immediate loading of these implants in a maxillary screw-retained provisional bridge was performed.

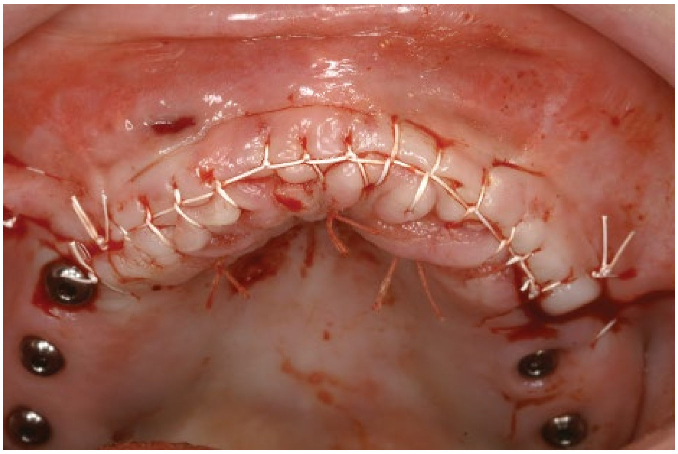

Figure 31.16 **(I)** Later, implants were placed in the anterior maxilla with simultaneous bony ridge augmentation.

Figure 31.16 **(J)** The aforementioned immediate temporary bridge was placed.

Figure 31.16 **(K)** The final maxillary ceramo-metal implant fixed bridge was seated along with mandibular single natural teeth and implant crowns.

Figure 31.16 **(L)** The patient was extremely pleased with the esthetic and functional treatment outcome and later pursued plastic surgery interventions to further enhance her facial esthetic and more youthful appearance.

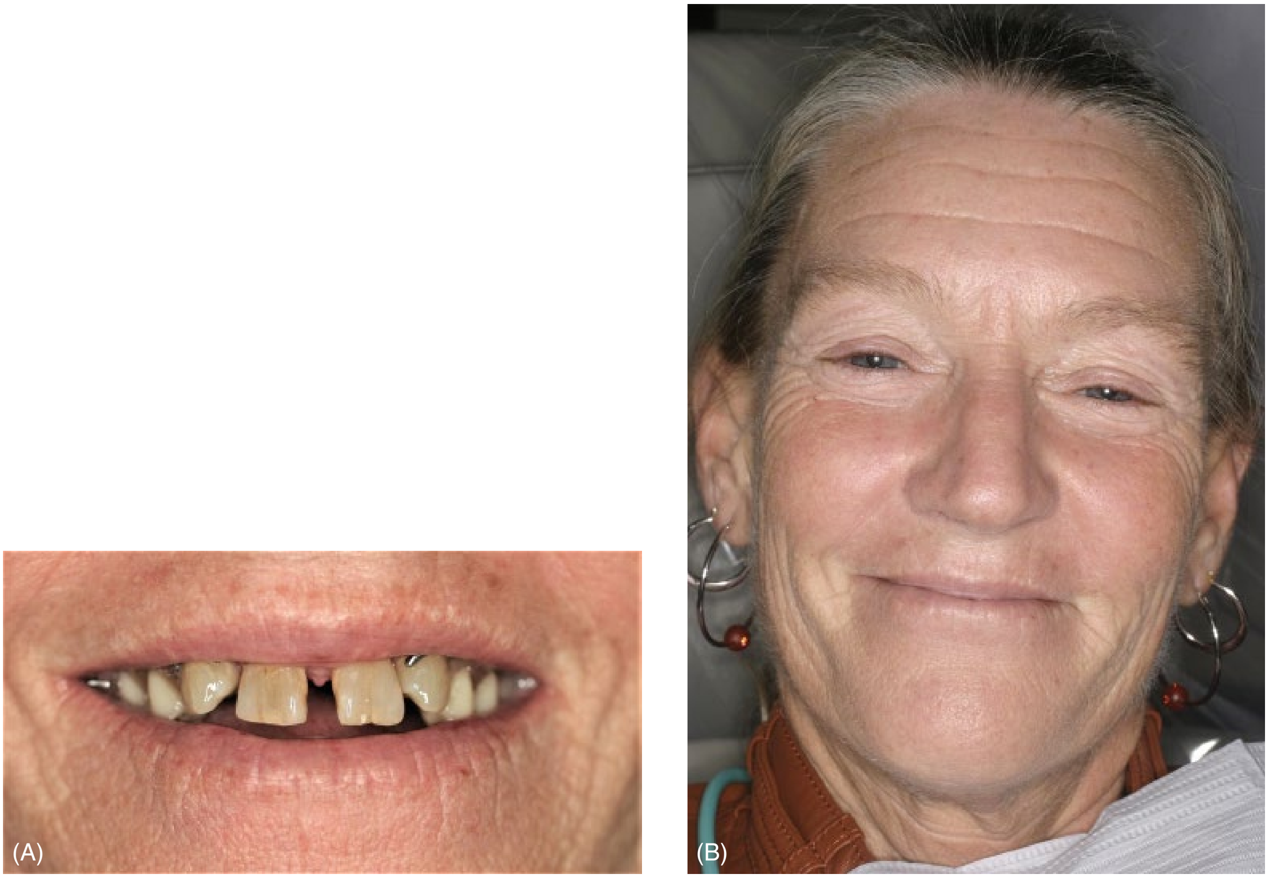

Figure 31.17 **(A, B)** This 60-year-old female was avoiding dental visits and treatment due to her extreme dental fears and anxiety.

Figure 31.17 **(C–E)** The patient had congenitally missing maxillary lateral incisors, large diastemas and flaring in her anterior maxillary teeth. In addition, she was missing all of her posterior maxillary teeth and mandibular incisors and all-but-one periodontally compromised molar #30.

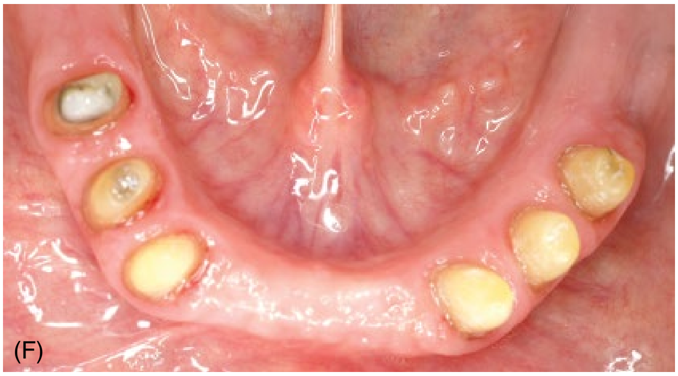

Figure 31.17 **(F, G)** The mandibular rehabilitation included extraction of a nonrestorable molar (#30) and preparation of lower right and left canines and premolars for a fixed bridge replacing the lower incisors. Note the metal rests as a contingency plan for a removable partial denture to replace her mandibular molars.

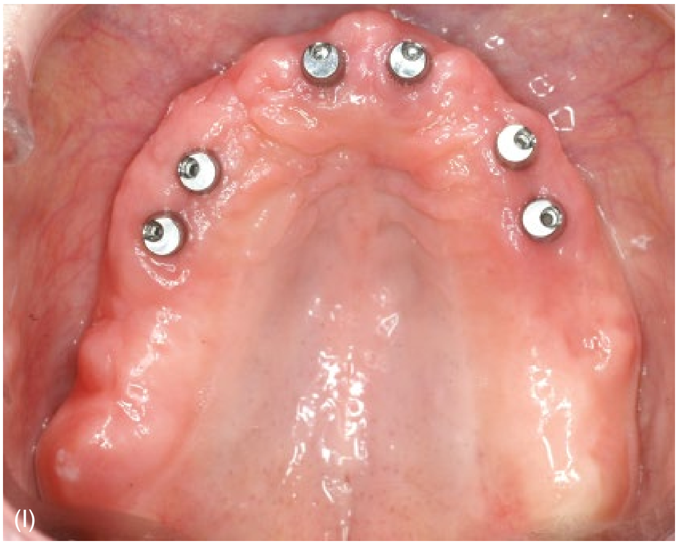

Figure 31.17 **(H, I)** A surgical guide was derived from cone beam computed tomography imaging and utilized in her implant surgery. The maxillary treatment included computer-aided design/manufacture surgical treatment planning and guidance for extraction of teeth #6, #8, #9, and #11 and placement of six Ankylos implants.

Figure 31.17 **(J, K)** The implants were immediately loaded in a maxillary treatment denture. Upon osseointegration, a final SynCone overdenture was fabricated.

Figure 31.17 **(L–N)** The patient's final treatment has restored not only her dental function and esthetics, but her trust in the dental profession.

Figure 31.17 **(O, P)** Six years later, the patient remains in great dental shape and among the most pleasant, compliant, and regular dental patients. The dramatic result she received is a true measure of the difference in quality of life that esthetic prosthetic dentistry can help provide.

Figure 31.18 **(A)** A 75-year-old female patient presented with advanced periodontal disease and loose failing dentition.

Figure 31.18(B) New patient photos show the advanced attachment loss and inflammation. Clinical examination revealed dental caries and mobility.

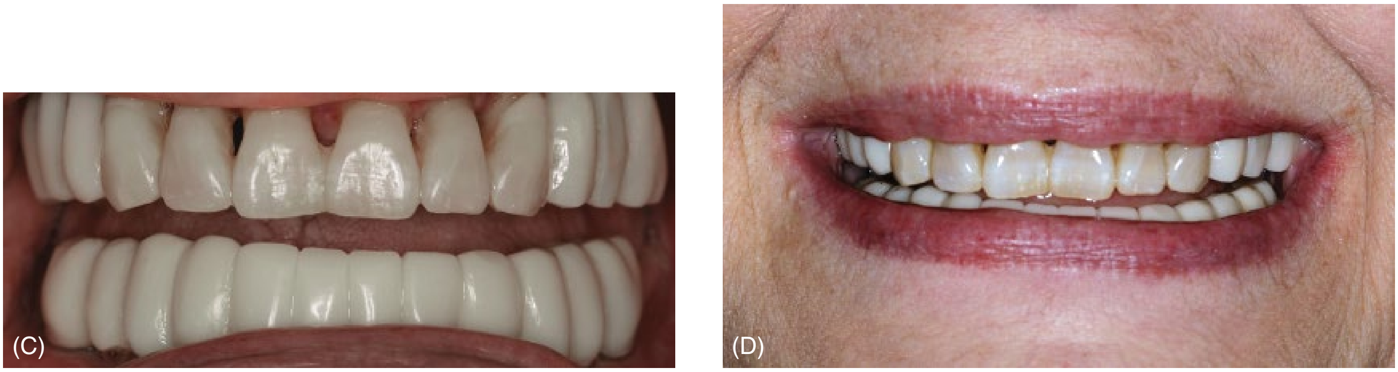

Figure 31.18 **(C, D)** After sequential surgeries, extraction of lower teeth with immediate implant placement and immediate provisionalization, bilateral sinus lift, and eventual implant placement and provisionalization. Full lower, upper right, and upper left posterior implant-retained provisional bridges.

Figure 31.18 **(E–H)** The decision was made to retain her maxillary anterior teeth until her maxillary posterior implants are restored, and eventually be replaced with implants as well. However, after periodontal therapy, replacement of old composite resin restorations as well as a lingual bonded retainer were completed, it was decided to retain her maxillary anterior teeth due to their improved prognosis.

Figure 31.18 **(I, J)** After seating full mandibular and maxillary posterior final implant ceramo-metal crowns and bridges and despite bleaching her maxillary front teeth, the patient inquired about improving their esthetics as well. A trial smile was performed based on an updated diagnostic wax-up. The teeth have been stable periodontally and the patient was extremely compliant with home care and frequent periodontal maintenance recalls. A change in treatment plan was made from extraction and implant placement to splinted porcelain-fused-to-metal crowns.

Conclusion

There are few things in a dental practice that can be more satisfying than helping a patient to obtain the best esthetic appearance possible; it can be just as important to work toward that goal when the patient is elderly. Although it may be the family and friends who enjoy seeing their loved one look and feel their best, ultimately it is the older individual who has the most to gain with enhanced esthetics and function. Esthetic dentistry has the potential to contribute greatly to improving the oral health and quality of life of older adults. Americans now have the potential to enjoy a lifetime of oral health rather than suffer from a lifetime of oral diseases. The desire to feel good and look healthy is not limited by age.

The new procedures, materials, and techniques that have provided an esthetic revolution in dentistry will provide older Americans with improved quality of life, greater self-esteem, and a lifetime of oral function. Patients should be given the opportunity to learn how esthetic dentistry can improve the quality of their life at any age. Even in the nursing home, life revolves around speaking, smiling, eating, and socializing—all functions of the oral cavity. An esthetic smile is an asset at any age and in any venue.

Figure 31.18 **(K–M)** Over 2 years after treatment completion, the patient continues to be compliant, healthy and happy with her treatment delivered.

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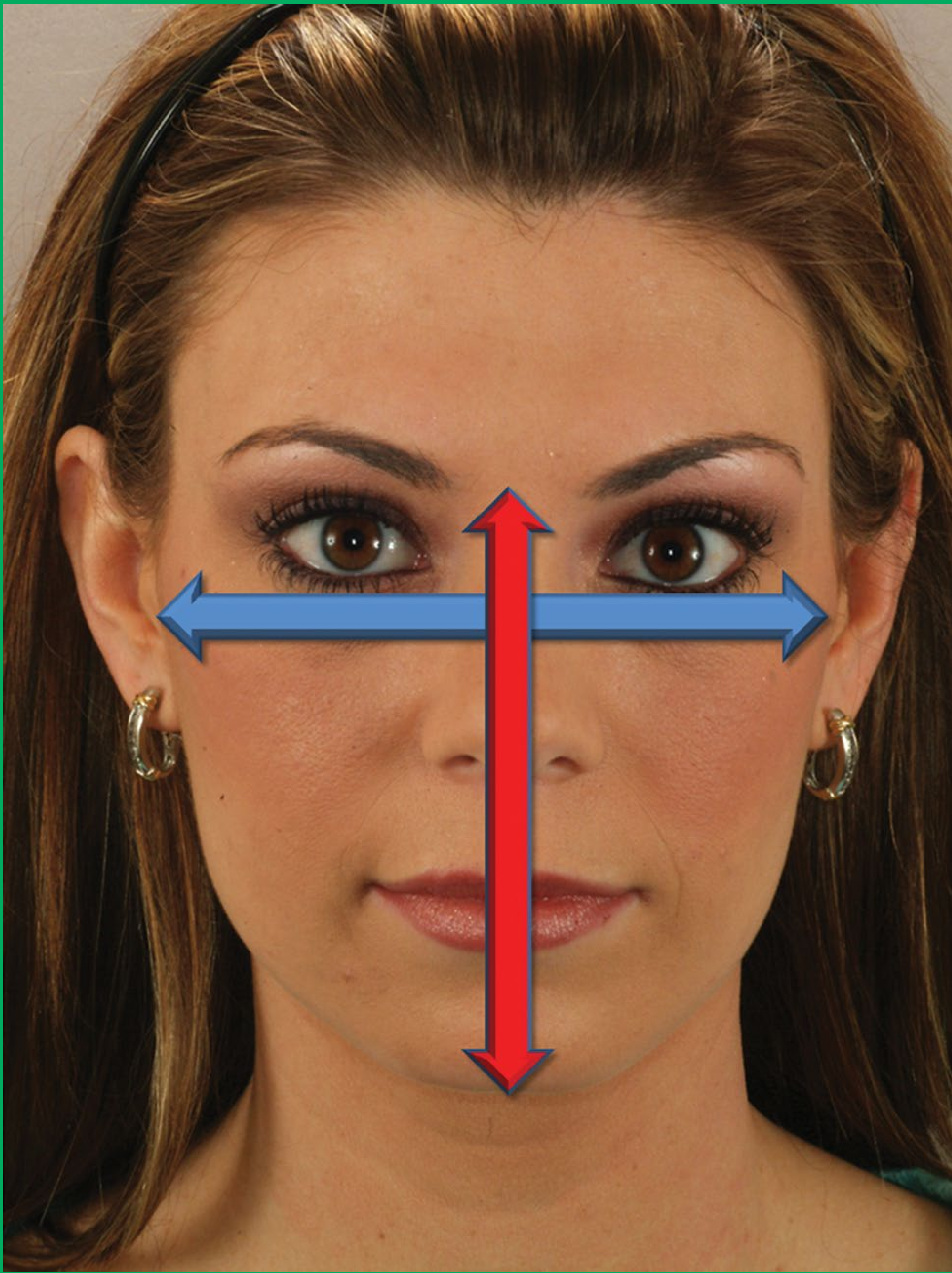

Chapter 32 Facial Considerations: An Orthodontic Perspective

David Sarver, DMD, MS

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An esthetic approach to evaluation: enhancement of appearance

While we teach our children that we should not judge a person by their looks, the reality is that the world often judges based on personal appearances. While patients may walk in our offices seeking to correct their bite, the reality is that most are seeking a complete enhancement of the appearance, including dentition, occlusion, their smile, and face, which will greatly affect their self-image and how others perceive them.

The primary focus of cosmetic dentistry focuses on the presentation of the teeth and surrounding smile framework. Contemporary dentistry broadens the esthetic analysis of the patient to include facial form and proportions. We refer to the facial esthetic portion of orthodontic diagnosis and treatment as enhancement of appearance.[1] It is important to analyze the morphologic form of the face, the overlying soft-tissue envelope, and the underlying facial skeleton integrated with the dentition to fully understand comprehensive dentofacial diagnosis. Patients who seek orthodontic and cosmetic dental treatment do so to improve their quality of life,[2] both for functional improvement and enhancement of appearance. To achieve both ideals—occlusion and facial esthetics—is the challenge. When discussing the need for treatment with our patients, occlusal discrepancies require treatment for preservation of dentition and long-term stable occlusion, but to treat only the occlusion treats only half of the patient. Likewise, treating only the esthetic component equally treats only half of the patient.

While the focus in the past has been in using cephalometric analysis as a significant determinant in treatment planning, today our focus is primarily based on soft-tissue assessment with the goal of achieving the necessary skeletal and dental changes to achieve both functional and esthetic enhancement. Conceptually and operatively, the orthodontist and surgeon must try to

Ronald E. Goldstein's Esthetics in Dentistry, Third Edition. Edited by Ronald E. Goldstein, Stephen J. Chu, Ernesto A. Lee, and Christian F.J. Stappert.

visualize the desired solution to the specific problem and then assess how a given solution will positively and equally negatively impact the various components. The concept of facial optimization involves the preservation of as many positive elements as possible, while harmonizing those elements that fall short of the esthetic and functional needs of the patient.

Diagnosis and treatment planning in three dimensions: face, smile, and teeth

A systematic analysis of all the facial components, both anatomically static and functionally dynamic, will lead to a greater appreciation of the subtleties of the interaction of each of the facial elements and how each can be appropriately managed through a unified treatment approach.[3, 4] Our approach to diagnosis and treatment planning includes three major areas: the face (macroesthetics), smile (miniesthetics), and teeth (microesthetic). These serve as a framework for systematic evaluation of the esthetic needs of each particular patient (Figure 32.1).[5, 6] This framework is a departure from the traditional approach based on models and, in the case of orthodontics, cephalometric values. Dental students will remember being taught about the importance of cephalometrics in orthodontic diagnosis, but today's approach is increasingly focused on the clinical examination and quantification of the patient's facial presentation. This leads all disciplines of dentistry and medicine to analyze facial esthetics in a more homogeneous fashion. Our functional goals of occlusion (Class I, overbite, overjet, etc.) still remain in place, but are evaluated in the context of an expanded dentofacial analysis.

1. **Macroesthetics** encompasses the face in all three planes of space. Examples of macroesthetic appearance issues include a long face, a short face, lack of chin prominence, and other facial features.
2. **Miniesthetics** focuses primarily on the smile framework. The smile framework is bordered by the upper and lower lips on smile animation and includes such assessments of excessive gingival display on smile, inadequate gingival display, inappropriate gingival heights, and excessive buccal corridors.
3. **Microesthetics** includes assessment of tooth proportion in height and width, gingival shape and contour, black triangular holes, tooth shade, and other dental attributes.

The goal of esthetic treatment planning is the improvement of negative attributes, while preserving those attributes that are deemed favorable. Traditional treatment planning focused on generating a problem list and pursuing solutions for each problem without regard for potential negative changes to the patient's existing positive attributes. For example, a classic orthodontic treatment of overjet reduction and Class I cuspid relations in a patient with a skeletal Class II mandibular deficiency would be removal of the maxillary first premolars to make space for retraction of the maxillary anterior teeth. While this satisfies the functional and occlusal problem, it may result in profile flattening and an unfortunate effect on overall facial appearance (Figure 32.2A and B). In contrast, a comprehensive esthetic treatment integrates the components of soft-tissue–skeletal analysis with static–dynamic assessment in three dimensions and the

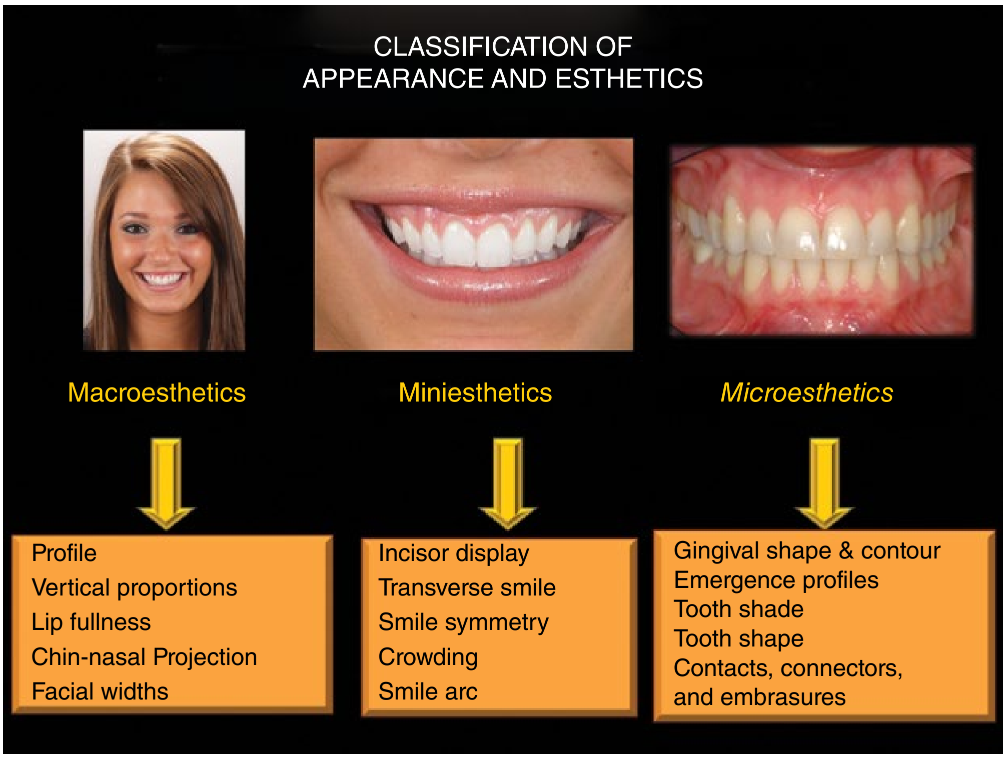

Figure 32.1 Diagnosis and treatment planning of appearance can be divided into three major areas: macroesthetics (the face), miniesthetics (the smile), and microesthetics (the teeth and gingiva).

Figure 32.2 **(A)** This patient was treated for her severe Class II malocclusion through extraction of maxillary first premolars for incisor retraction and overjet reduction. Because the skeletal mandibular deficiency was not addressed, the malocclusion was corrected, but the esthetic outcome was compromised.

Figure 32.2 **(B)** After retreatment with orthodontics and surgical bimaxillary advancement, her profile has greatly improved.

positive and negative impact of any one component on another (Figure 32.3). The starting point for the macroesthetic examination is the frontal perspective and is the focus of this chapter.

Macroesthetic evaluation of the face: frontal view

A contemporary analysis of the frontal face needs to go beyond simple categories when defining positive as well as negative attributes that should be considered in the treatment plan. Figure 32.4 and Table 32.1 illustrates the facial landmarks that will be used in the description of the dentofacial analysis.

Excellent imaging naturally infers high-quality care. Quality photographs are an important component in analysis and documentation of the patient's face and serve multiple purposes:

- to allow the clinician to visualize the patient's features and clearly determine the direction of treatment;
- documentation for medicolegal purposes;
- for use in treatment plan presentation to our patients.

For ideal photographic representation of the face, the recommendation is that the camera be positioned in the "portrait" position to maximize use of the photographic field (Figure 32.5). If the camera orientation is in "landscape view", the photo captures too much unneeded background and detracts from the image by diminishing the size of the face (Figure 32.6).

The following facial photographs are recommended as the expected routine for each patient.[7]

Frontal view

The patient assumes a natural head position and looks straight ahead into the camera. Four types of frontal photographs are useful:

- **Frontal at rest** (Figure 32.7). If lip incompetence is present, the lips should be in repose and the mandible in rest position.
- **Frontal view with the teeth in maximal intercuspation, with the lips closed**, even if this strains the patient. This photograph serves as clear documentation of lip strain and its esthetic effect, and the lips-together picture is recommended in patients who have lip incompetence. If lips-apart posture

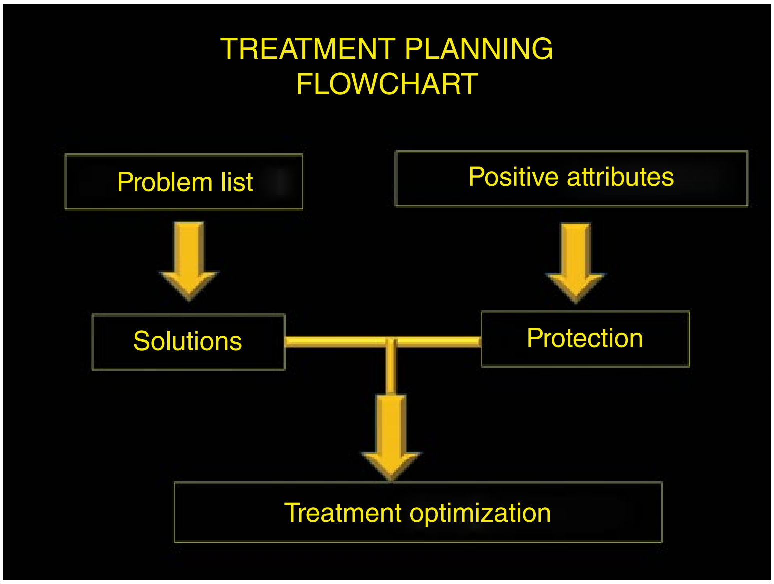

Figure 32.3 Contemporary diagnosis integrates the components of soft-tissue–skeletal analysis with static–dynamic assessment in three dimensions and an understanding of the positive and negative impacts of any one component may have on another.

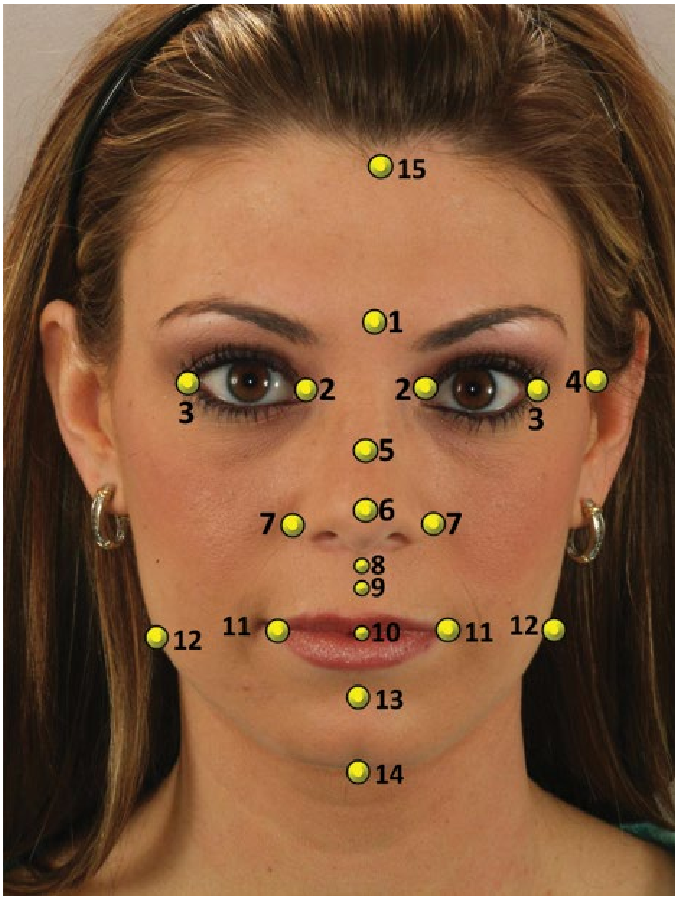

Figure 32.4 The facial landmarks that are used in the description of the dentofacial analysis.

Table 32.1 Frontal Soft-Tissue Points

Glabella	The most anterior aspect of the forehead as it progresses inferior into the nose
Inner canthus	The medial conjunction of the upper and lower eyelids
Outer canthus	The lateral conjunction of the upper and lower eyelids
Zygoma	The outermost aspect of the zygomatic prominence
Mid dorsum	The midpoint of the bony nasal dorsum
Nasal tip	The midpoint of the nasal tip
Alar base	The most lateral aspect of the ala of the nose
Base of nose	The intersection of the nasal columella with the upper lip
Mid philtrum	The midpoint of the philtrum
Inferior philtral tubercle	The most inferior limit of the philtral projection or tubercle of the upper lip
Outer commissure	The lateral conjunction of the upper and lower lips
Gonial angle	The point at the intersection of the posterior ramus and body of the mandible
Labiomental sulcus	The deepest curvature of the lower lip
Menton	The most inferior point of the chin
Trichion	The hairline

Figure 32.5 For ideal photographic representation of the face, the recommendation is that the camera be positioned in the "portrait" position.

Figure 32.6 Orienting the camera in "landscape" position captures much of the background. This is not only unneeded, but detracts from the image by diminishing the size of the face in the picture.

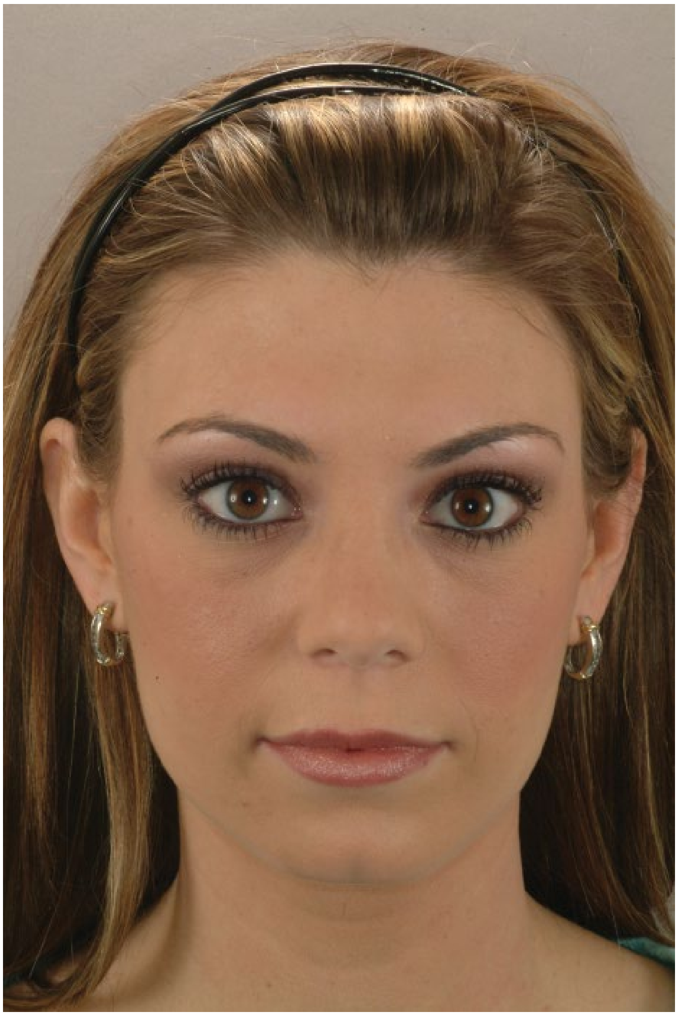

Figure 32.7 The frontal at rest image.

is present, then an unstrained image is also recommended. The reason for this image is to allow visualization of the philtrum–commissure height relationship, etiologic in the differential diagnosis of excessive gingival display on smile.

- **Frontal dynamic (smile)** (Figure 32.8). As described in more detail later in this chapter, the smile can vary with emotion. A patient who is smiling for a photograph tends not to elevate the lip as extensively as a laughing patient. The smiling picture demonstrates the amount of incisor show on smile (percentage of maxillary incisor display on smile) and any excessive gingival display. The still image of the smile can be variable. If you think about it, we squeeze off a picture that is about 1/125 of a second duration in a process that has a start and a finish (from the lips together through the smile animation back to the lips being together).

Oblique view (three-quarter, 45°)

The patient is posed in natural head position looking 45° to the camera, including the following three views:

- **Oblique at rest** (Figure 32.9). This view is valuable for examination of the midface and is particularly informative of midface deformities, including nasal deformity. We should

Figure 32.8 The frontal dynamic or smile image.

recognize that persons are not seen just on profile or from the front, so the three-quarter view is particularly valuable in assessing the way a patient's face is more often viewed by others. This view also reveals anatomic characteristics that are difficult to quantify but are important esthetic factors, such as the chin–neck area, the prominence of the gonial angle, and the length and definition of the border of the mandible. The view also permits focus on lip fullness and vermilion display. For a patient with obvious facial asymmetry, oblique views of both sides are recommended.

- **Oblique on smile** (Figure 32.10). There are diagnostic limitations of plaster casts, virtual models, and, as far as we are concerned, virtually all static records because they do not reflect the relationships of the teeth to the lips and surrounding soft tissue, especially in evaluation of the smile.[8,9] Often, in clinical practice, a patient or parent will ask why the teeth appear flared, and they do a credible job of illustrating what they are seeing by holding their hands next to the child's face to make sure that we see it too. This observation is often not discernible on the models or on the cephalogram, but is readily observable on the patient. The oblique view of the smile reveals characteristics of the smile not obtainable through those means and it aids the visualization of both incisor flare and occlusal plane orientation. A particular point for observation is the anteroposterior cant of the occlusal plane.

In the most desirable orientation, the occlusal plane is consonant with the curvature of the lower lip on smile (the smile arc). Deviations from this orientation that should be noted as potential problems include a downward cant of the posterior maxilla, an upward cant of the anterior maxilla, or variations of both. In the initial examination and diagnostic phase of treatment, visualization of the occlusal plane in its relationship to the upper and the lower lip is important.

Profile view

The profile photographs also should be taken in a natural head position. The most common method used for positioning the patient properly is to have the patient look in a mirror, orienting the head on the visual axis. The picture boundaries should emphasize the areas of information needed for documentation and diagnosis. My recommendation is that the inferior border be slightly above the scapula, at the base of the neck. This position permits visualization of the contours of the chin and neck area. The superior border should be only slightly above the top of the head, and the right border slightly ahead of the nasal tip.

The inclusion of more background simply adds unneeded information to the photograph. Some clinicians prefer that the left border stop just behind the ear, whereas others prefer a full head shot. Under any circumstance, the hair should be pulled behind the ear to permit visualization of the entire face.

Two profile images are beneficial:

- **Profile at rest** (Figure 32.11). The lips should be relaxed. Lip strain is illustrated better in the frontal view, so a profile photograph with the lips strained in closure is unnecessary.
- **Profile smile** (Figure 32.12). The profile smile image allows one to see the angulation of the maxillary incisors, an important esthetic factor that patients see clearly and orthodontists tend to miss because the inclination noted on cephalometric radiographs may not represent what one sees on direct examination.
- **An optional submental view** (Figure 32.13). Such a view may be taken to document mandibular asymmetry. In patients with asymmetries, submental views can be particularly revealing.

Technology and facial imaging

It is possible to use computer software to calibrate images for quantification and measurement. If we know the dimensions of an object in the field of view, we can use it to calibrate the image, and then measure any dimension we are interested in. For example, on the computer screen, we can digitize the width of one of the central incisors, which allows calibration of the image. The clinician can then measure and calculate the height/width ratio and proportionality of the anterior teeth. Carrying this technology forward, it is also possible to utilize a digitizing module to

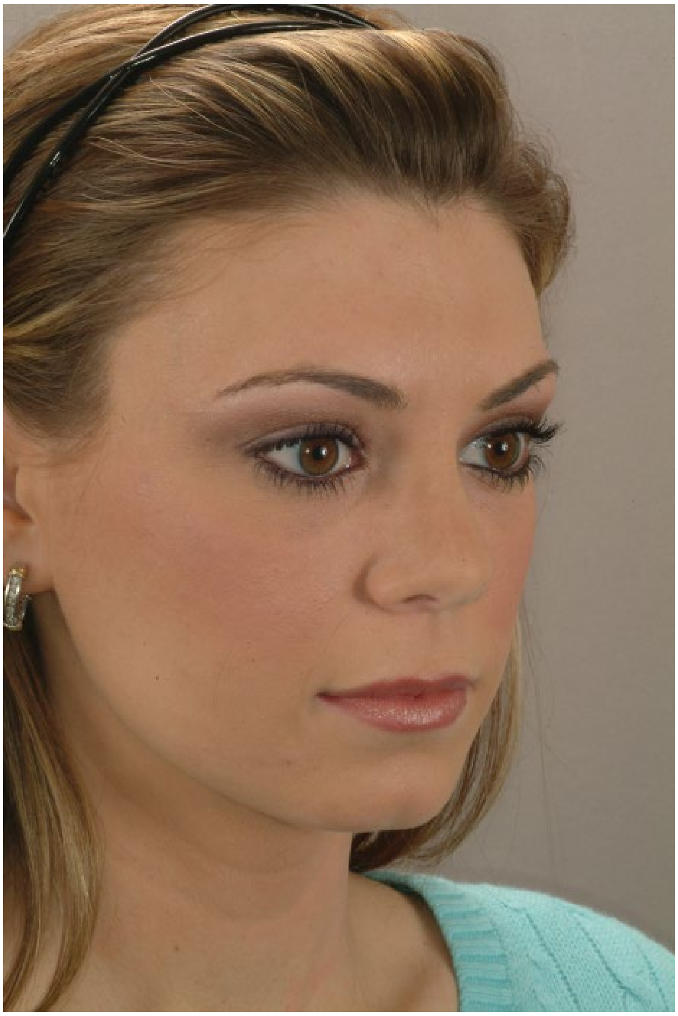

Figure 32.9 The oblique at rest image.

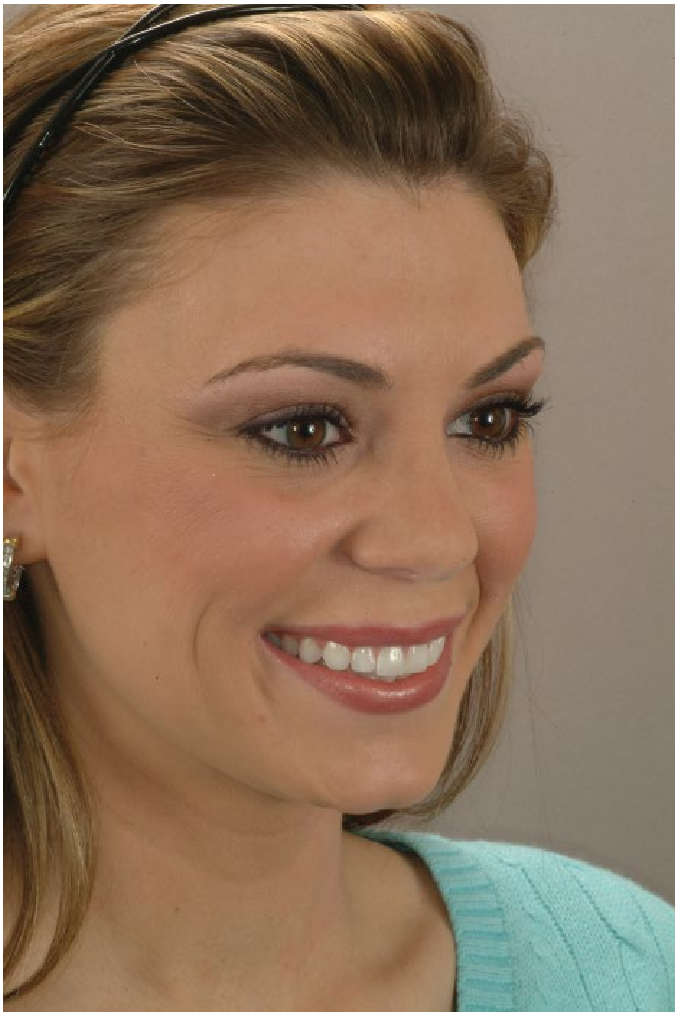

Figure 32.10 The oblique on smile image.

digitize the points of the face, smile, and teeth and have the ratios calculated automatically.

Three-dimensional facial mapping is also possible in today's clinical and research environment (Figure 32.14A and B). The images are obtained with a special type of camera that provides a nonradiographic image and which can be rotated on the computer screen for further analysis. It is also possible to calibrate and measure these images as well.

Dentofacial analysis: clinical examination

The direct clinical examination is critical to successful esthetic and functional dentofacial diagnosis. The systematic approach to looking at every element of the face and smile and measuring them can virtually lead us to the correct diagnosis. The progression of the examination we recommend is as follows.

Vertical facial proportions

The ideal face is vertically divided into equal thirds by horizontal lines adjacent to the hairline, the nasal base, and lower border of the chin[10] (Figure 32.15). Orthodontic and surgical/orthodontic treatment is usually concentrated with the lower facial third. Measurement of the upper face can often be difficult with the variability in identification of landmarks such as the location of the hairline. In the ideal lower third of the face, the upper lip makes up the upper third, and the lower lip and chin compose the lower two-thirds (Figure 32.16). Disproportion of the vertical facial thirds may be a result of many dental and skeletal factors, and these proportional relationships may help us define the contributing factors related to vertical dentofacial deformities.

Facial index

While transverse and vertical relationships comprise the major components of the frontal examination and analysis, the proportional relationship of height and width is far more important than absolute values in establishing overall facial type. In cosmetic dentistry, it is well established that attractive teeth tend to have certain proportions, and the same is true in faces. The *facial index* is defined as the ratio of facial width to facial height (Figure 32.17) using a line from zygoma to zygoma for the width measurement and nasion to

Figure 32.11 The profile at rest image.

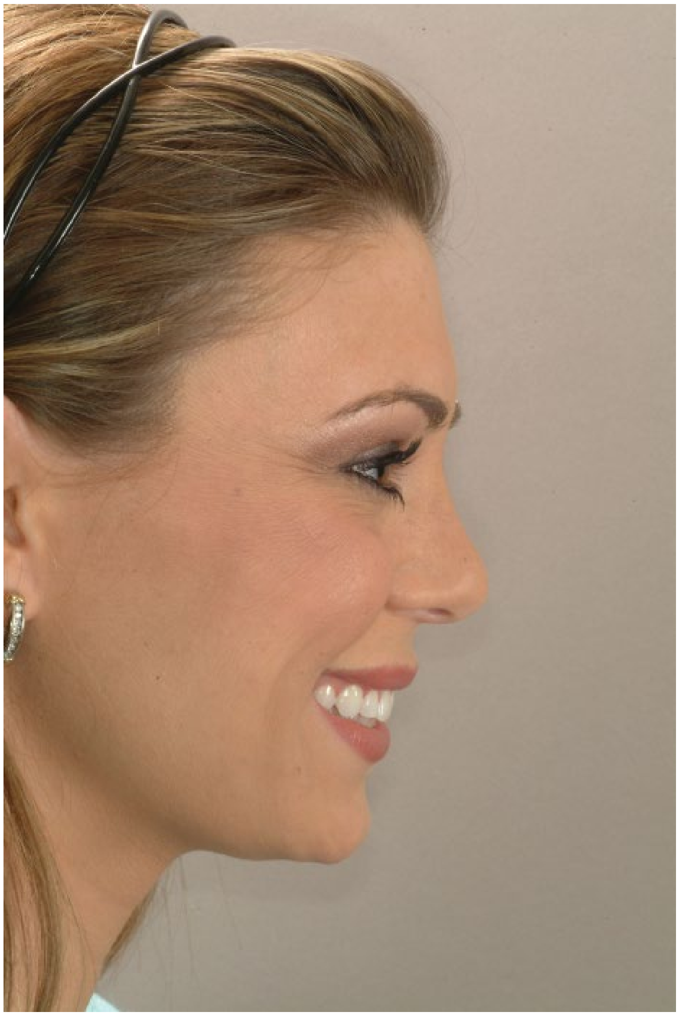

Figure 32.12 The profile smile image.

midsymphysis for the facial height. Farkas and Munro[11] report that the average facial index for males is 88.5% and for females is 86.2%. The classic frontal analysis categorizes faces as either mesocephalic (normal facial heights), brachycephalic (short lower face), or dolichocephalic (long lower face) (Figures 32.18, 32.19, and 32.20). The differentiation between these facial types has to do with the general proportionality of facial width to facial height, with brachycephalic faces being broader and shorter in comparison with the longer and narrower dolichocephalic faces.

Facial taper

Another way to view facial proportionality is the comparison of the zygomatic width and the intergonial width, which can be referred to as the *facial taper*.[12] While studies are currently establishing normative values, Figure 32.21 demonstrates the facial taper of a proportional face. A dramatic example of the esthetic improvement associated with changes in facial taper as a result of orthognathic surgery can be viewed in Figure 32.22A and B. The patient presented with diminished middle third and a square facial taper pattern. Her skeletal pattern was the determinant of her facial pattern, so an orthodontic–orthognathic approach to treatment was indicated. After orthodontic preparation, the patient underwent maxillomandibular surgery to rotate the lower face in such a way as to increase the lower face and steepen the mandibular plane. Even though the width was not changed with the surgical procedure, the face appears to be narrower from the increase in vertical height and resulting change in facial taper.

Transverse facial proportions: the rule of fifths

The assessment of the transverse components of facial width is best described by the rule of fifths.[7] This method describes the ideal transverse relationships of the face. The face is divided sagittally into five equal parts from helix to helix of the outer ears (Figure 32.23). Each of the segments should be one eye distance in width.

The middle fifth of the face is delineated by the inner canthus of the eyes. A vertical line from the inner canthus should be coincident with the alar base of the nose. Variation in this facial fifth could be due to transverse deficiencies or excesses in either the inner canthi or alar base. For example, hypertelorism in

Figure 32.13 An optional submental view may be taken to document mandibular asymmetry.

craniofacial syndromes can create disproportionate transverse facial esthetics.

A vertical line from the outer canthus of the eyes frames the medial three-fifths of the face, which should be coincident with the gonial angles of the mandible. Although disproportion may be very subtle, it is worth noting since our treatments can positively change the shape or relative proportion of the gonial angles.

The outer two-fifths of the face are measured from the lateral canthus to lateral helix of the ear, which represents the width of the ears. Unless this abnormality is part of the chief complaint, prominent ears are often a difficult feature to discuss with the patient because laypeople only recognize its effect on the face in severe cases. However, studies clearly indicate that large ears are judged by laypeople to be one of the most unesthetic features, particularly in males. Otoplastic surgical procedures are relatively atraumatic and can dramatically improve facial appearance. These procedures can be performed on adolescents and adults, as is illustrated in Figure 32.24A and B.

Another significant frontal relationship is the midpupillary distance, which should be transversely aligned with the commissures of the mouth.[8] Although this is considered the ideal transverse facial proportionality, there is little that can be done therapeutically to correct this disproportion, except in craniofacial synostosis such as Apert syndrome.

Nasal anatomy in the transverse plane should also be assessed through proportionality. The width of the alar base should be approximately the same as the intercanthal distance, which should be the same as the width of an eye. If the intercanthal distance is smaller than an eye width, it is better to keep the nose slightly wider than the intercanthal distance. The width of the alar base is heavily influenced by inherited ethnic characteristics.

Figure 32.14 **(A)** Three-dimensional facial mapping is also possible in today's clinical and research environment. The images are obtained with a special type of camera that provides a nonradiographic image which can be rotated on the computer screen for further analysis. It is also possible to calibrate and measure these images as well. This is of a patient prior to orthognathic surgery.

Figure 32.14 **(B)** The three-dimensional facial map after orthognathic surgery and veneers (3dMd, Atlanta, GA).

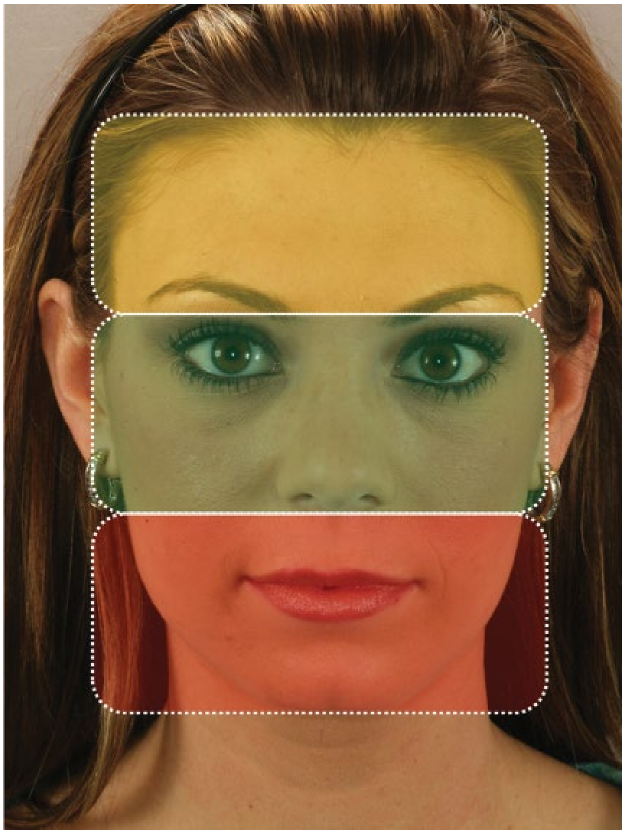

Figure 32.15 Ideal facial proportions in equal vertical thirds.

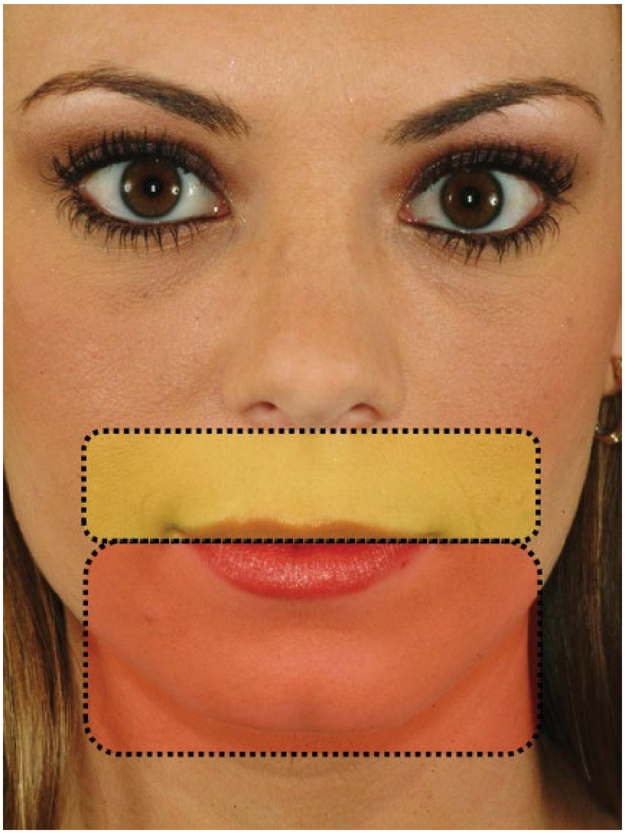

Figure 32.16 In the ideal lower third of the face, the upper lip makes up the upper third, and the lower lip and chin compose the lower two-thirds.

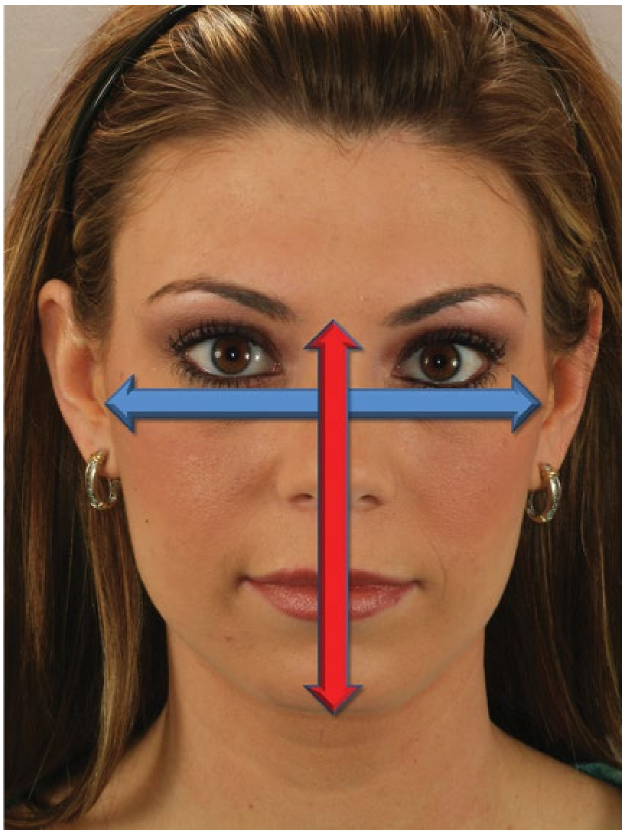

Figure 32.17 The facial index is the ratio of facial width to facial height using a line from zygoma to zygoma for the width measurement and nasion to midsymphysis for the facial height.

Figure 32.18 Mesocephalic facial form has normal facial heights.

Figure 32.19 Brachycephalic facial form is characterized by a short, square lower facial third.

Figure 32.20 Dolichocephalic facial form is characterized by a long, narrow lower facial third.

Facial asymmetry

Facial asymmetry is traditionally assessed in the frontal plane; however, asymmetry occurs in all three planes, and the rotational aspect is described in the "Macroesthetics and smile dimensions" section describing the concepts of pitch, roll, and yaw.

Nasal tip to midsagittal plane

The patient's head should be elevated slightly to better visualize the nasal tip in relation to the midsagittal plane (Figure 32.25). This is evaluated first to reduce the risk of treating the maxillary midline to a distorted nose.

Maxillary dental midline to midsagittal plane

The maxillary dental midline should be evaluated relative to the midsagittal plane. This is best visualized by identifying the peaks of the upper vermilion border of the lips that correlate to the philtral columns, which correlate to the midsagittal plane. In this way, we can readily see the maxillary dental midline in relation to the midsagittal plane as demonstrated in Figure 32.26. A discrepancy could be due to either dental factors or skeletal maxillary rotation. Maxillary rotation is a rarely occurring clinical finding and is usually accompanied by posterior dental crossbite.

Mandibular asymmetry with or without functional shift

Mandibular asymmetry is suspected when the midsymphysis is not coincident with the midsagittal plane. An important diagnostic factor is whether a lateral functional shift is present secondary to a functional shift of the mandible due to crossbite. When the patient is manipulated into centric relation, a bilateral, end-to-end crossbite usually is present, and as the patient moves their teeth into full occlusion they must choose a side to move their mandible into maximum intercuspation. This lateral shift is indicative of true mandibular asymmetry, but of a narrow maxilla resulting in a functional shift of the mandible.

True mandibular asymmetry is suspected when, in closure into centric relation, no lateral functional shift occurs. The truly asymmetric mandible may be due to an inherited asymmetric facial growth pattern or a result of localized or systemic factors. A thorough history of traumatic injuries and a review of systems of the patient will help ascertain potential etiologies of true mandibular asymmetry.

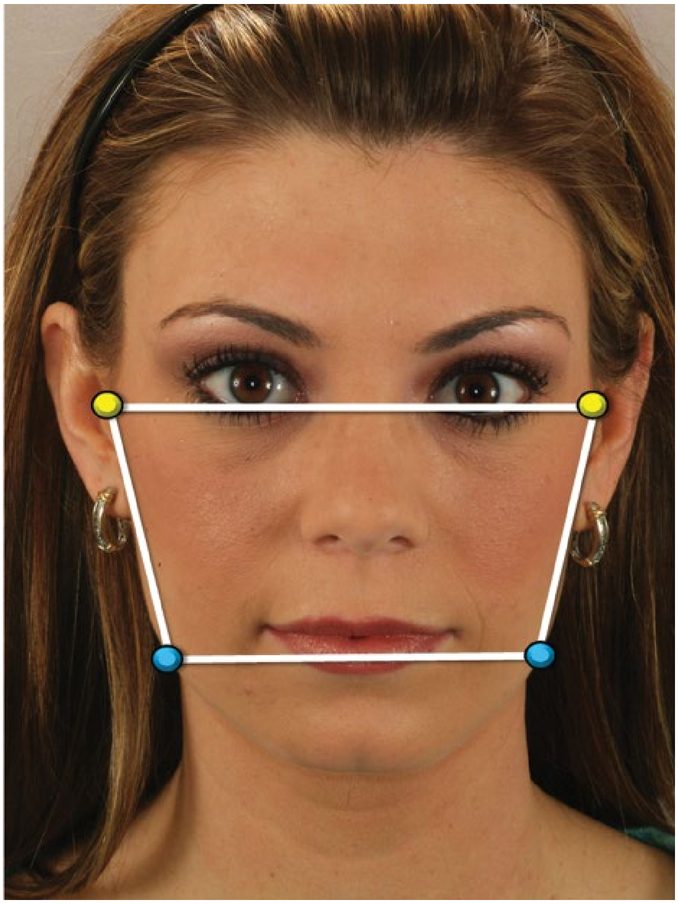

Figure 32.21 The facial taper of a proportional face.

Figure 32.22 **(A)** This patient had a diminished middle facial third and a square facial taper pattern.

Chin asymmetry

Facial asymmetry in some cases may be limited to the chin only. If the systematic evaluation of facial symmetry has dental and skeletal midlines and vertical relationships of the maxilla normal and lower facial asymmetry is noted, then the asymmetry may be isolated to the chin. Measurement of the midsymphysis to the midsagittal plane is a logical indicator of chin asymmetry, but the parasymphyseal heights should also be measured when chin asymmetry is suspected (Figure 32.27A–D).

Maxillomandibular asymmetry

Mandibular asymmetry is often accompanied by maxillary compensation, which is reflected clinically by a transverse cant of the maxilla. This means that evaluation of mandibular deformity should now include the possibility of maxillomandibular deformity, which is described later in this chapter. Transverse tilting of the maxilla may be detectable cephalometrically but is most evident during the macroesthetic examination. The patient in Figure 32.28A is an excellent example. Her smile was characterized by a transverse cant, with the left side of the maxilla significantly lower than the right. The submental view (Figure 32.28B) reflects the chin point (menton) placed to the left of midsagittal plane, with the right mandible longer than the left. The maxilla has compensated during growth for the mandibular asymmetry, resulting in the severe asymmetry of her smile (Figure 32.28C). Correction was achieved by surgical leveling of the maxilla and mandibular surgery, resulting in excellent symmetry (Figure 32.28D and E).

Macroesthetic evaluation of the face: oblique view

The oblique view in the macroesthetic examination affords the clinician another perspective for evaluating the facial thirds. In the upper face, we may view the relative projection of the orbital rim and malar eminence. Orbital and malar retrusion is often seen in craniofacial syndromes. Cheek projection is evaluated in the area of the zygoma and malar scaffold. Skin laxity and atrophy of the malar fat pad in this area may actually be a characteristic of aging, and therefore seen in the older orthognathic population. There is evidence[13] that this loss of midfacial support may be attributed to decreased skeletal volume as well the soft tissue changes. The midfacial area can be described as deficient, balanced, or prominent. Nasal anatomy, which was

Figure 32.22 **(B)** Maxillomandibular surgery was designed to improve the facial taper and facial height.

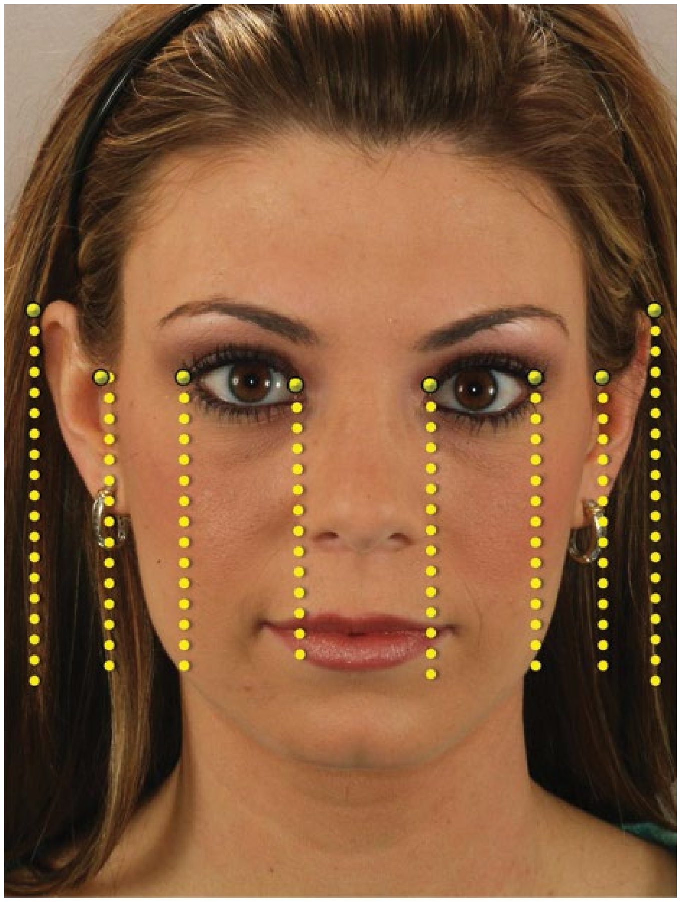

Figure 32.23 The ideal transverse relationships of the face with the face divided sagittally into five equal parts (the width of the eye) from helix to helix of the outer ears.

described in the frontal examination, may also be characterized in this dimension.

Lip anatomy is also examined in the oblique and lateral views. The philtral area and vermilion of the maxillary lip should be clearly demarcated. The height of the philtrum should be noted as short, balanced, or excessive. Vermilion display should be termed as excessive, balanced, or thin.

The relative projection of the maxilla and mandible can be assessed in the oblique view. Midface deficiency can result in increased nasolabial folding, relaxed upper lip support, and altered columella and nasal tip support.

One of the greatest values of the oblique view is visualization of the body and gonial angle of the mandible as well as the cervicomental area.[14] The patient in Figure 32.29 illustrates a desirable definition of the chin–neck anatomy where the gonial angle is well delineated and defined, with a moderately acute angle. The patient in Figure 32.30 has a dolichofacial skeletal pattern with a steeper mandibular plane, not as esthetically pleasing as the previous illustration. The patient in Figure 32.31 demonstrates a brachyfacial skeletal pattern with a very acute gonial angle and short lower face.

Macroesthetic evaluation of the face: profile view

The last view in the macroesthetic examination is the profile perspective. Natural head position is essential for accurate evaluation of profile characteristics.[15–18] The patient should be instructed to look straight ahead and, if possible, into their own image in an appropriately placed mirror. The visual axis is what determines "natural head position." The classic vertical facial thirds also apply in profile view. An assessment of lower facial deficiency or excess should be noted. Figure 32.32 and Table **32.2** illustrate the landmarks used in describing the soft-tissue profile.

Maxillary and mandibular sagittal position can be described by means of facial divergence. The lower third of the face is evaluated in reference to the anterior soft-tissue point at the glabella. Based on the position of the maxilla and mandible relative to this point, a patient's profile will be described as straight, convex, or concave, and either anteriorly or posteriorly divergent. Figure 32.33 illustrates the anterior facial plane formed from lines connecting the glabella to the base of the nose (subnasale) and the chin point.

The nasolabial angle describes the inclination of the columella in relation to the upper lip. The ideal nasolabial angle should be

Figure 32.24 **(A)** The young patient had disproportionate width of the outer facial fifth because of his ear prominence.

Figure 32.24 **(B)** Otoplasty was performed to improve his appearance.

in the range of 85–105° (Figure 32.34). The nasolabial angle is determined by several factors: (1) the anteroposterior position of the maxilla to some degree; (2) the anteroposterior position of the maxillary incisors; (3) vertical position or rotation of the nasal tip, which can result in a more obtuse or acute nasolabial angle; and (4) soft-tissue thickness of the maxillary lip that contributes the nasolabial angle, where a thin upper lip favors a flatter angle and a thicker lip favors an acute angle. The patient in Figure 32.35A demonstrates the severe maxillary dentoalveolar protrusion and its effect on the nasolabial angle. Because of her protrusion, she had a severe Class II malocclusion with 9 mm of overjet, resulting a very acute nasolabial angle. We elected to treat her through removal of maxillary first premolars and maximum retraction of the maxillary anterior teeth, reducing overjet, upper lip support, and improved nasolabial angle and esthetic lip balance (Figure 32.35B).

While the nasolabial angle is largely influenced by the hard-tissue structures, the nose itself should also be evaluated for possible inclusion in the problem list or attributes. The nasal tip elevation can be established as the position of the nasal tip relative to a perpendicular to the line from the glabella to the chin point at the base of the nose (Figure 32.36). Nasal projection is a description of the nose in height from the glabella to the base of the nose (subnasale) and length by nasal tip to the alar base (Figure 32.37).

Lip projection (Figure 32.38) is a function of maxillomandibular protrusion or retrusion, dental protrusion or retrusion, and/or lip thickness. The description of lip projection should include pertinent information from any of the aforementioned sources. For example, a patient with lower lip protrusion may be maxillary (midface) deficient with dentoalveolar compensation including flared incisors and a thin maxillary vermilion display, or simply may have a thick lower lip that appears protrusive.

The patient in Figure 32.39A had a large maxillary midline diastema as a result of distal drift of the centrals because of

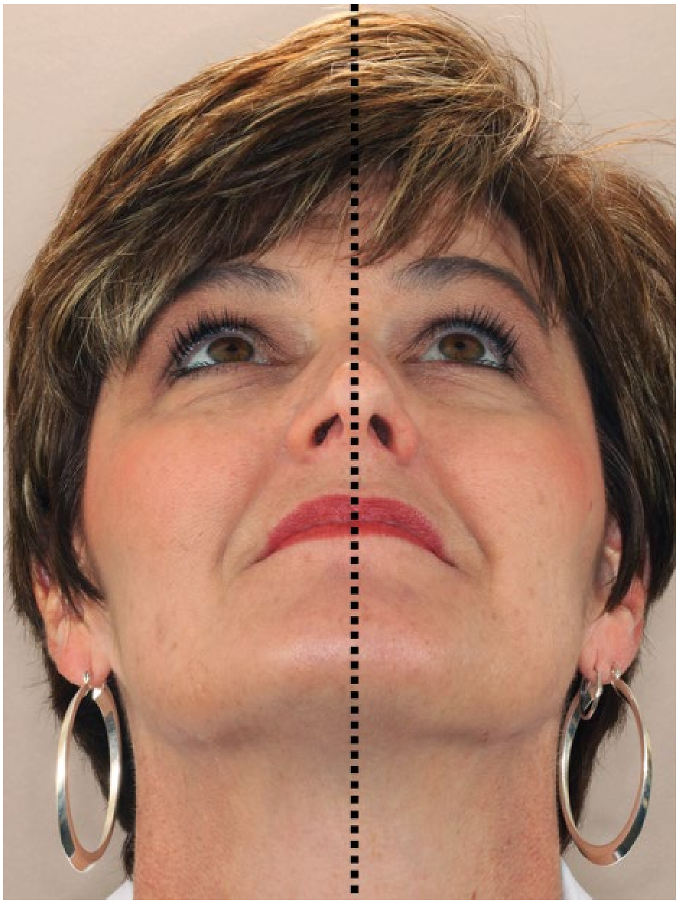

Figure 32.25 Having the patient elevate the head slightly to better visualize the nasal tip in relation to the midsagittal plane provides the best view to evaluate the position of the nasal tip.

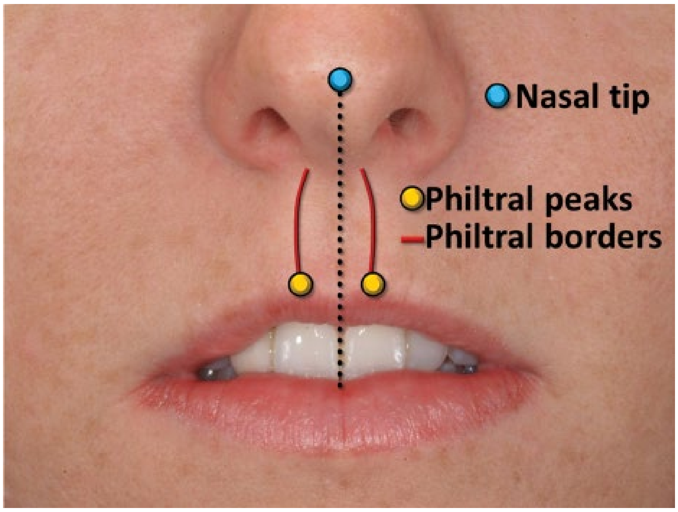

Figure 32.26 The maxillary dental midline is best visualized by its relation to the peaks of the upper vermilion border of the lips that correlate to the philtral columns.

congenitally missing lateral incisors. Conventional wisdom would dictate to orthodontically move the centrals together to close the diastema and create space for implants for prosthodontic restoration of the missing laterals. However, her macroesthetic evaluation (Figure 32.39B) demonstrated marked bidental protrusion with excessive lip projection in relation to the nose and chin. Our treatment plan reflected the global treatment approach of macro–mini–micro by removing lower first premolars for space to retract the lower incisors to reduce protrusion. The maxillary space was also closed posteriorly and the cuspids reshaped and lateralized (Figure 32.39C), thus eliminating the need for implants. The final profile (Figure 32.39D) had a significant improvement in lip protrusion and facial balance.

The labiomental angle (Figure 32.40) is defined as the fold of soft tissue between the lower lip and the chin and may vary greatly in form and depth. The clinical variables that can affect the labiomental fold include:

1. Lower incisor position, where upright lower incisors tend to result in a shallow labiomental angle because of lack of lower lip projection, whereas excessive lower incisor proclination deepens the labiomental fold.
2. Vertical height of the lower facial third, which has a direct bearing on chin position and the labiomental fold. Diminished lower facial height will usually result in a deeper labiomental fold (just as in the overclosed full denture patient), whereas a patient with a long lower facial third has a tendency toward a flat labiomental fold.
3. Mandibular deficiency with associated dental compensation may produce lower lip eversion, excessive vermilion display, and a pronounced labiomental sulcus because of the compensatory proclination and procumbency of the lower incisors.

The patient in Figure 32.41A had a severe Class II malocclusion with a deep bite and severe overjet; compare this with the final occlusion idealized (Figure 32.41B). His frontal facial pattern (Figure 32.41C) was characterized by a short lower facial with soft-tissue redundancy due to vertical overclosure, resulting in a deep labiomental sulcus. His profile (Figure 32.41D) reflected his severe mandibular deficiency with eversion of the lower lip because of his overjet and position of the maxillary incisors between his upper and lower lips. After surgical orthodontic treatment with mandibular advancement and facial lengthening, the vertical facial proportions were more appropriate (Figure 32.41E) and esthetic, and the labiomental sulcus improved as a result of the increased facial height and elimination of overjet. The final profile was also more balanced (Figure 32.41F).

Chin projection is determined by the amount of anteroposterior bony projection of the anterior, inferior border of the mandible, and the amount of soft tissue that overlays that bony projection. In the adolescent, the amount of chin is directly correlated to the amount of mandibular growth that occurs, because the chin point itself is borne on the mandible as it grows anteriorly.

Figure 32.27 **(A)** This patient had a facial asymmetry, but the clinical examination and quantification leads us to the correct diagnosis as to its etiology.

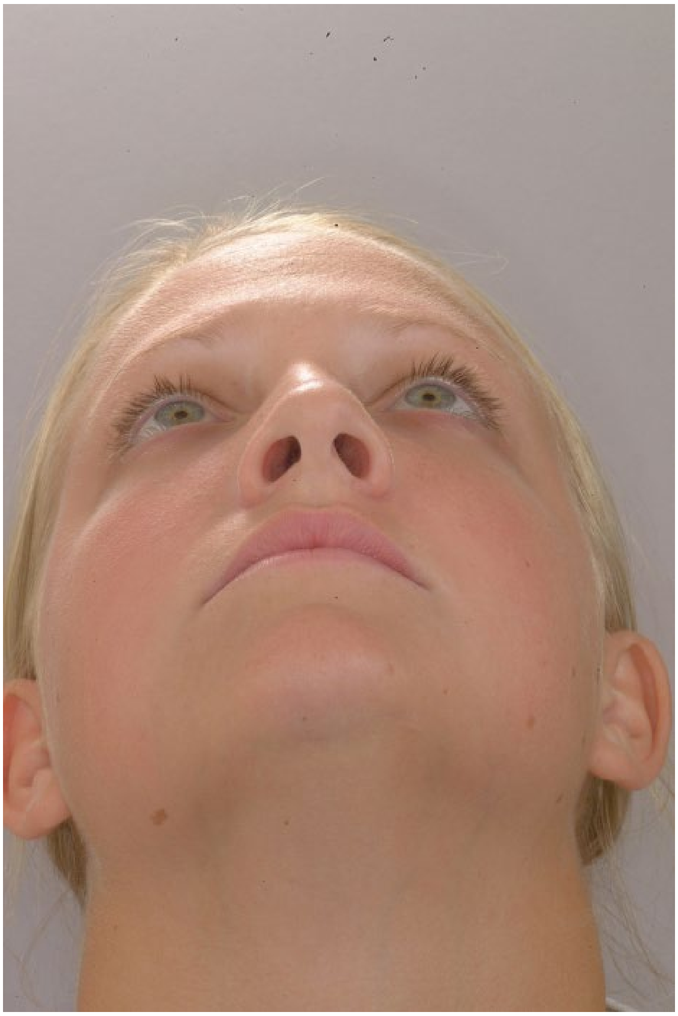

Figure 32.27 **(B)** The submental view demonstrates the nasal tip is to the left, but the midsymphysis is on to the midsagittal plane.

Figure 32.27 **(C)** This view demonstrates the lower dental midline slightly to the right of the midsymphysis.

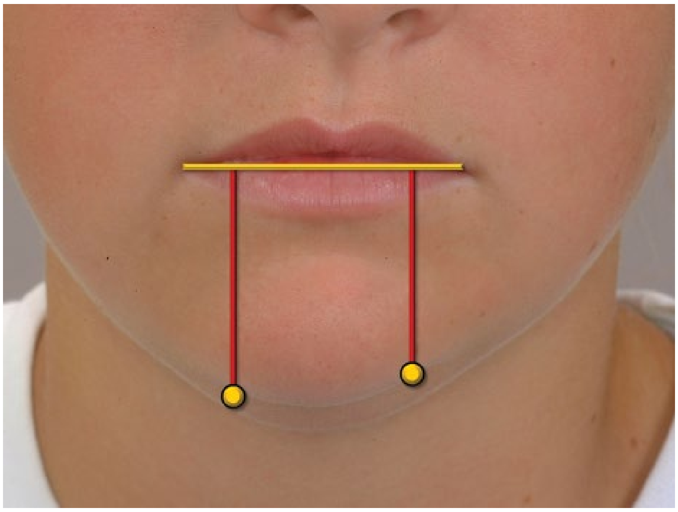

Figure 32.27 **(D)** More careful examination reveals the right parasymphysis was longer than the left, thus leading to the impression of facial asymmetry.

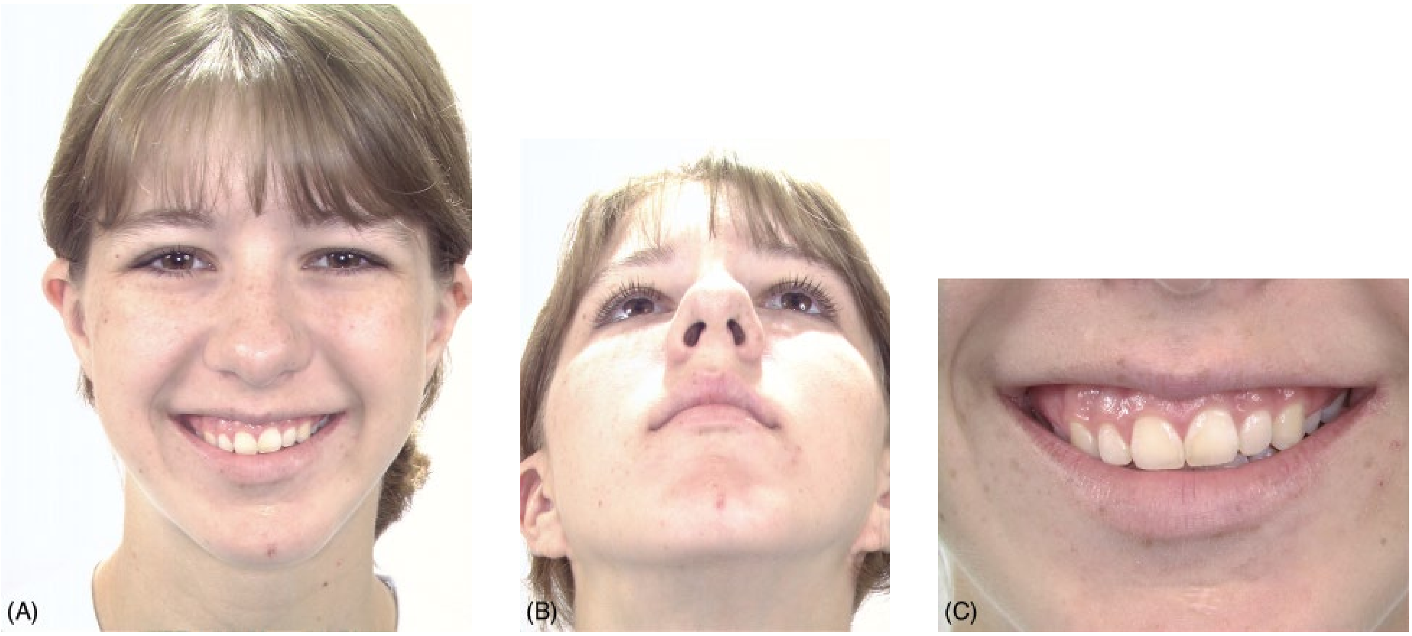

Figure 32.28 **(A)** This patient's smile had an undesirable transverse cant with the left side of the maxilla significantly lower than the right. **(B)** The submental view reflects the chin point (menton) placed to the left of the midsagittal plane, with the right mandible longer than the left. **(C)** The maxilla has compensated during growth for the mandibular asymmetry, resulting in the severe asymmetry of her smile.

Figure 32.28 **(D)** The final facial result after surgical leveling of the maxilla and mandibular surgery to correct the mandibular asymmetry.

Figure 32.28 **(E)** The close-up smile after surgical leveling of the maxilla reflected excellent smile symmetry.

The angle between the lower lip, chin, and R point (the deepest point along the chin–neck contour) should be approximately 90°. An obtuse angle often indicates (1) chin deficiency, (2) lower lip procumbency, (3) excessive submental fat, (4) retropositioned mandible, and (5) low hyoid bone position.

Another important measure in this area is the chin–neck length and chin–neck angle (Figure 32.42). The angle, also termed the cervicomental angle, has been studied extensively in plastic surgery and orthognathic literature. Studies report that a wide range of normal neck morphology exists, and that the cervicomental angle may vary between 105° and 120°, with gender being a major consideration. Age of the patient must be considered with regard to this area. Soft- tissue "sag" due to the loss of skin elasticity during aging is a major cause of change in the

Figure 32.29 This patient has a desirable definition of the chin–neck anatomy with the gonial angle well delineated and defined, and with a moderately acute angle.

Figure 32.30 This patient has a dolichofacial skeletal pattern with a steeper mandibular plane, which is not as esthetically pleasing as the previous illustration.

cervicomental region. Weight gain is another important factor in the morphology of this area, as is the anatomical position of the hyoid bone. The patient in Figure 32.43A was treated as an adolescent to a very nice Class I occlusion. Her frontal vertical facial proportions were a bit long in the lower face, with lip incompetence a result of the long lower face, and a short maxillary lip length. Because of her vertical maxillary excess and short philtrum, her smile was too gummy (Figure 32.43B). Her profile (Figure 32.43C) was very convex with a marked unattractive chin–neck length and obtuse cervicomental angle. The submental area was a result of (1) down and back rotation of the mandible because of the vertical maxillary excess, (2) mandibular deficiency, (3) lack of chin projection, (4) excessive submental fat deposition, and (5) an unfavorable platysmal muscle morphology.

Her treatment plan was designed to surgically superiorly reposition the maxilla to reduce the lower facial height and decrease the excessive gingival display on smile. V–-Y cheiloplasty and rhinoplasty were also performed simultaneously to improve the lip length and nasal esthetics. In addition, advancement of both the maxilla and mandible was planned to increase lower facial projection, thus improving the chin–neck length and cervicomental angle. Further enhancement included submental fat removal and platysmal lift (resection of the platysmal muscle to tighten the gonial and neck soft tissues). Her final smile (Figure 32.43D) was greatly improved, as was her profile (Figure 32.43E).

Macroesthetics and smile dimensions

Smile asymmetry may also be due to soft-tissue considerations, such as an asymmetric smile curtain. In the asymmetric smile curtain, there is a differential elevation of the upper lip during smile, which gives the illusion of transverse cant to the maxilla. This smile characteristic emphasizes the importance of direct clinical examination in treatment planning the smile, since this soft-tissue animation is not visible in a frontal radiograph or reflected in study models. It is not well documented in static photographic images, and is documented best in digital video clips.

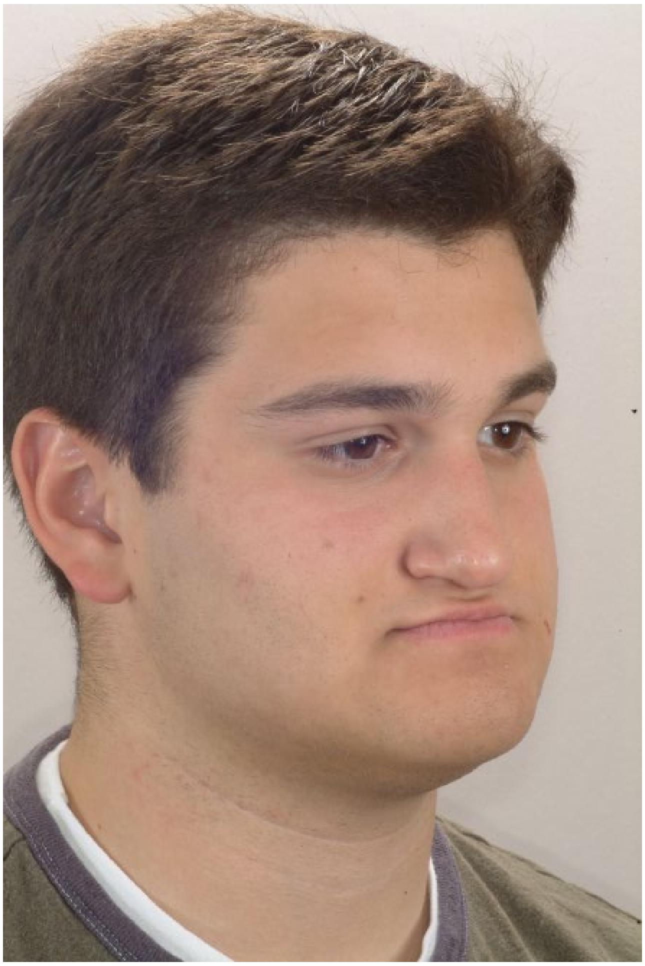

Figure 32.31 This person demonstrates a brachyfacial skeletal pattern with a very acute gonial angle and short lower face.

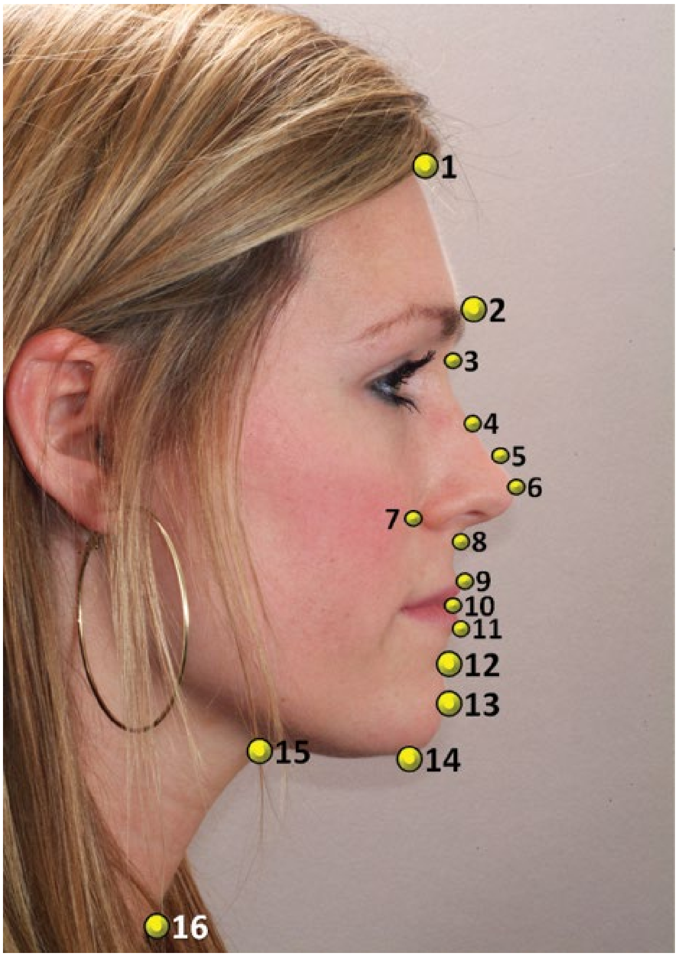

Figure 32.32 The landmarks used in describing the soft-tissue profile.

Table 32.2 Profile Soft-Tissue Points

Trichion	The hairline
Glabella	The most anterior aspect of the forehead as it progresses inferior into the nose
Radix (soft-tissue nasion)	The deepest point on the profile between glabella and the nasal dorsum
Mid dorsum	The midpoint of the nasal dorsum
Supratip break	The junction of the nasal dorsum and the nasal tip cartilage
Nasal tip	The most anterior point of the nose
Alar base	The most distal aspect of the ala at the base of the nose
Base of nose	The intersection of the nasal columella with the upper lip
Upper lip anterior limit	The most anterior point of the upper lip
Lip junction	The intersection of the upper and lower lips
Lower lip anterior limit	The most anterior point of the lower lip
Labiomental sulcus	The deepest curvature of the lower lip
Chin point	The most anterior point of the chin
Menton	The most inferior point on the base of the chin
Reflex point	The deepest point on the curvature of the neck
Base of neck	The intersection of the neck and the sternal complex

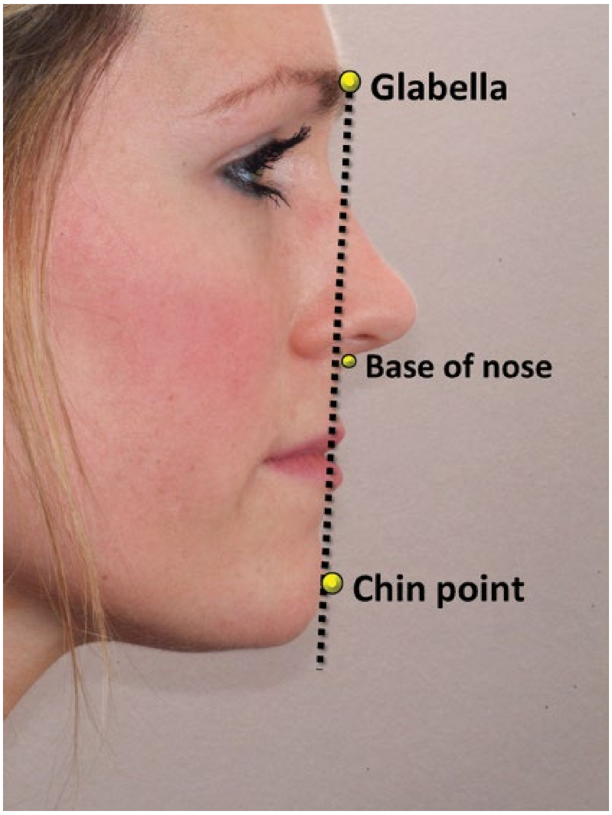

Figure 32.33 The anterior facial plane is formed from lines connecting the glabella to the base of the nose (subnasale) and the chin point.

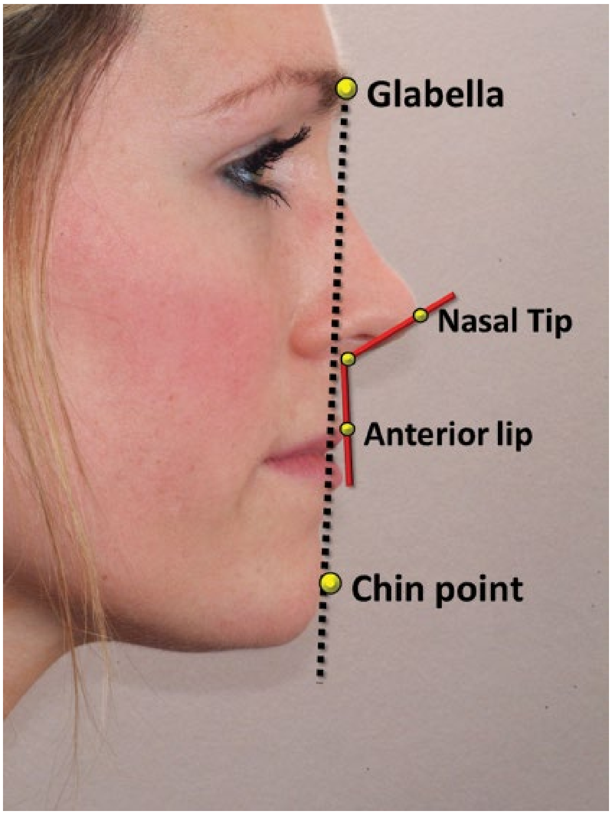

Figure 32.34 The nasolabial angle describes the inclination of the columella in relation to the upper lip. The ideal nasolabial angle should be in the range of 85–105°.

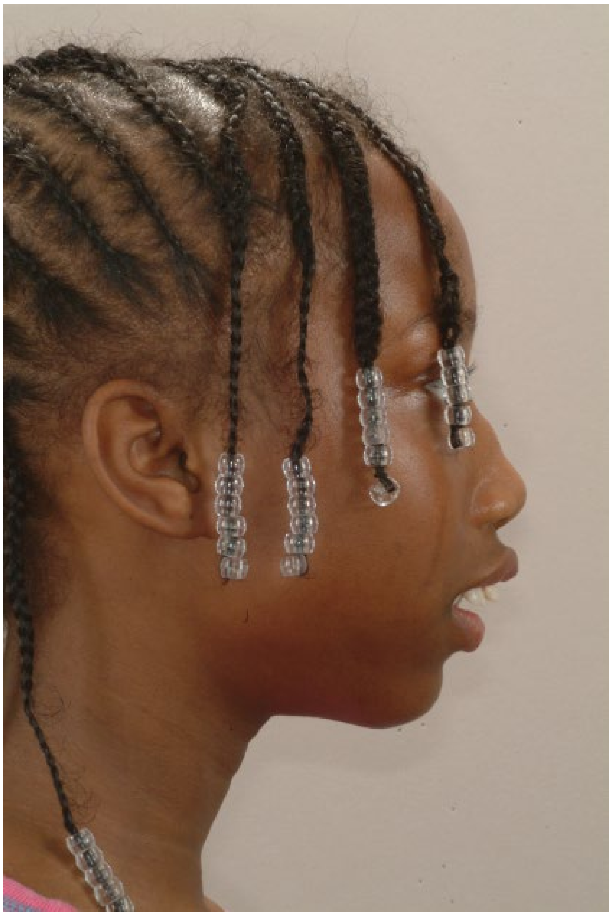

Figure 32.35 **(A)** This young patient had a severe maxillary and dental protrusion with a very acute nasolabial angle.

Figure 32.35 **(B)** After removal of maxillary first premolars, orthodontic treatment retracted the maxillary anterior teeth, resulting in a more favorable nasolabial angle.

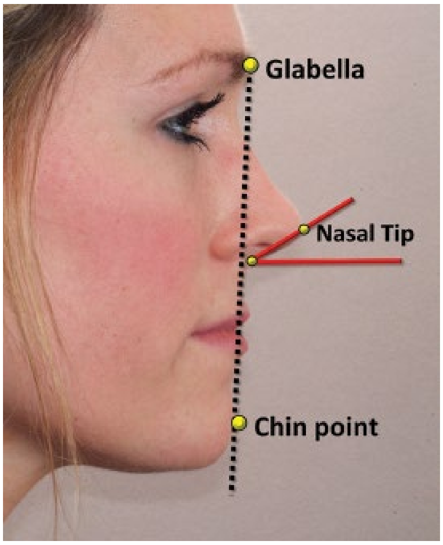

Figure 32.36 Nasal tip elevation reflects the position of the nasal tip relative to a perpendicular to the line from the glabella to the chin point at the base of the nose.

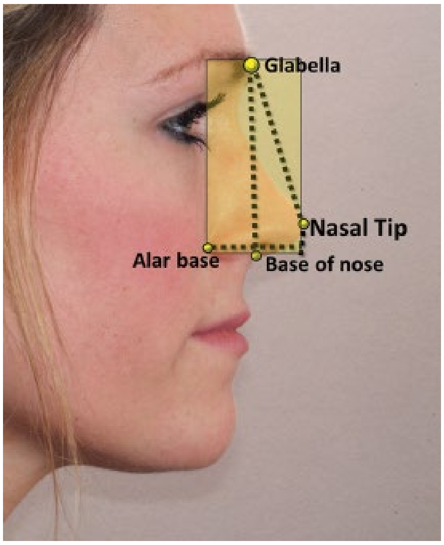

Figure 32.37 Nasal projection is a description of the nose in height from glabella to the base of the nose (subnasale) and length by nasal tip to the alar base.

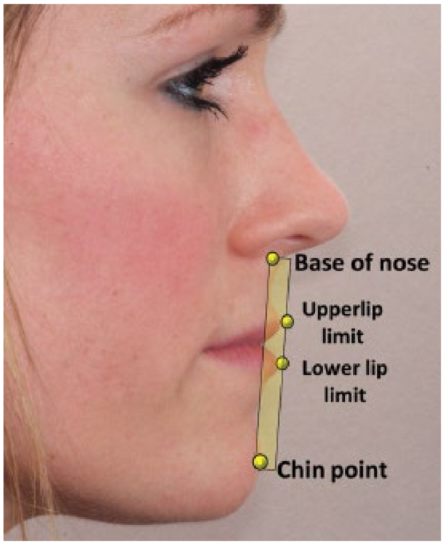

Figure 32.38 Lip projection is a function of maxillomandibular protrusion or retrusion, dental protrusion or retrusion, and/or lip thickness and can be measured from the base of the nose and the chin point to establish its position in relation to those structures.

Figure 32.39 **(A)** A young girl was congenitally missing both maxillary lateral incisors with a very large maxillary diastema. A normal option to consider would be to close the diastema and place implants and crowns for restoration.

Transverse cant of the maxilla can be due to (1) differential eruption and placement of the anterior teeth and (2) skeletal asymmetry of the skull base and/or mandible resulting in a compensatory cant to the maxilla. Intraoral images or even mounted dental casts do not adequately reflect the relationship of the maxilla to the smile. Only frontal smile visualization permits the orthodontist to visualize any tooth-related asymmetry transversely.

The smile arc is defined as the relationship of the curvature of the incisal edges of the maxillary incisors, canines, premolars, and molars to the curvature of the lower lip in the posed social smile.[19, 20] Figure 32.44 demonstrates that the ideal smile arc has the maxillary incisal edge curvature parallel to the curvature of the lower lip upon smile. We have expanded that definition to

Figure 32.39 **(B)** She had marked lip projection secondary to her severe bidental protrusion.

Figure 32.39 **(C)** We elected to extract lower first premolars to make space for protrusion reduction and close all the maxillary space.

include the occlusal plane as being parallel to the curvature of the lower lip upon smile, and the term consonant is used to describe this parallel relationship. A nonconsonant or flat smile arc is characterized by the maxillary incisal curvature being flatter than the curvature of the lower lip on smile. In spite of the professional interest only being a recent phenomenon, recent

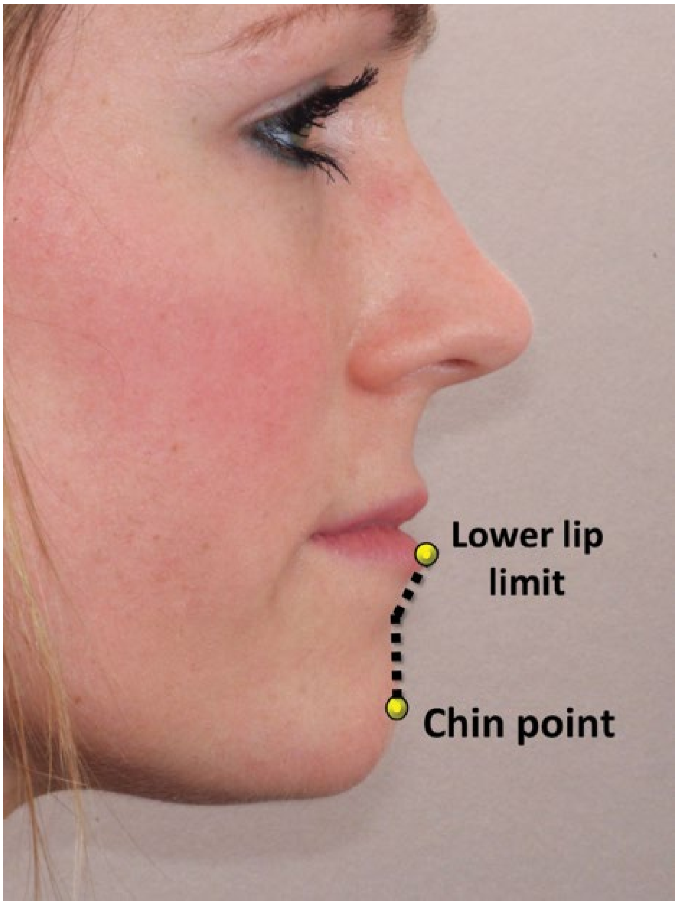

Figure 32.40 The labiomental angle is defined as the fold of soft tissue between the lower lip and the chin and may vary greatly in form and depth.

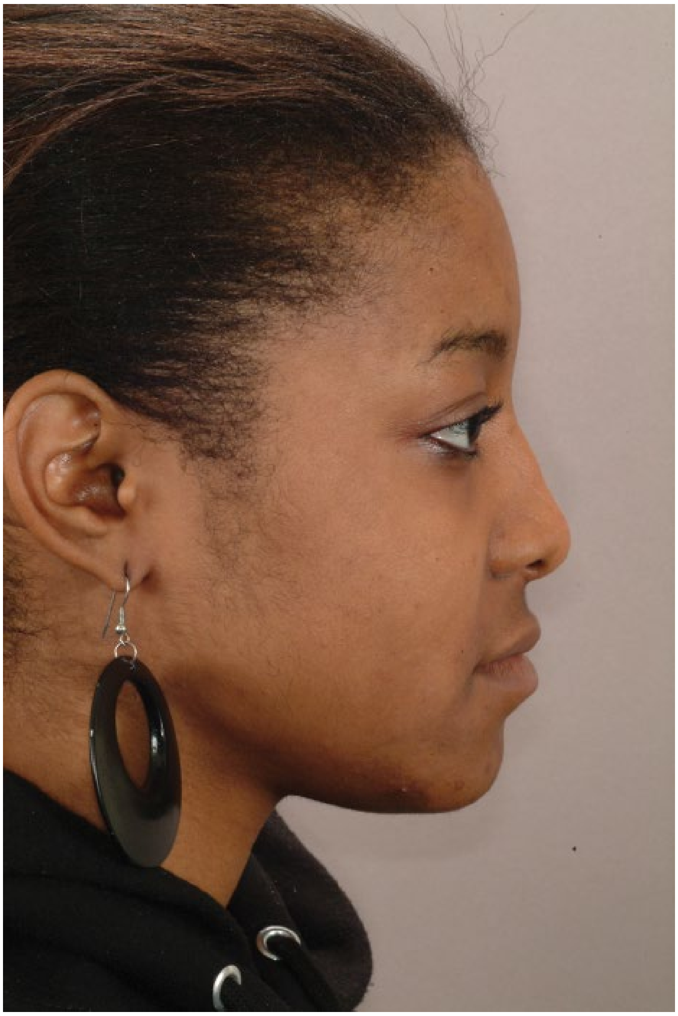

Figure 32.39 **(D)** The final profile was greatly improved, with the need for implants eliminated.

studies reveal that laypeople assess the smile arc as the most important feature in an ideal smile.[21] Early definitions of the smile arc were limited to the curvature of the canines and the incisors to the lower lip on smile because smile evaluation was made on the direct frontal view. But we prefer the oblique view since it reflects other issues that may affect the smile arc, like tilt of the occlusal plane, supereruption of maxillary incisors, and so on.

Pitch, roll, and yaw

Our analysis up to this point has focused on three of the six attributes needed to describe the position of the dentition in the face and the orientation of the head. Simple Class I, II, and III classifications do not adequately reflect the complexities of the craniofacial complex since the concept came from Angle over 100 years ago as the first classification system regarding tooth occlusion. A more complete description is necessary to describe the position of an airplane in space: translation (forward/backward, up/down, right/left), which must be combined with rotation about three perpendicular axes (yaw, pitch, and roll) and is analogous to our effort to describe the orientation of the

Figure 32.41 **(A)** This patient had a severe Class II malocclusion with a deep bite and severe overjet.

Figure 32.41 **(B)** The finished intraoral shows ideal overbite/overjet.

Figure 32.41 **(C)** His facial pattern had a short lower facial with soft-tissue redundancy.

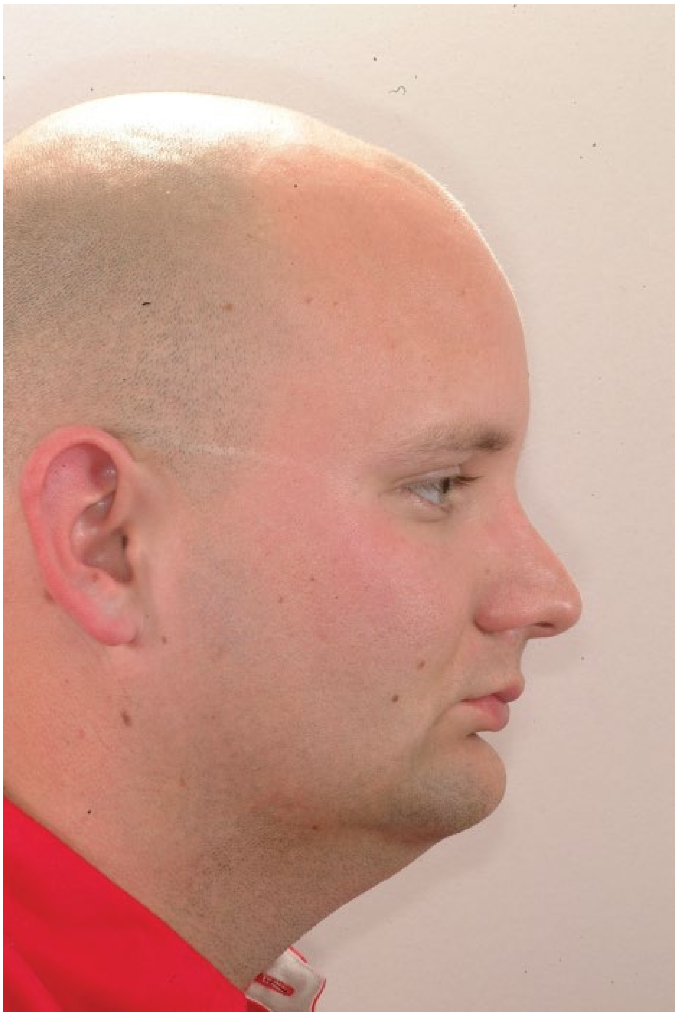

Figure 32.41 **(D)** His profile was mandibular deficient with lower lip eversion resulting in a deep labiomental sulcus.

Figure 32.41 **(E)** After orthodontic preparation, the malocclusion was corrected with mandibular advancement, increasing the lower facial height and correcting the overjet.

Figure 32.41 **(F)** The final profile with a more balanced profile and facial proportions.

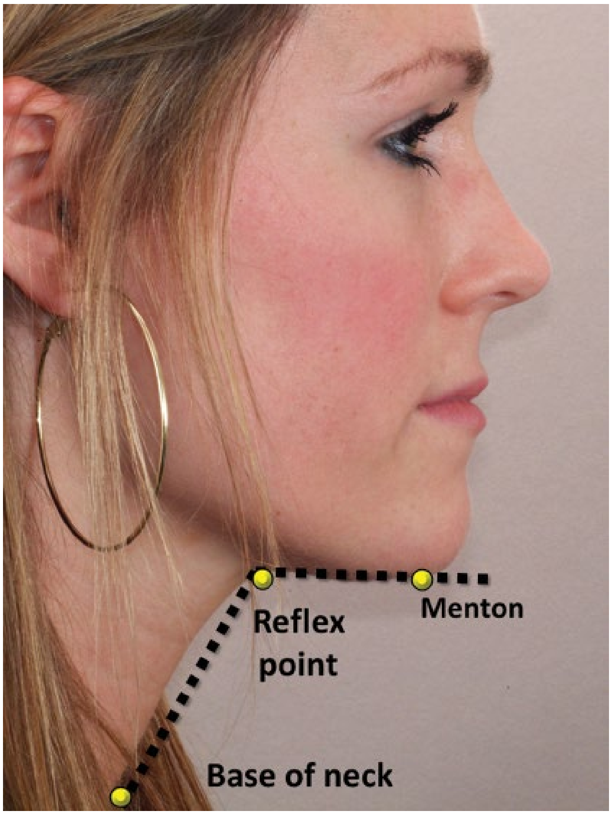

Figure 32.42 The chin–neck length and chin–neck angle are important esthetic features often not included in the esthetic assessment of a patient's dentofacial evaluation. Chin–neck length is from the reflex point to the chin point, and cervicomental angle is measured from the chin point to the reflex point to the base of the neck.

Figure 32.43 **(A)** This patient was treated as an adolescent to a very nice Class I occlusion. Her frontal vertical facial proportions were long in the lower face, with lip incompetence a result of the long lower face and a short maxillary lip length. **(B)** Because of the vertical maxillary excess and short philtrum, she exhibited excessive gingival display on smile. **(C)** Her profile was very convex, with a markedly unattractive chin–neck length and obtuse cervicomental angle.

Figure 32.43 **(D)** After orthodontic surgical treatment with maxillary impaction and V–Y cheiloplasty, the facial proportions and smile were greatly enhanced.

Figure 32.43 **(E)** The profile improvement was a result of bimaxillary advancement, chin advancement, submental fat removal, and platysmal lift.

Figure 32.44 The ideal smile arc is defined as where the maxillary incisal edge curvature and occlusal plane are parallel to the curvature of the lower lip upon smile.

dental and skeletal relationships. The introduction of the rotational axes in the description of dentofacial deformities adds precision of the description and, consequently, facilitates development of the problem list (Figure 32.45).[22]

Clinical case study

A 19-year-old patient was referred by her general dentist for improvement in the appearance of her smile. She had a combination of esthetic and functional issues that required an interdisciplinary combination of orthodontics, orthognathic surgery, and plastic surgery.

Macroesthetic analysis

At rest she had the following attributes (Figure 32.46):

- a short lower facial third relative to facial width;
- a wide alar width relative to the intercanthal distance;
- slightly downturned and deep commissures;
- diminished lip support and vermillion display.

Our patient's facial proportions were characterized by a short lower face (often associated with vertical maxillary deficiency) with inadequate lip support for a 19-year-old. She was referred by her dentist for evaluation of her smile esthetic presentation (Figure 32.47) with spacing present and lack of tooth display on smile. The profile (Figure 32.48) provided an important clue: it was concave with a Class III appearance. Her profile was concave with an acute nasolabial angle, and her chin point is anterior of the forehead and base of the nose. The upper lip is also behind the lower lip. Her chin–neck length is adequate, but chin–neck angle slightly obtuse, particularly for a 19-year-old female.

Proclined or flared-appearing incisors can be either dental or skeletal in origin, which makes the correct diagnosis and appropriate treatment even more challenging. How do we make the determination as to the underlying etiology of the incisor proclination? We have previously described a more complete method

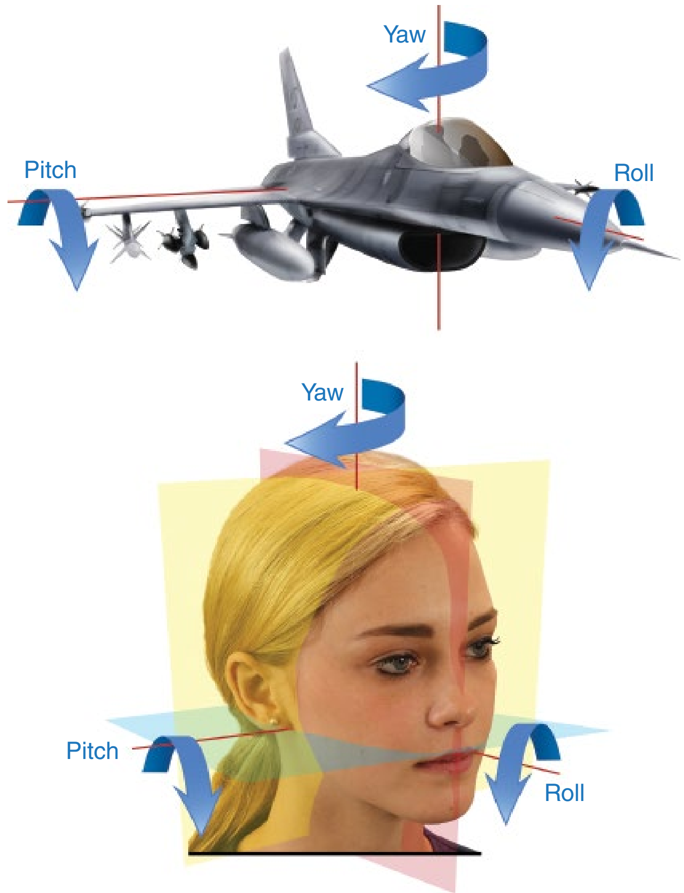

Figure 32.45 Simple Class I, II, and III classifications simply do not adequately reflect the complexities of the craniofacial complex. The introduction of the three rotational axes (pitch, roil, and yaw) in the description of dentofacial deformities adds precision of the description and, consequently, facilitates development of the problem list. This schematic demonstrates the visualization of the face and skeleton in terms of pitch, roll, and yaw. *Source*: Ackerman JL et al.[22]

of craniofacial morphology by describing the concepts of pitch, roll, and yaw to define the facial skeletal pattern. The macroesthetic evaluation is important to leading us to the correct diagnosis.

The Angle classification was inadequate since it describes only the anteroposterior position of the teeth and was never intended to define jaw relationships. In this case, using the Angle classification, we tend to think in terms of the mandible being too large or the maxilla too small. Therefore, our plan most likely would involve movement of the maxilla forward or the mandible back. The concept of pitch, roll, and yaw was intended to emphasize this deficiency in descriptive potential. While her midface was deficient relative to the mandible, the overall skeletal pattern really represented a counterclockwise pitch of the lower face. This is best visualized on the oblique view (Figure 32.49). By facilitating our visual evaluation of the spatial orientation of the maxillary and palatal occlusal planes on smile (Figure 32.50), the oblique view is important in distinguishing the skeletal incisor flare problem from the dental one.

As part of the macroesthetic analysis, the smile was evaluated in the context of its fit and proportion with the overall facial

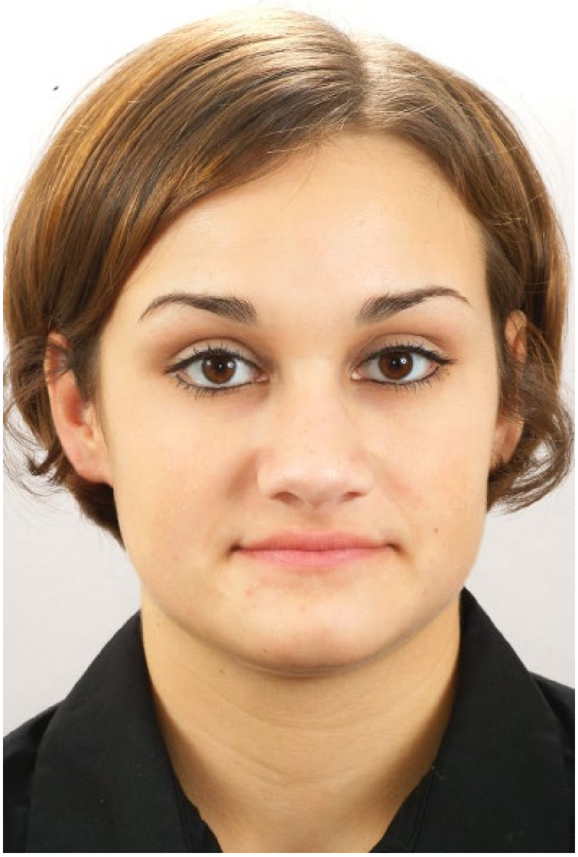

Figure 32.46 This 19-year-old patient had concerns about her overall appearance.

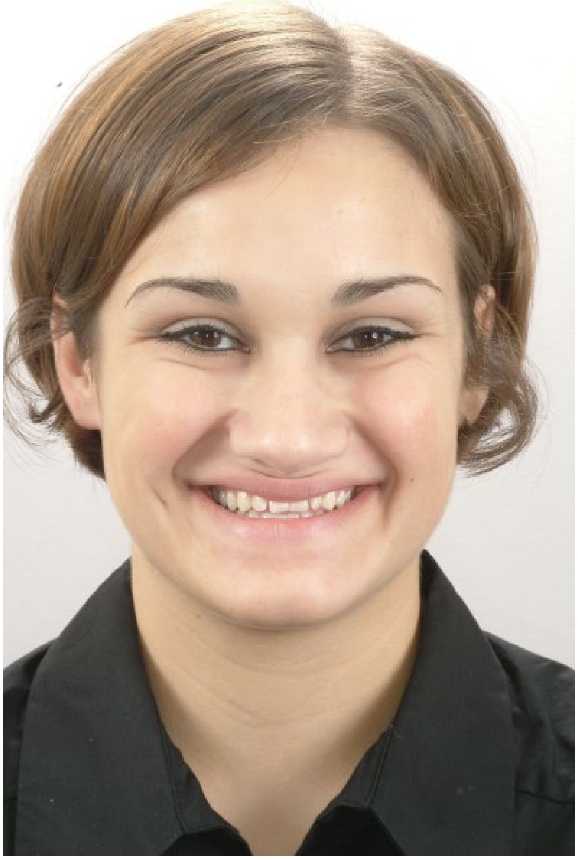

Figure 32.47 Referred by her dentist for smile evaluation, spacing was noted in addition to a lack of tooth display on smile.

Figure 32.48 The profile was concave, and, in terms of the Angle classification, we tend to call it a "Class III" profile. The Angle classification is a dental system of classification and was never intended to describe skeletal relations.

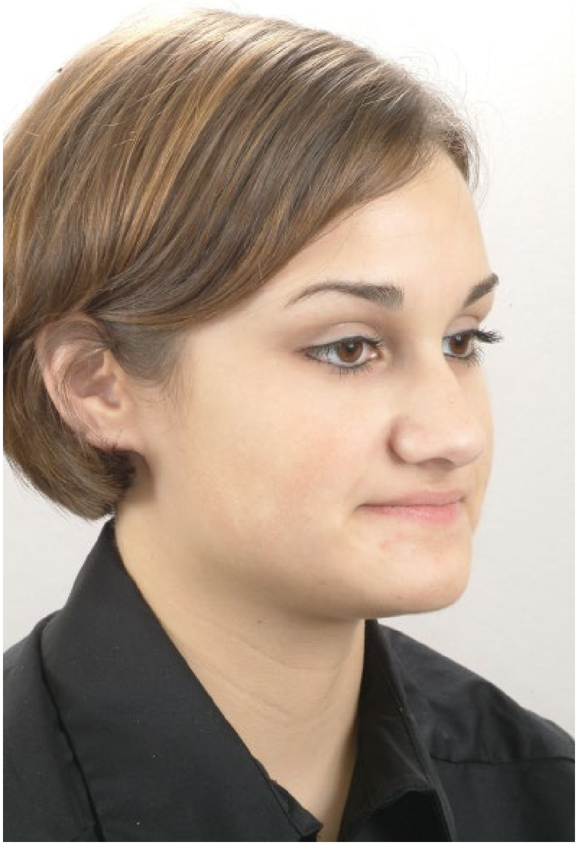

Figure 32.49 Midfacial characteristics such as inadequate lip support are best visualized on the oblique facial view.

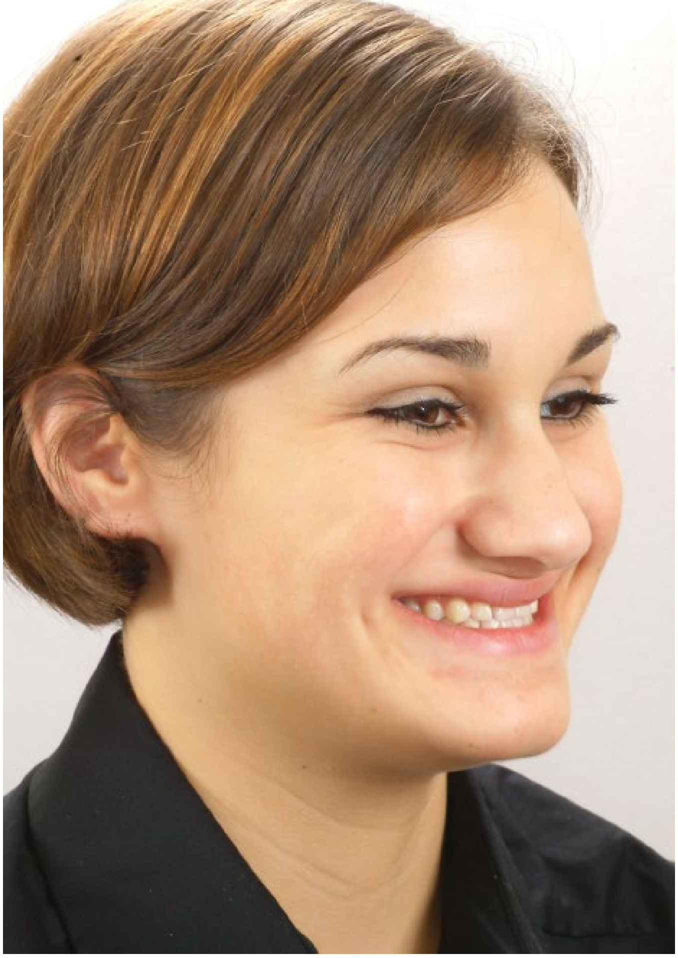

Figure 32.50 The patient's oblique smile image shows the maxillary occlusal plane is flatter than the mandibular plane, a view we can realize without cephalometric radiography.

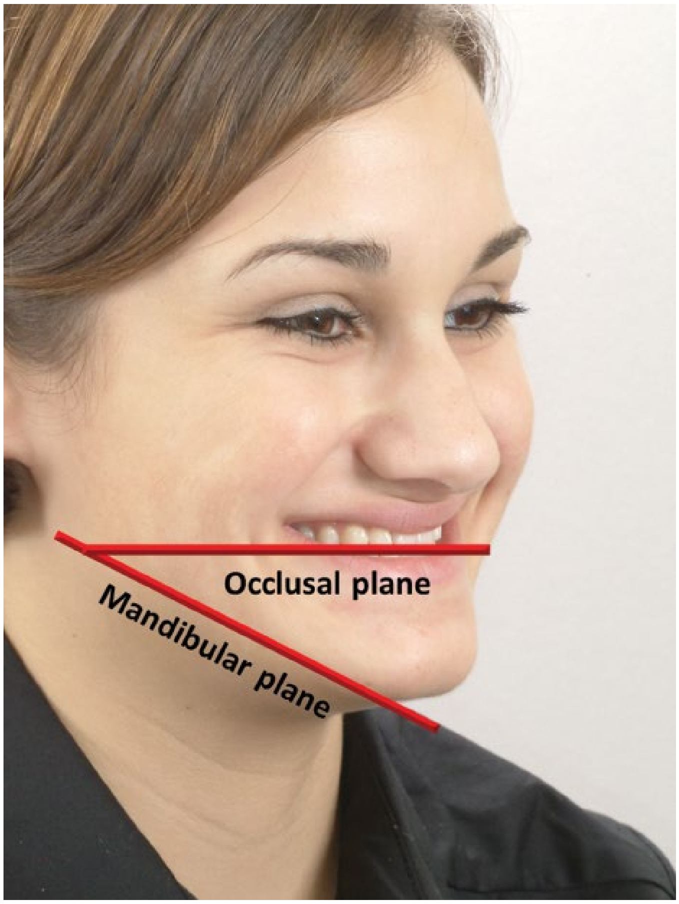

Figure 32.51 The oblique smile picture gives us a good recognition of her interocclusal relationships, and also the "pitch" of her maxillary occlusal plane relative to the Frankfort and mandibular planes.

dimension. On smiling, the patient did not show all of her upper teeth. (Her smile characteristics will be discussed in more depth in the miniesthetic assessment.) In evaluation of her oblique resting relationship, the lack of lip support is even more evident, as is the midfacial characteristics of a low nasal tip, nasal projection, and lack of nasal definition. In Figure 32.51, her oblique smile picture gives us a good recognition of her interocclusal relationships and also the "pitch" of her maxillary occlusal plane relative to the Frankfort and mandibular planes. Her smile retracts the lips, and retracts the nasal tip, accentuating the facial flatness. Her occlusal plane has a counterclockwise pitch to ideal. In other words, the occlusal plane and palatal plane are flatter than the mandibular plane compared with the more ideal example in Figure 32.52.

Miniesthetic analysis

The frontal close-up smile (Figure 32.53) revealed many quantitative and measurable aspects of her smile. On clinical examination, we measured zero incisor display at rest, 5 mm of maxillary incisor display on smile, and her maxillary incisor crown height was 10 mm. These measurements virtually lead us to our orthognathic surgical plan in order to achieve ideal incisor display. If the amount of incisor display on smile is 5 mm and crown height is 10 mm, then the anterior downgraft of the maxilla would equal 5 mm to expose the entire upper incisor on smile.

As a result of the vertical and rotational skeletal pattern, her anterior tooth display on smile was only 4 mm, with the crown height measured at 10 mm. Her smile arc was also nonconsonant, or flat.[5–9] The oblique smile images (Figure 32.54) reflect the flare of the maxillary incisors as a result of the counterclockwise positioning of the maxillary occlusal and palatal planes.

Microesthetic analysis (teeth)

The shape of the maxillary incisors and gingival contour were within normal limits.

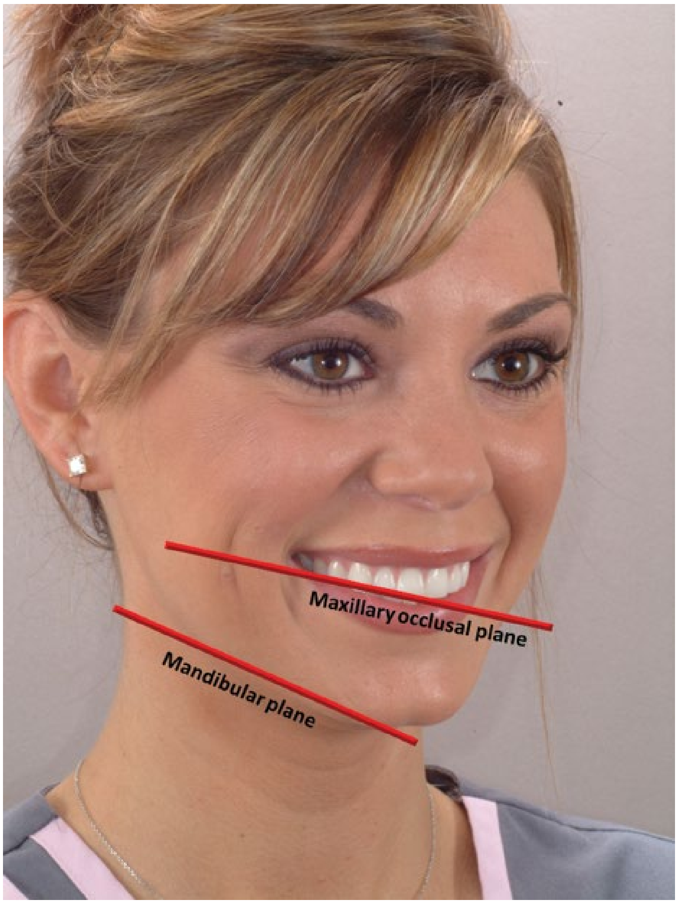

Figure 32.52 In a patient with ideal facial and smile esthetics, the maxillary occlusal plane and mandibular plane are more divergent and closer to ideal.

Figure 32.53 Anterior tooth display on smile was only 4 mm, central incisor crown height 10 mm, and a flat or nonconsonant smile arc.

Figure 32.54 The oblique smile image reflects the flare of the maxillary incisors as a result of the counterclockwise positioning of the maxillary occlusal and palatal planes.

Orthodontic–surgical treatment

Our treatment started with orthodontic preparation for a surgical plan of maxillomandibular occlusal plane rotation in a clockwise direction.[10–12] The surgery was planned with the synergistic concepts of macro- and miniesthetics in mind. So the surgical phase of treatment will be presented in a stepwise fashion to illustrate the cause and effect aspect of the quantification of our clinical examination and resulting plan. The surgical treatment plan consisted of both orthognathic and soft-tissue surgery (Figure 32.55).

The maxillary osteotomy

The surgical plan starts with the ideal vertical and anteroposterior placement of the maxillary incisors. This concept is certainly not different from contemporary esthetic dental planning, in which placement of the maxillary incisor is of paramount importance. A Le Fort I osteotomy of the maxilla was performed with anterior downgraft, thus changing the pitch of the maxilla. The amount of anterior downgraft was determined as follows:

- only 5 mm of maxillary incisor was displayed on smile;
- the incisor crown height was 10 mm;
- therefore, the anterior maxilla was downgrafted 5 mm to attain full incisor display on smile.

The maxillary downgraft of the anterior maxilla was planned to increase the amount of incisor display on smile. Downgraft of the anterior maxilla would additionally steepen the occlusal and palatal planes, which would offer a better match of the curvature of the maxillary dental arch to the curvature of the lower lip on smile (improving the consonance of the smile arc). The anterior maxillary vertically lengthening would also result in a compensatory downward movement of the mandible, which would increase the lower facial height, thus improving the facial proportions.

Because of the diminished lip support, maxillary advancement was also planned. And since the occlusal plane was to be changed, mandibular surgery through bilateral sagittal split osteotomy was also required.[23] Advancement of the mandible was planned:

1. To keep the posterior occlusion in contact. As the anterior maxilla moves inferiorly, the mandible must rotate opened, with loss of occlusal contact in the posterior. The mandibular ramus osteotomy allowed the body of the mandible to rotate concomitantly with positioning of the maxilla.
2. To advance the mandible in addition to the maxillary advancement. This would increase lip support, preventing rotation of the chin point posteriorly, resulting in a more obtuse chin neck angle and shorter chin neck length.

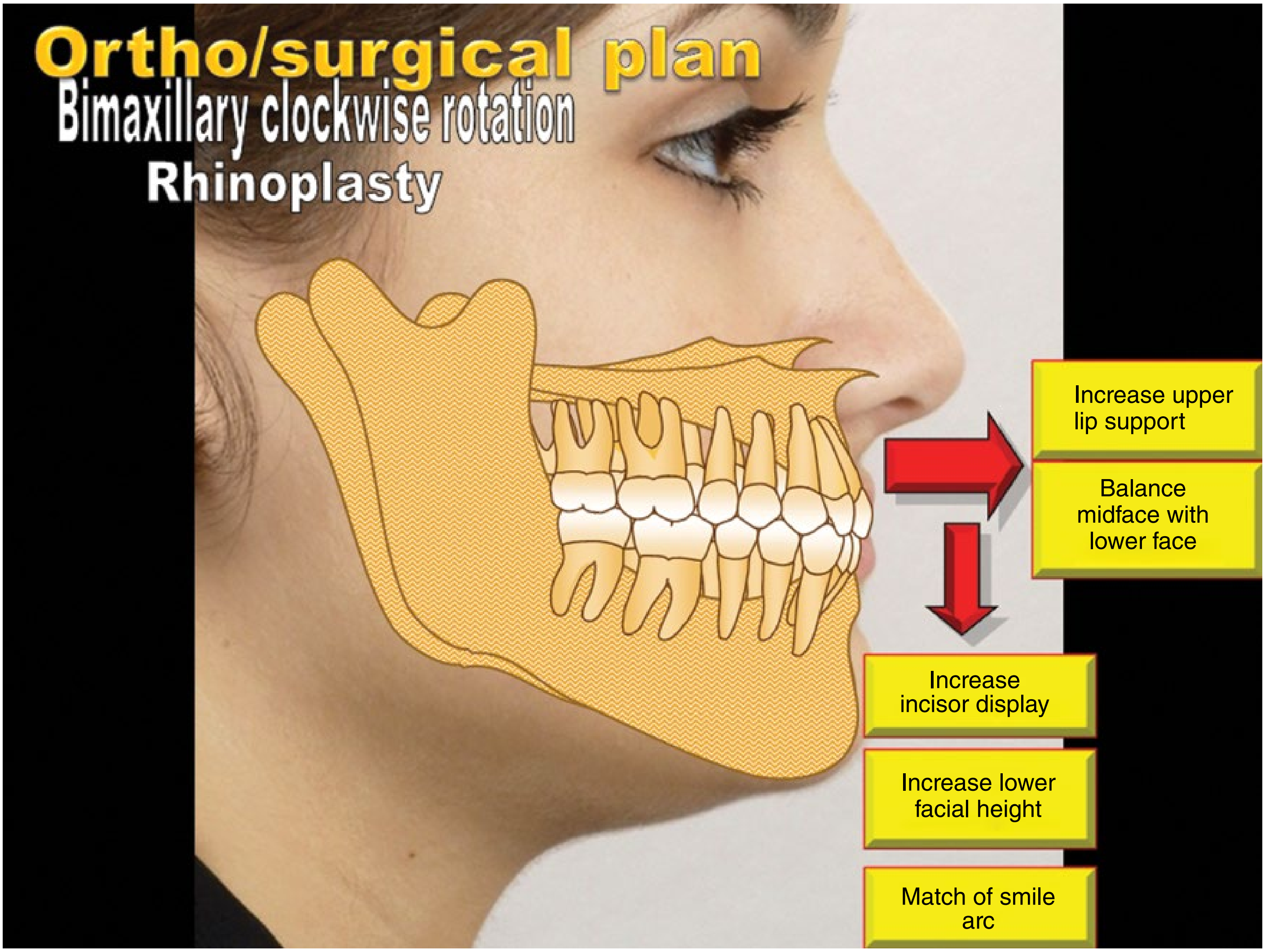

Figure 32.55 The overall treatment plan consisted of maxillary advancement with anterior downgraft to increase facial height, lip support, incisor display on smile, and to tip the occlusal plane to improve the smile arc. The mandibular osteotomy rotated the mandible clockwise in response to the new maxillary position.

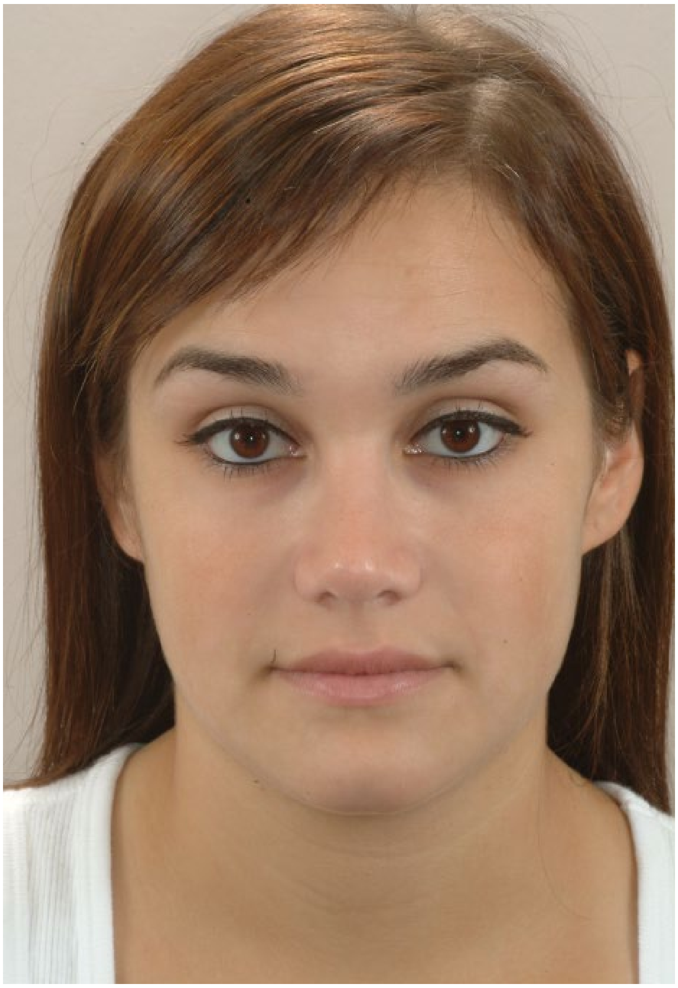

Figure 32.56 The final frontal facial appearance was much more youthful and appealing, and the facial dimensions were more appropriate and the advancement of both jaws greatly enhanced resting lip support.

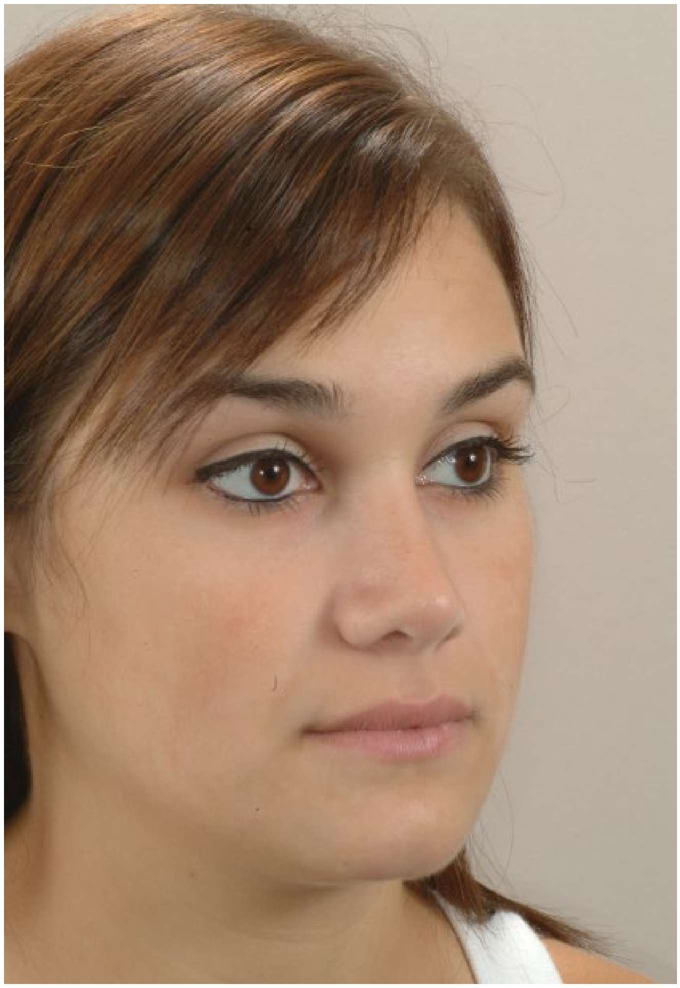

Figure 32.57 The oblique image demonstrates the esthetic refinement and enhancement of the nose and midface with maxillary advancement and rhinoplasty.

Rhinoplasty

The expected changes of the nose as a result of the maxillary surgery were an increase in tip projection, deepening of the supra-tip depression, tip rotation, and alar base widening. Thus, in consultation with the plastic surgeon, a simultaneous rhinoplasty was planned[24] to counter these effects and a V–Y cheiloplasty to increase her lip length.

The rhinoplasty was performed simultaneously with the osteotomies.[13–23] The purpose of the rhinoplasty was twofold:

- Because her nose was already wide and maxillary advancement would cause further widening of the nasal base, the rhinoplasty was indicated so the esthetics of the midface were not compromised by the orthognathic surgery.
- Rhinoplasty was indicated to improve the overall esthetics of her face.

Since the greatest risk for the patient undergoing jaw surgery is the anesthesia, performing the rhinoplasty at the same time did not present any increased risk. Our philosophy is to maximize the risk/benefit ratio of every procedure. Consequently, there was no increased risk, but a greatly increased benefit to the patient's overall appearance in performing rhinoplasty.

Final results

The final facial appearance was much more youthful and appealing and the facial dimensions were more appropriate (Figure 32.56). There is significant improvement in all three components of her esthetic appearance with the increase in lower facial and dramatic increase in vermillion display and lip display. The oblique image (Figure 32.57) demonstrates the esthetic refinement and enhancement of the nose and midface with maxillary advancement and rhinoplasty. The rhinoplasty was successful in narrowing the base of the nose, as well as the refinement of the dorsum and tip, giving her a continuation of the brow into the dorsum and tip. The advancement of both jaws greatly enhanced resting lip support, and anterior downgraft of the maxilla resulted in full incisor display on smile Figure 32.58). The smile arc was enhanced by tipping the curvature of the anterior sweep of the maxillary teeth to better match the curvature of the lower lip (Figure 32.59). The final

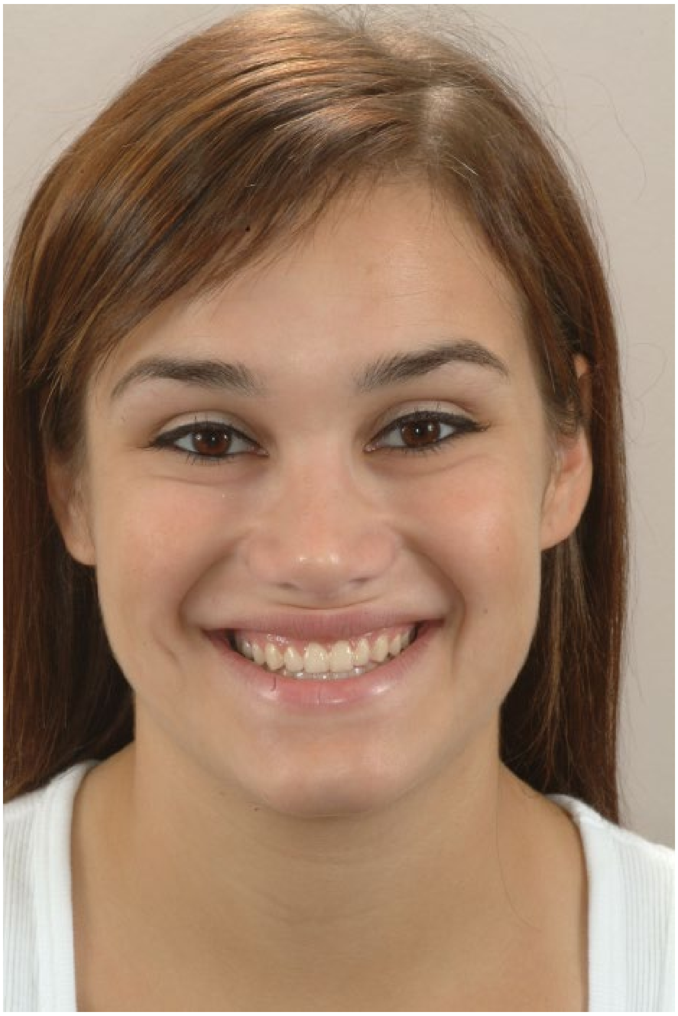

Figure 32.58 The advancement of both jaws greatly enhanced resting lip support, and anterior downgraft of the maxilla resulted in full incisor display on smile.

Figure 32.60 The final profile was much more esthetic, with anteroposterior balance of the maxilla and mandible along with improved facial proportions.

Figure 32.59 The smile arc was enhanced by tipping the curvature of the anterior sweep of the maxillary teeth to better match the curvature of the lower lip.

Figure 32.61 The final occlusal photographs reflected an excellent occlusal outcome.

profile was much more esthetic, with anteroposterior balance of the maxilla and mandible along with improved facial proportions (Figure 32.60). The final occlusal photograph is shown in Figure 32.61. The frontal smile underwent remarkable changes that occur with increase in incisor display. The overall results were much more youthful in appearance, which is of paramount importance in facial rejuvenation.

Acknowledgements

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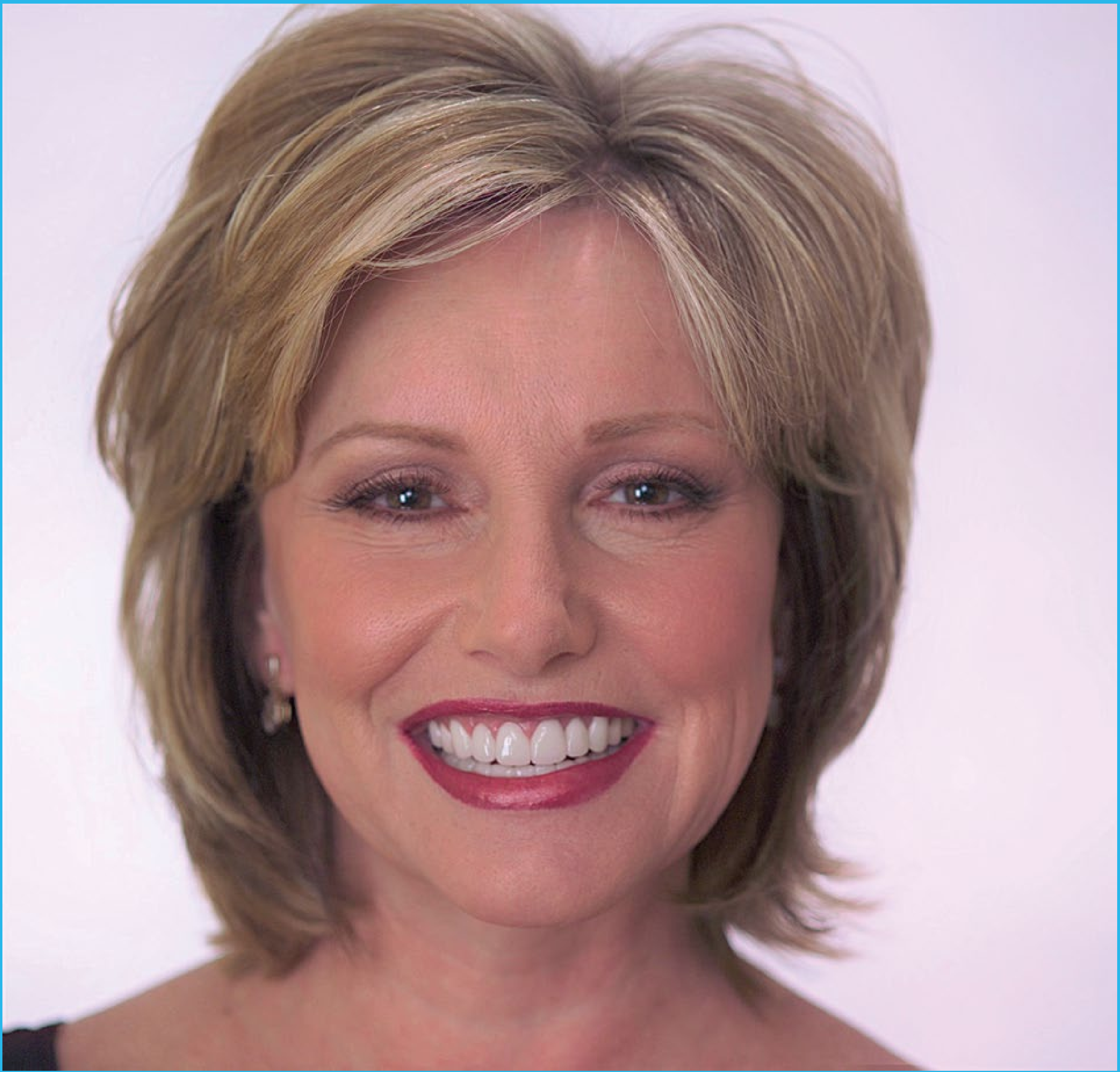
Additional resources

Sarver DM, Ackerman MB. Dynamic smile visualization and quantification: Part I. Evolution of the concept and dynamic records for smile capture. *Am J Dentofac Orthop* 2003;124;4–12.



Chapter 33 Facial Considerations in Esthetic Restorations

Ronald E. Goldstein, DDS and Bruno P. Silva, DMD, PhD

Chapter Outline

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Esthetics and beauty have been studied and discussed for thousands of years. Although in years past it may have been taboo to even speak about the possibility that your patient may eventually want or need facial plastic surgery, such is not the case today. In fact, if your patient's are in need of orthodontic therapy to improve their appearance or if they need you to rebuild the smile to reduce the appearance of aging, let them know the advantage, and sometimes necessity, of having the dental treatment completed before any other facial surgery is planned.

The concept of esthetics is defined as "the philosophical discipline that studies beauty and art." It is a very broad concept, subjective and ambiguous. Hegel stated: "Beauty as the essence of imagination and perception cannot be an exact science."[1] Modern dentistry cannot be based merely on subjective concepts; predictable results are required instead. Multiple studies have tried to determine the objective and esthetic criteria that are associated with a beautiful and attractive smile.

Ronald E. Goldstein's Esthetics in Dentistry, Third Edition. Edited by Ronald E. Goldstein, Stephen J. Chu, Ernesto A. Lee, and Christian F.J. Stappert.

The sum total of this phenomenon is that esthetic dentistry must adopt a new paradigm for the concept of treatment planning for a patient. The science is so dramatic and the outcomes are so revolutionary that the traditional concepts of treatment planning for a patient who wants to look forever young are obsolete. The art and science of esthetic dentistry is becoming central to building the foundation on which all other treatment modalities must emerge to satisfy the ever increasing desire of agelessness.

Visual perception is just as important for the esthetic evaluation as the visual examination is for the clinical examination.[1,2] Therefore, understanding the processes that are involved in the perception of beauty will help clinicians in the esthetic diagnosis process. The perception process involves the organization and integration of sensorial data by the intellect. A response is triggered in the intellect based on previous experiences or dogmas, which are interpreted subconsciously. The area of the brain responsible for perception is not located in the cognitive region. Rather, it is located in the subconscious or primitive side, called the limbic system, where instincts are believed to reside. This limbic system most strongly perceives the visual cues of balance, symmetry, and proportion, and therefore defines beauty objectively[3] (Figure 33.1).

While artists need inspiration, clinicians cannot seat the patient in the dental chair and wait for inspiration to appear. Dental professionals need scientific methods, diagnosis, and protocols.[3] Even art is taught via principles and tenets, leaving the rest to the creativity of the artist. Yet, when the human body is the canvas, there is little room for such creativity, save for in the development and utilization of various techniques. Different types of tissue interact in a smile: teeth, lips, gums, and skin. The smile then interacts with the remaining facial structures to be seen as a whole entity. Numerous dental-related studies have analyzed the smile in efforts to discover which characteristics make it more or less attractive to establish objective clinical criteria to guide the restorative dentist, which will be discussed thoroughly in this chapter.

Importance of facial diagnosis

Kokich et al.[4] were one of the first to study the perception of the esthetic discrepancies of the smile. They established the levels of recognition for the different types of esthetic discrepancies for both dentists and laypeople. Since then, diverse studies have focused on the esthetic alterations, mainly by laypeople representing the patients seeking dental treatment.[3–9] Most of these studies showed pictures of a smile alone, having eliminated other

(A) (B)

Figure 33.1 Human perception of what is considered beautiful resides in the subconscious, and is based in a larger part on balance, symmetry, and proportion. Here are examples of both female **(A)** and male **(B)** faces that have been judged as "beautiful."

surrounding facial structures to avoid superfluous factors that could potentially confuse or bias the observer.[4–6,8] However, elimination of the surrounding facial structures creates an artificial perception. We rarely see a smile segregated and apart from the face. Lombardi[10] established the principles of visual perception as they apply to denture esthetics. One principle was that "isolation" is improbable and that the mind is constantly observing, analyzing, processing, and interpreting the relationship "in between" objects (Figure 8.5).

Teeth are framed by the lips to create the smile, which is then framed by the face. All of this gives a global expression to the gesture of smiling. We cannot ignore the role that some facial structures play in the overall perception of the smile. Beyer and Lindauer[7] published an investigation about the impact that different facial structures have on the esthetic perception of midline discrepancies. He concluded that facial structures and their deviations affect the way observers perceive smile esthetics. However, too many variables existed in the Beyer and Lindauer[7] study and they were unable to reach conclusions regarding how different facial structures can influence or interfere with our perception of the smile.

Currently, our field is limited not only by the degree of visual detail that some conservative treatments require but also by our postural working position. We have a tendency to sit too close to and hunched over the patient, which neutralizes our ability to best frame the facial composition. It is necessary to step back from our routine treatment position, because shortening the distance to more than that of a social conversational position will reduce the visual examination field to a dentofacial perspective instead of an overall viewpoint that would help diagnose a facially directed esthetic evaluation (Figure 33.2A and B). Therefore, patients are asked to stand close to a neutral-colored background wall to take full facial photographs. Studying these two different dimensional views allows us to clearly visualize facial discrepancies (Figure 33.3A and B). The subtleties of the interaction of the different facial elements associated with the smile can be better appreciated when a systematic analysis of all the different facial components is

Figure 33.2 **(A, B)** The distance at which we view a person's face affects our judgment. For instance, note how the close-up photo results in a lack of ability to accurately evaluate balance and proportion, which can affect smile design.

Figure 33.3 **(A, B)** Looking at the face directly in our traditional dental treatment position does not allow for an accurate, facially directed esthetic evaluation. A two-dimensional digital photograph of the face makes it easier to view facial discrepancies and silhouette form. A neutral background for these photos is preferred.

performed, inclusive of the static and the functionally dynamic smile.[11]

When a patient presents with an esthetic problem or complaint, avoid the mistake of diagnosing only the particular tooth or teeth in question. The teeth should always be kept in perspective with the entire smile, and the smile in perspective with the total face. Only then can a comprehensive diagnostic evaluation be presented to the patient. This does not mean that every patient with a discolored or fractured tooth is a candidate for an extended analysis of facial form and diagnosis. On the contrary, the objective is to fulfill the patient's goal of looking as good as they want to. Most patients will want to look their ultimate best, whereas others will want to improve only one isolated tooth to achieve the appearance they are comfortable with.

Generally, patients demanding esthetic restorative treatment do so to improve confidence within themselves and outward appeal to others, allowing an overall enhanced quality of life. In addition, a long-term stable occlusion must be acquired, and treatment of any occlusal discrepancies must be done to preserve the dentition. Despite teaching children to look for inner beauty, the reality is that perception is formulated on physical appearance and presentation. Although some patients may wish to correct their occlusion to improve function, most patients seek treatment to improve the appearance of their dentition, occlusion, smile, and face. There is a general consensus regarding the importance of the role that occlusion plays in mid- and long-term restorative dentistry. But treating only the occlusion would be like treating one small part of the puzzle, not unlike a patient who only seeks a pleasing smile. The challenge lies within trying to integrate the function and esthetics of the smile into the total facial composition.[11]

Facial expressions

The dentist is in the best position to diagnose abnormalities that can alter facial expressions. Certain people typically have tense or sad expressions. Reverse smile lines, abnormalities in the teeth or lips, or wrinkles in the mouth can contribute to such expressions. Wrinkles around the mouth and other lip problems could be corrected by plastic surgery, lip filler, injections such as Botox®, or improved with makeup. The dentist should be aware of the types of corrections that can be accomplished by the generalist or more appropriately by specialists in prosthodontics or related fields such as plastic or orthognathic surgery.

Certain patients will appreciate the fact that you have both an understanding of and a working relationship with plastic surgery. True interdisciplinary therapy encompasses both dental and medical specialists, especially when it concerns the patient's need to look and feel better about their total appearance. The question is how to approach the subject of plastic surgery without offending the patient. The best way is to include the term in normal conversation about a possible problem. For instance, if the patient has a nose that severely deviates from the midline and the patient expects the dental restoration to correct the intraoral midline, the response could be as follows: "I can correct the jaw midline to line up with a bisected line from your facial midline to your chin, but it may call more attention to your nose. We may want to get a consultation with a plastic surgeon to see what it would take to correct that as well." Because many times the correction might also include an orthodontist and/or a cosmetic periodontist, you might also say "I work with a great interdisciplinary team of orthodontists, oral surgeons, plastic surgeons, and periodontists and I think it would be wise to at least get a group consultation to explore all the possibilities (and all your alternatives)." Neither suggestion is offensive and does show your concern for the patient to get the very best esthetic result. Remember, the most a patient can say is "I am not interested," and you can document the fact that you did give your patient the option.

Esthetic dental procedures can change facial expression and frequently alter one's personality. Many times, when a patient with an unhappy appearance receives an esthetic smile transformation, a favorable change in personality occurs. They may say that they smile more because they are proud of their teeth, when in reality their self-image has improved and their personality has assumed the associated positive traits.

Facial asymmetry

Symmetry is one of the main concerns in esthetics.[1,2,5,10,12–17] Symmetry refers to the regularity in the organization of forms and objects. Some consider symmetry and balance to be related, while others highlight the differences between them.[1,2] The importance of symmetry increases the closer the midline or center is approached. When we enhance midline symmetry, the transition between hemispheres is smoother; the closer we get to the midline, the easier it becomes to identify asymmetries.[2,18]

Symmetry can be horizontal or vertical when it refers to a line as the image on a mirror, or radial when it refers to an axis. Horizontal symmetry is psychologically predictable and comfortable, but it tends to be monotonous.

Few naturally possess a completely symmetrical face. But a face does not have to be symmetrical to be considered beautiful. In fact, several winners of beauty contests, as well as movie and TV stars, have asymmetrical faces, based on our inspection of over 1000 photographs (Figure 33.4A and B).

As observers, we wish to see objects that form a composition in a stable position, as the human eye is conditioned by expectations based on previous experiences.[1,10,12] The human being is externally considered as two symmetrical parts. By definition, this would imply the existence of a mathematically equal image of both right and left facial halves. However, these statements are not categorical, as the symmetrical theory is affected by

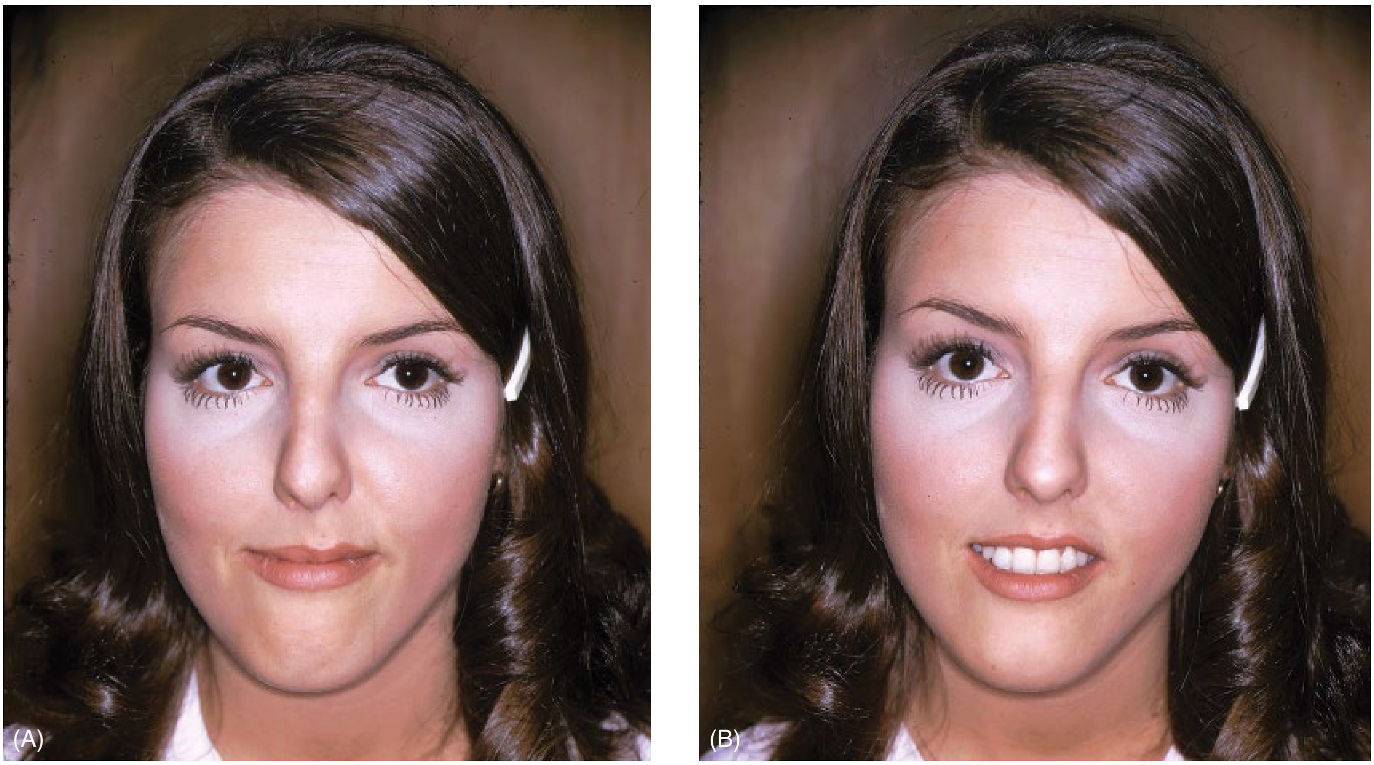

Figure 33.4 **(A, B)** A two-dimensional photograph makes it easier to diagnose facial asymmetry, which is important for smile design.

Figure 33.5 Although this model was judged as the most beautiful by a major magazine, she pointed out to Dr Goldstein how asymmetrical her face was.

biological imperfections, some inherent to natural developmental processes and others to the environment.[19]

Facial asymmetry, within certain limits, is not considered to be a pathological condition, despite the nonexistence of objective scientific criteria to differentiate normal and abnormal asymmetries. This judgment generally results from subjective criteria and the harmonic sense of the clinician or technician[19] (Figure 33.5). According to some studies, it is not uncommon to find slight facial asymmetries within a normative population absent of pathology.[13,20–29] The soft tissues disguise the possible skeletal imbalances,[13,26] thereby making skeletal asymmetries that fall below 3% clinically insignificant.[21]

Our approach has always been to first engage the new patient in conversation, hopefully motivating the patient to smile or laugh naturally. Video records can be made with a patient's consent. These dynamic records can help with the diagnosis and also with reminding the dentist of the patient's chief complaint and other small details that can be unnoticed at the first interview. It is recommended to maintain eye-to-eye contact, but to note any negative facial aspect that takes the focus away from the eyes; it can be a deviated nose or chin, but more than likely it will be something related to the smile. It is extremely important to communicate in a positive manner any facial deviation you find. Failure to do so may well cause serious problems later on when restorations do not satisfy the patient's quest for a perfectly symmetrical result, when, in actuality, obtaining symmetrical perfection was never possible to begin with. Trying to explain this fact after having placed restorations becomes a defensive tactic, which may create difficulties in having the patient understand the possible limitations of the esthetic results. Therefore, the patient's space asymmetry will result in improvement, but still be a compromise from what they may envision. It is crucial to have the patient understand this in treatment planning. Furthermore, it is always a good idea to state this fact in a written document signed by both clinician and patient.

Facial midline

To analyze facial symmetry, one must first and foremost know how to establish the facial midline. Because of the existing differences between both facial halves, the facial midline is hardly defined as a precise geometrical division. This can explain the differences found when defining this parameter: a vertical line through the forehead, the septum, the dental midline, and the chin;[2] a vertical imaginary line bisecting the nasion, subnasal, pogonion, trichion, and pronasale points;[15] a vertical line through the glabella, nose, philtrum, and the chin's extremity;[30] and a vertical line through the philtrum when the pupils are in line with the natural posture of the head.[31,32]

The definition of the facial midline can be extremely controversial; it is quite difficult to draw a line based on unclear anatomical spots such as the "nose," "forehead," "septum," and "chin," although these definitions can be found in the literature, which somehow explains the difficulty in defining this parameter. We agree that a vertical line through the philtrum, when the pupils are in line with the natural posture of the head,[31,32] seems to be the best way to define the facial midline for a diagnostic purpose (Figure 33.6A). However, they suggest that the most important parameter might not be finding the exact landmarks that define the midline of a geometrically irregular shape such as the face. Rather, it may be understanding the process that our perception uses to establish the hypothetical facial midline, imposed by facial and dentofacial elements, to analyze the apparent symmetry. This hypothetical facial midline can also be called the perceived facial midline and is determined by all facial midline structures, such as the glabella, nose, philtrum, and menton (Figure 33.6B). A line does not need to be expressed to be perceived; it can be suggested by two or three points in a directional movement.[1]

Except in cases of pathology or injury, it is generally accepted that, even when the human face is "symmetrical," one-half does not mirror the other. Renner states "Differences in facial symmetry are due in large measure to differential development of the facial muscles on each side of the face as well as the underlying supportive skeletal structure"[33] (Figure 33.7A–D).

The dominant hemisphere of the brain is thought to strongly influence differences in facial muscle development; the brain is

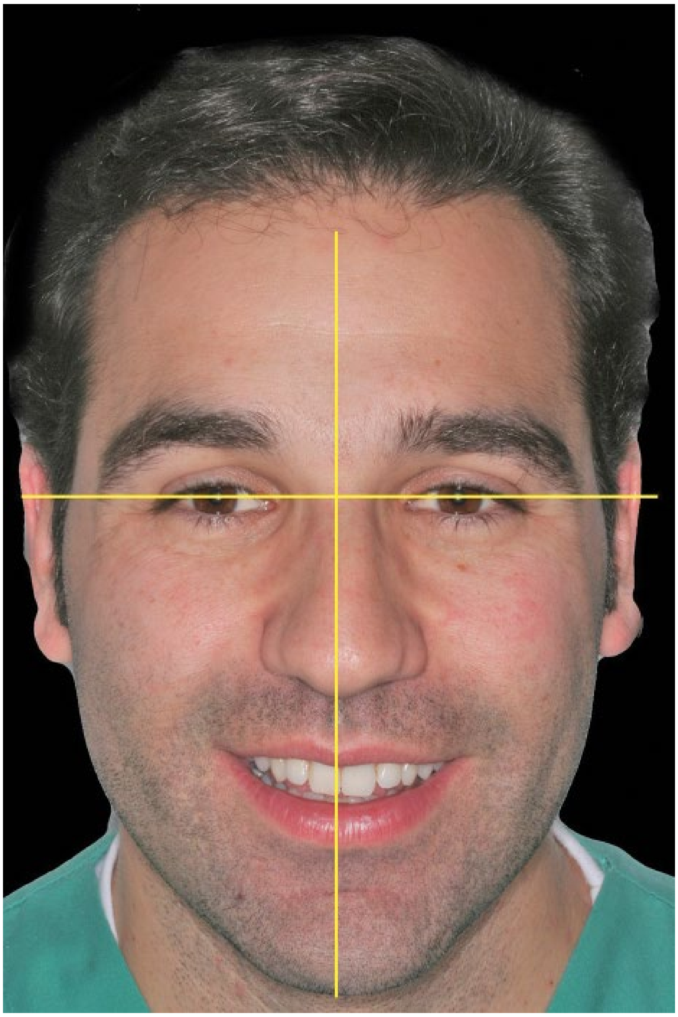

Figure 33.6 **(A)** Facial midline—vertical line through the philtrum when the pupils are in line with the natural posture of the head.

Figure 33.6 **(B)** Perceived facial midline, determined by all facial midline structures, such as glabella, nose, philtrum, and menton.

governed by the principle of contralaterality, with the right cerebral hemisphere controlling the left half of the face, and vice versa. To a great extent, this slightly uneven development creates nuances of expression in an individual and adds interest and uniqueness to a face.

In many individuals, features of the face slant one way or the other and make it difficult to see the true midline in the dentition. Figure 33.8A shows an attractive face where the incisal plane and dental midline are actually canted, but because the nose is deviated, and the interpupillary line in the natural head position is not completely parallel with the horizon, the canting can go unnoticed. An eccentric midline of the teeth is in many cases acceptable and may enhance the illusion of harmonious composition. The midline is important within the overall facial considerations and must be analyzed carefully.

Patients tend to concentrate on the dental arch midline and are quick to think that it is not perfectly aligned. This is because most patients think the facial midline must coincide with the midline on their central incisors. But the true problem is that the appearance of asymmetry can be the fault of any other facial element, such as the lips, philtrum, nose, or chin or arch alignment. Therefore, it is imperative to diagnose and present to the patient any facial anatomic anomaly or asymmetry that may influence the esthetic result. This can be done using digital photography software, such as Adobe Photoshop®, to analyze face symmetry. Figure 33.8B shows how Adobe Photoshop can be used to align the interpupillary line with the horizontal and to trace reference lines to emphasize canting of the incisal plane and dental midline. The most important factor is having a good facial picture, with the patient standing up with their head in natural position. Long-haired patients should pull their hair back to completely expose both sides of the face so that the picture can be as centered as possible on the face. A striped background helps to establish the relation of the interpupillary line, in patient's natural head position, with the horizon. Tilted pictures can create the illusion of facial asymmetries by exposing more of one side of the face than the other. Figure 33.8C and D shows how a slightly tilted picture to the left side of the patient can lead to a misperception of the incisal canting.

The importance of comprehensive consideration of various facial characteristics, especially in anticipation of anterior restorative procedures, cannot be overemphasized.

Figure 33.7 **(A, B)** To show that the face is not totally symmetrical, the face was bisected and mirrored to provide perfect symmetry. Studies have shown that perfect symmetry is not as appealing as slight asymmetry.

Figure 33.7 **(C, D)** The right side and left side are mirrored to show perfect symmetry.

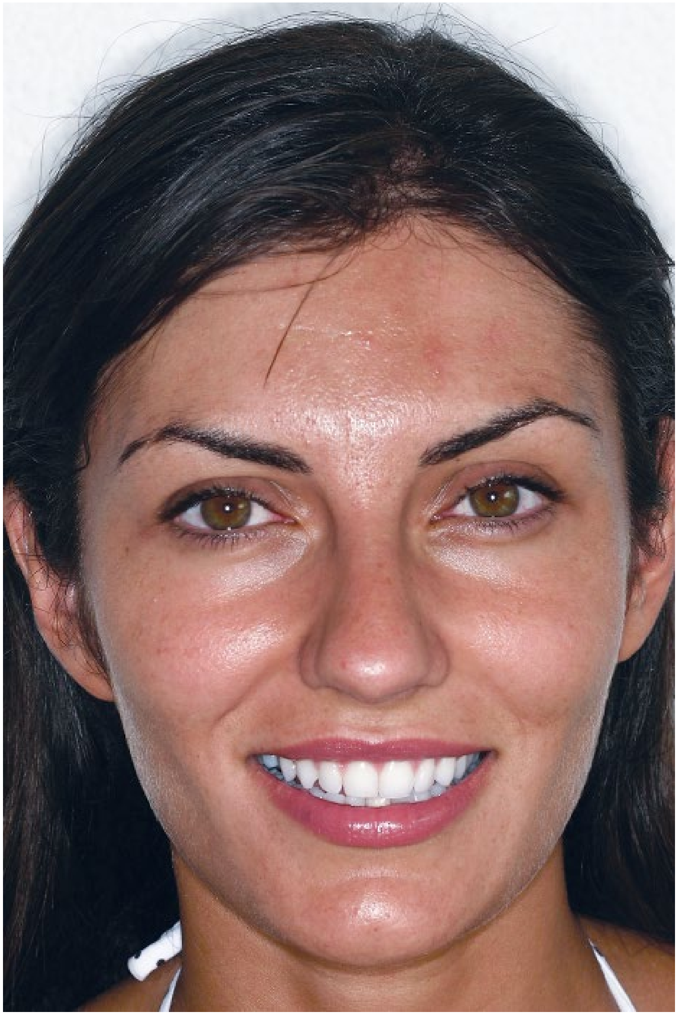

Figure 33.8 **(A)** An attractive face where the incisal plane and dental midline are canted. The nose deviation, and the interpupillary line, in natural head position, is not completely parallel with the horizon; the canted midline and incisal plane can be unnoticed.

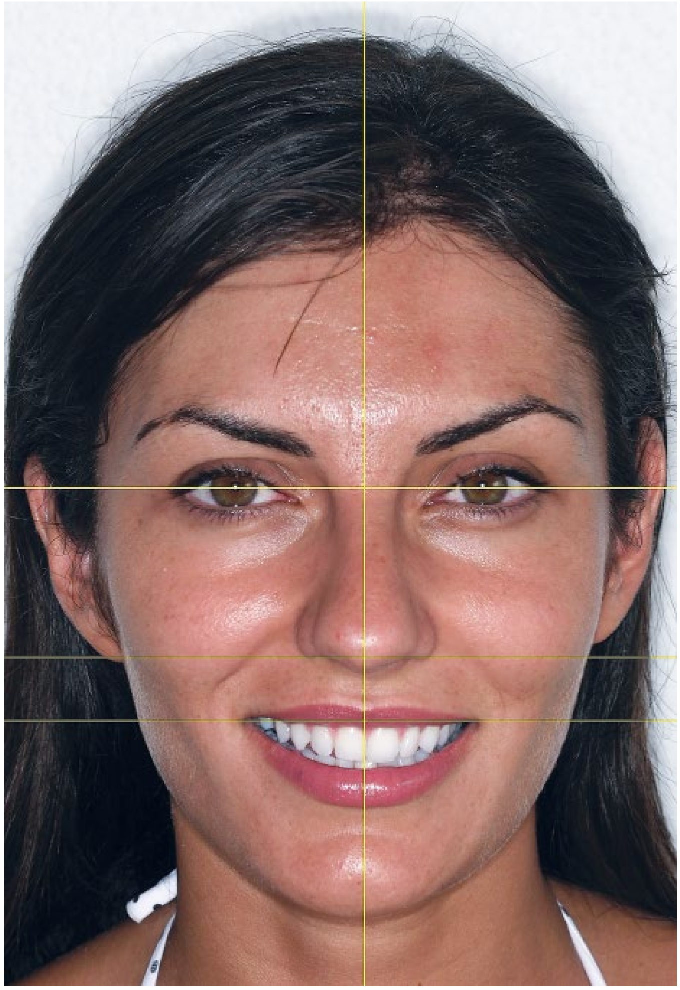

Figure 33.8 **(B)** After aligning the interpupillary line with the horizontal and by tracing some reference lines, using Adobe Photoshop, the incisal plane and dental midline canting are now more evident.

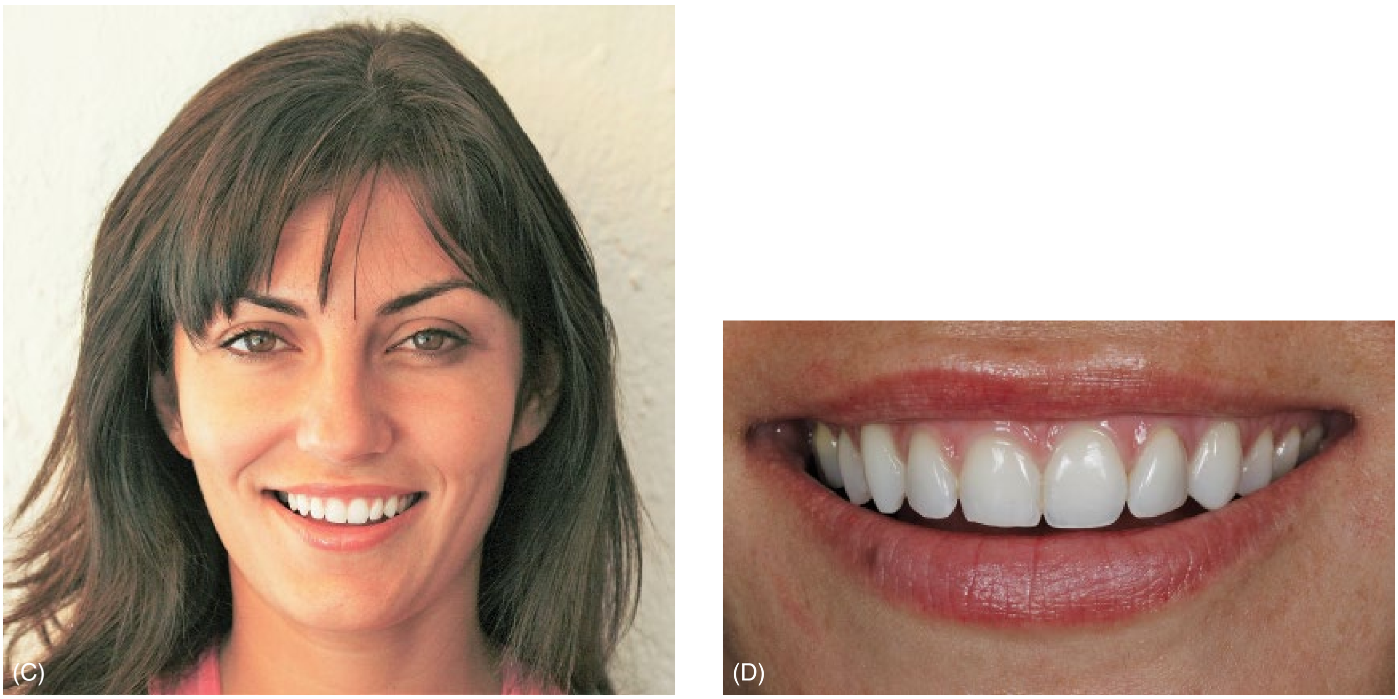

Figure 33.8 **(C, D)** Shows how a slightly tilted picture to the left side of the patient can lead to a misperception of the incisal and dental midline canting.

The midline or vertical division of the face into halves is one aspect often overlooked by the dentist. The relationship between the midline of the face and the midline of the maxillary dental arch can have a definite influence on the composition and harmony of esthetic restorations. In the final analysis, it is of utmost importance to inform patients of any limitations regarding midline discrepancies, so they will not expect perfection in the final result.

The dental midline should be perpendicular to the incisal plane and parallel to the midline of the face (Figure 33.9). Error may occur in slanting the midline formed by the mesial line angle of the central incisors either to the left or to the right. This may result in the illusion of malposition of the teeth or distortion of facial expression. Figure 33.10A–D shows a patient whose naturally slanted midline was acceptable to her, but her chief complaint was that her lateral incisors did not show when she spoke, giving the illusion that she had no teeth. Full porcelain crowns were placed on the lateral incisors to create a fuller smile and speaking line.

Figure 33.9 A piece of dental floss extending from the patient's forehead to their chin helps both the patient and practitioner visualize the dental and facial midlines.

The maxillary centrals and cuspids were reduced proximally to allow normal-sized lateral incisors to be placed. Because the midline deviation was of no concern to the patient, no correction was indicated, and even with a deviated midline the patient has an attractive smile.

On the other hand, a patient may request a midline correction. For example, the 23-year-old woman in Figure 33.11A and B presented with a deviated midline and incisal wear. The patient was extremely concerned about her unattractive smile because she was an entertainer. A measurement of the true midline showed a diagonal deviation to the left (Figure 33.11B), and the incisal wear had produced what appeared to be an arch deformity. Because the patient wanted an economic immediate result, composite resin bonding was selected (Figure 33.11C and D). Figure 33.11E and F shows graphically how the esthetic transformation was accomplished.

True arch deformity can also be visually improved with a combination of periodontal cosmetic surgery consisting of crown raising. Next, restorative treatment could include ceramic veneer or full crown restorations (Figure 33.12A–D).

Asymmetry location

In the literature we find relevant differences in the asymmetry degree that can be found on different facial areas. Several studies agree that the gonion is one of the facial landmarks where the face presents greater asymmetry.[13,15,34] One of the explanations for this fact is the functional response to an asymmetric chewing action.[35–37]

In 2001, Ferrario published a three-dimensional investigation stating that the tragion, gonion, and zygyon points were the facial paired landmarks with greater asymmetries, whereas the endocanthi had the least asymmetries.[34] The nasal tip or pronasale was the most asymmetric point out of the ones placed on the midline, and this asymmetry was greater in males than in females; the same difference between sexes was noted with the pogonion (Figure 33.13).

The most recent research using three-dimensional methods tends to highlight the middle third of the face as showing greater asymmetry, although the most asymmetric points registered in this third are the tragion, gonion, and zygion, which are distant from the facial midline. However, the most asymmetrical point located on the midline was the pronasale (Figure 33.13).

Esthetic relevance of facial symmetry

Facial symmetry was suggested as a stability frame of development that can even be relevant when choosing a partner in human beings.[38] Numerous articles state there is a positive relationship between facial symmetry and beauty.[38] However, some recent investigations found that symmetrical faces are still classified as the most attractive when only one of the halves is presented.[38] This suggests that it is not because of the symmetry but because symmetrical faces usually have characteristics (that are not identified) that make them more attractive or esthetic.[38,39] Tarnow et al. implied there is a strong relationship between the tenets of beauty in a smile and the parallelism between reference

Figure 33.10 **(A–D)** This 26-year-old female presented with a deviated dental midline. Her chief complaint, however, was that her lateral incisors did not show during speech. (A, B) Full porcelain crowns were placed on the lateral incisors to create a fuller smile and speaking line. Since the midline deviation was of no concern to the patient, no correction was indicated (C, D).

lines and the teeth with the facial midline.[15] Symmetry should be the ultimate goal, not so much to achieve it but to get close to it. The focus should be placed on similar and differing parts of the face and compared with concepts of esthetic guidelines. Similar disharmonies can be brought to smile design. For example, bolder and slightly misaligned teeth will blend with a face that is noticeably asymmetrical. Strict symmetry in a smile may appear beautiful in a very symmetrical face but unnatural in a very asymmetrical face.[15] These imperfections were named "perfect imperfections" by Gebhard,[40] who considers that these tenets are important in creating diversity, naturality, and unique attractiveness in a smile design.

According to Springer et al.,[41] symmetry is one of the characteristics of an esthetic and attractive face, but there are exceptions to this rule (Figure 33.7A and B). Under some circumstances, symmetry can be completely unacceptable from an esthetic point of view. Several publications[42–44] demonstrate that an asymmetrical face is rated better from an esthetic standpoint versus a completely symmetrical face, which would be obtained artificially by joining two same right or left halves of the face (Figure 33.7C and D). This can be explained by horizontal symmetry, which is psychologically predictable and tends to be monotonous because diversity is missing to catch the observer's attention.

The golden proportion

Since the days of ancient Greece, beauty and numerical values have been closely associated, specifically in regard to the theory of proportions, which applies and implies arithmetic. The

Figure 33.11 **(A–D)** This 23-year-old wanted to improve her smile. Her facial midline was measured with dental floss, showing a deviation of her dental midline diagonally to the right. The midline deviation and worn smile line were corrected with direct resin bonding on three of the maxillary anterior teeth.

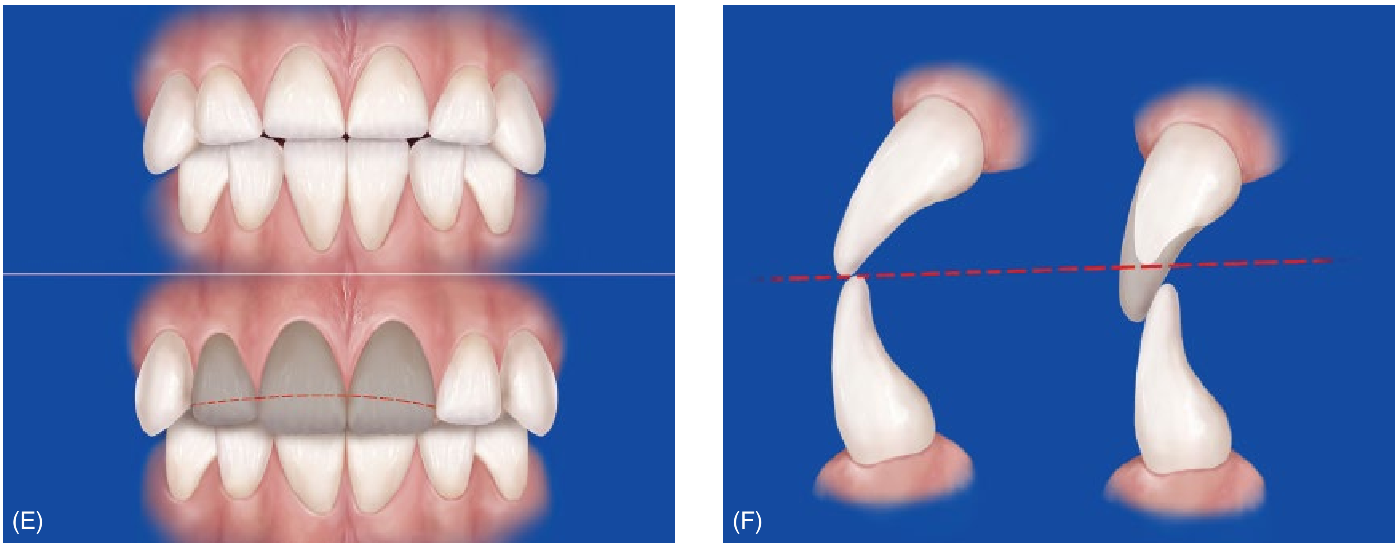

Figure 33.11 **(E, F)** This illustration demonstrates how by contouring and beveling the lower incisors, the upper incisors can be lengthened without altering their protrusive relationship.

concept of perceived beauty corresponds to the harmony of proportions. Applying mathematics to the arts as a new objective criterion of evaluation led to generations of philosophers and mathematicians attempting to find a formula to express beauty.[3,45]

The Greek civilization was concerned about finding methods for craftsmen and artists to quantify beauty and reproduce it in a predictable way. Their aim was to discover a simple arithmetic formula to represent harmony and beauty. This led to Pythagoras in 530 BC trying to find a mathematical answer to what was beautiful and ugly, and the result was the golden proportion. The "golden rule" or "golden proportion" used the number 1.618 as the "perfect" proportion and subsequently applied this to all fields of art and esthetics, including dentistry[3,45,46] (see Chapter 9). According to this rule, animated or unanimated objects that followed this ratio possessed an inherent beauty.

The beauty of flowers and faces was identified with characteristics that agreed with the ratio 1.618. Architects and sculptors of ancient times exploited the golden proportion to create buildings, such as the Pantheon in Athens and classical statues. Many artists also used this proportion to create masterpieces, such as Piero della Francesca and his *Baptism of Christ*. Plato claimed that other proportions or recurrent ratios could also show beauty. He disqualified the pretensions of the Pythagoras concept of beauty without answering the universality of the golden number.[2]

Studies on human facial morphology revealed a polar growth center in the base of the sphenoid. The growth registered around this point seemed to display proportion radially. Around this point the structures grew less than more distant ones, to keep the proportionality of the face in a three-dimensional context. Several facial and dental structures and landmarks have shown consistency in golden progressions. Examples are the width between the inner canthus to the nose ala; the length of the philtrum cupid's bow to the base of nose's columella, and the vertical height of upper and lower lip combination; and the lower and upper central incisor width, and the apparent width of six anterior maxillary teeth from a frontal perspective. Although, if all animals and plants were to obey this ratio we would be surrounded by clones. However, in the animal world, if some characteristics do not show standard dimensions, beauty may be compromised. What is the reason behind this disparity? To create diversity and individuality, the recurrent proportions or ratios are more important than a specific ratio (see Chapter 9).

Nowadays, the idea of beauty resulting from a combination of ratios/average proportions and individual subjective sensibility inherent to a determined space and time seems more acceptable. The beauty of the dentofacial composition strongly depends on the presence of several ratios and elements that are connected to structural or biometric beauty; this also applies to tooth arrangements (Figure 33.14).

Facial analysis

A systematic facial and dentofacial analysis protocol should be adopted on a routine basis, to avoid misdiagnosing any situation that can compromise the overall esthetic outcome. Generally speaking, the full face may be divided into vertical halves, left and right, and into horizontal thirds: (1) the superior third, composed of the forehead and hair; (2) the middle, containing the eyes, nose, zygomatic region, and ears; and (3) the inferior, comprising the lips, cheek, and chin. For Caucasian patients, the facial horizontal thirds are approximately equal, and the midline bisects the face between the eyes from forehead to chin (Figure 33.15).

In clinical practice, the standard records include digital photographs, radiographs, and mounted or unmounted study

Figure 33.12 **(A)** This patient has a deviated arch form. **(B)** The deviated arch was corrected by periodontal and restorative procedures, see page 1098.

Figure 33.12 **(C, D)** Cosmetic periodontal surgery consisted of crown raising followed by brighter looking all-ceramic crowns in much better alignment that helped to improve her smile and facial beauty.

models. The most used facial images include frontal at rest, frontal smile, and profile at rest 1 : 1 images, which do not provide enough diagnostic information as they do not contain enough information for three-dimensional visualization and quantification.[11] A complete facial analysis requires more records and perspectives: profile smiling, facial oblique 45° smiling for both sides, close-up frontal smile, and close-up oblique 45° smile for both sides. In addition to these static records, contemporary smile analysis also requires dynamic records. Digital technology allows clinicians to record anterior tooth display during speech and smiling. The video record should also be taken in the frontal position and another in an oblique view.

Before proceeding to a detailed facial analysis, it is important to differentiate between the posed smile and the spontaneous smile. Posed smiles have been used for a long time in esthetic assessments for their reproducibility, but current video graphic and computer technologies allow us to perform other diagnostic assessments.

Posed smiles can be influenced by the individual's skills and emotional background. Patients that are either embarrassed by their appearance or that suffer from dental phobia will display a learned or an inhibited smile by hiding the teeth with the lips, hands, or changing the head position. Van der Geld et al.[47] studied the vertical and transversal characteristics of a posed and spontaneous smile and came to the conclusion that maxillary lip-line heights during spontaneous smiling were significantly higher than during posed smiling. Compared with spontaneous smiling, tooth display in the molar area during posed smiling decreased by up to 30% along with a significant reduction of smile width. During the posed smile, the mandibular lip-line heights also changed and the lower teeth were covered more by the lower lip than during the spontaneous smile.[47]

Facial analysis can be divided into two major components: facial analysis and dentofacial analysis. Facial analysis looks into relations of the smile with the other major facial structures, and dentofacial analysis pays attention to the teeth with the surrounding facial structures located on the lower third of the face.

Facial analysis: frontal view

For the frontal analysis, the patient should be with the head in the natural position, allowing the patient to sit or stand upright in front of the observer; this is the optimal position to evaluate the frontal plane.[30] Faces can be classified as mesocephalic, brachycephalic, or dolichocephalic by the classic frontal analysis, the difference being in the facial width to facial height general proportions. Brachycephalic faces are broader and shorter in comparison with dolichocephalic, which are longer and narrower (Figure 33.16).[11]

Facial reference lines

Reference lines are defined by points or structures that are taken into account during the perception process to find out if an esthetic composition is harmonically distributed. The reference

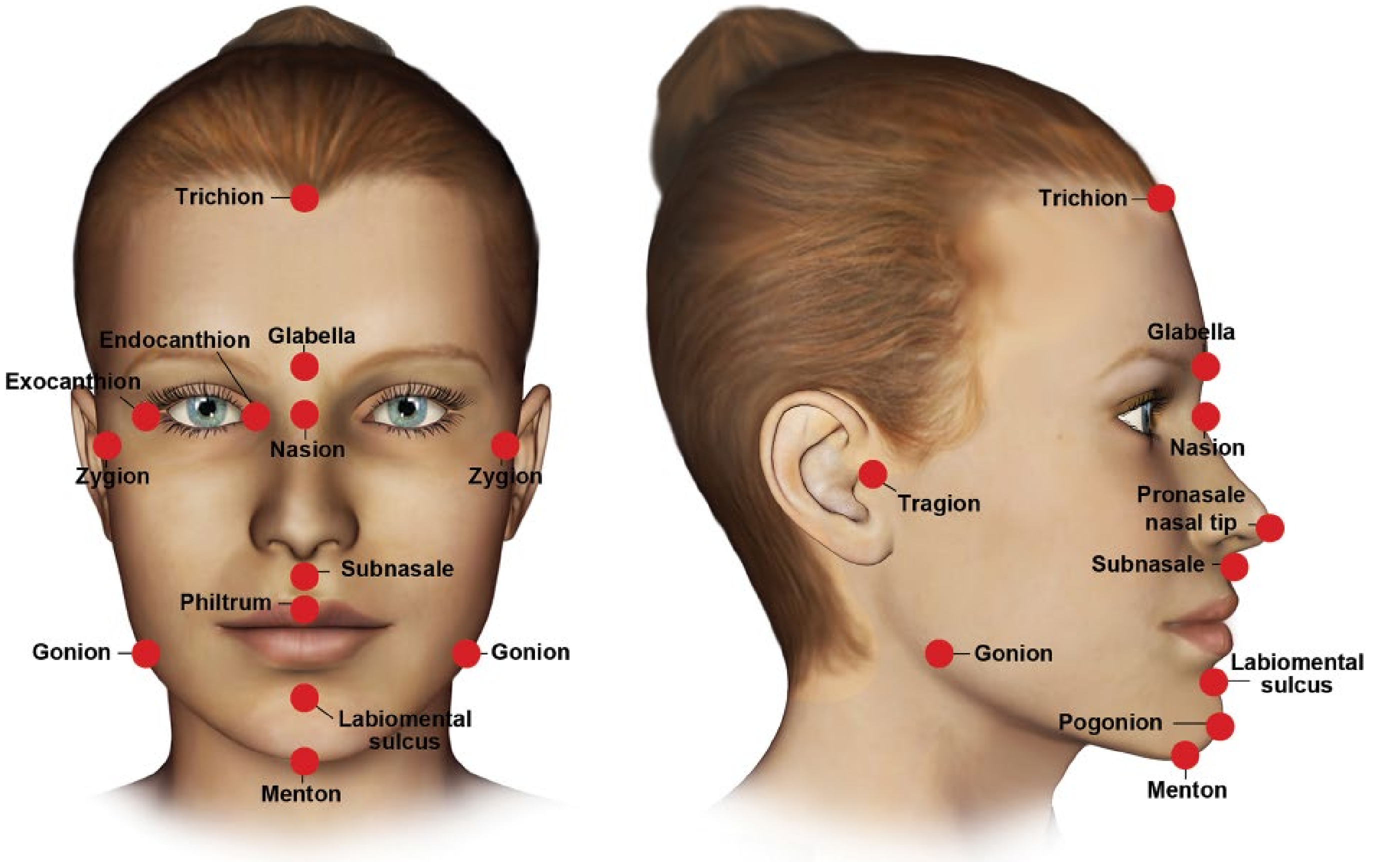

Figure 33.13 Frontal and profile facial landmarks associated with identifying facial asymmetry.

Figure 33.14 **(A, B)** Direct composite resin bonding for the six maxillary anterior teeth was chosen to restore this young lady's too narrow incisors. The final result demonstrates more appropriately sized teeth with more harmonious proportions.

lines of facial and dentofacial compositions are considered one of the key factors of biological and structural beauty.[2] Remember that a line does not need to be expressed to be perceived; it can be suggested by two or three points in a directional movement.[1]

When we look at a face in the frontal plane, our brain considers multiple reference lines. The most important reference lines in the frontal plane are the interpupillary line and the facial midline. These two lines define a "T," which works as the dorsal spine of the whole facial architecture.[10,12] All the facial structures should be parallel or perpendicular to one of these lines. When artists start drawing a face, they first establish a "T." In an esthetically attractive face, the interpupillary line is also parallel to other horizontal reference lines, such as the commissural line, inter-ear line, lip line, and the eyebrow lines[12,31,32,48] (Figure 33.17).

The most harmonic relation between two lines is parallelism; attraction originates from the general sense of parallelism and symmetry between facial characteristics, but it does not need to

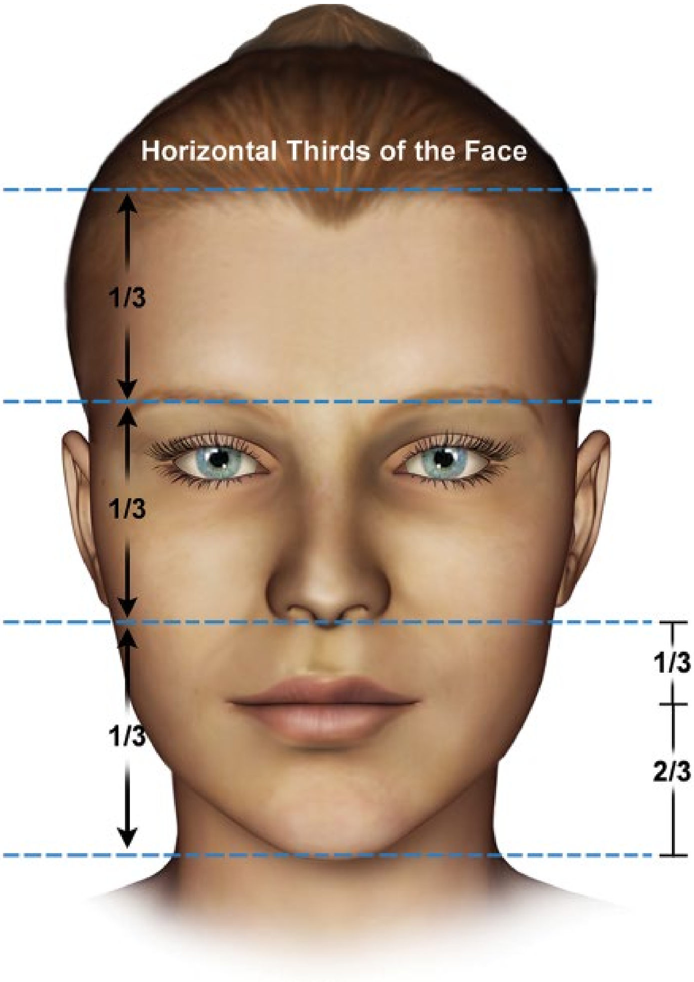

Figure 33.15 In Caucasian patients, the facial horizontal thirds are approximately equal.

Figure 33.16 The first (leftmost) face, demonstrating equal facial thirds, is classified as mesocephalic. The middle face is more square, with the lower third being diminished in proportion, which is classified as brachycephalic. The face on the right is typical of one that is dolichocephalic, which indicates a larger lower facial third.

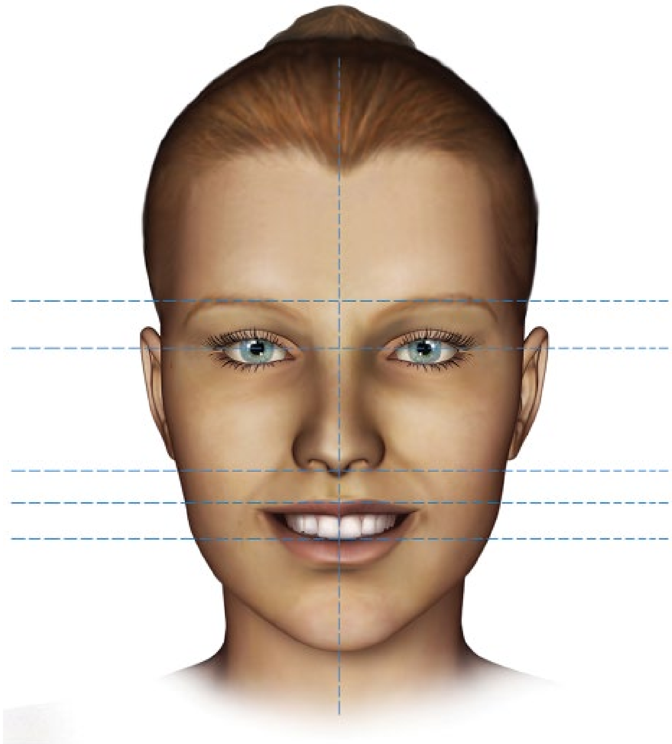

Figure 33.17 Looking at the face from a frontal view, facial reference lines help define dentofacial proportions. The "T" that is formed by the interpupillary line and the facial midline is of utmost importance.

be strictly from parallelism. Most people have nonevident inclinations that require little or no correction. The irregularities created by slight inclinations can cause some tension within the related structures and may need partial fixing, or, if the patient is very demanding, even total correction might be possible.[12] But, which inclinations are the ones that really matter in terms of esthetics? Several authors[2,4,10,12] suggest that axial inclination of the dental midline is esthetically unacceptable for it does not respect the parallelism rule. Midline shifting is considered less important provided that it is parallel to the facial midline. It was observed in a perceptional study with 196 lay subjects that asymmetric deviations of some facial midline structures, such as the nose tip and chin, modify how the dental midline canting is perceived. They found that when the dental midline was canted in the same direction as nose tip and chin the esthetic ratings were higher than when the canting was opposite the nose and chin deviation (Figure 33.18A and B).[49] The same rule was observed for the dental midline shift (Figure 33.19A and B).[50]

This implies that because some facial structures such as nose and chin frequently present asymmetries, the perceived facial midline is not always perpendicular to the horizontal, and mild inclinations of the dental midline are allowed without breaking the esthetic harmony, provided the parallelism among facial elements is preserved (Figure 33.8A). We believe that the same rule can be applied to interproximal contacts.

The lips work as curtains regulating the degree of dental exposure, both during resting and smiling. They are arguably the most dynamic structure in whole face. The labial commissures define a very important horizontal reference line known as the commissural line (Figure 33.17). Besides the commissural line, there are other labial reference lines that are used to evaluate teeth exposure of maxillary teeth at rest. During smiling, these lines will also determine the amount of gingival exposure. Incisal edges of the maxillary teeth define another reference line: the incisal curve. According to Tjan et al.,[51] this line is parallel to the lower lip in 85% of the population. Golub[52] established that one of the most significant facial juxtapositions is the dental midline being perpendicular to the interpupillary line; it centers the smile on the face. The hypothetical midline, or the one imposed by the elements of the facial and dentofacial composition and the perpendicularity with the horizontal reference lines, guarantees the presence of segregation forces, a fundamental requirement for esthetic approval.[1,12,52] To conclude, it can be said that multiple lines can help us understand the human face, and achieving a balance between symmetry and harmony is required in any technique.[18]

Vertical facial proportions

The optimal facial proportion generally follows the facial thirds concept, which divides the face vertically into three equal parts.[1,11] Artists and orthodontists generally agree upon the concept of using facial thirds to evaluate beauty. More attractive faces display optimal balance when these proportions are present.[53,54] The upper third is defined by an imaginary line parallel to the horizontal that crosses the hairline (trichion) and another one that passes through the midbrow; the middle third goes from the midbrow to the subnasale region, and the lower third is the area between the subnasale and the menton's soft tissues. The ideal lower third can be further divided in thirds, with the upper lip being the upper third and the lower lip and chin representing the lower two-thirds[11] (Figure 33.15). There are several skeletal causes behind disproportions among vertical facial thirds, and analyzing the proportional relationships can aid in diagnosing the different factors involved in vertical facial deformities.[11] Measuring the upper third can often be difficult because of the variability in landmarks such as the location of the hairline (trichion). The 1 : 1 proportion between the middle and the lower thirds should not be used as a determining factor when undertaking facial height changes. This is because the degree of incisor exposure and the interlabial gap (see Chapter 32) in the lower third play a much more important role when assessing balance.[31] If the lower third height is larger than the upper two-thirds and the patient cannot close the lips without strain (Figure 33.20A and B), the esthetic proportion of the face as a whole can be restored by surgically modifying the patient's alveolar height and/or vertical dimension[55] (Figure 33.21A–C).

The aging process is greatly noticeable in the lower third of the face, which presents an excellent opportunity to rejuvenate a patient's looks. During the normal aging process, facial and masticatory muscles undergo degrees of atrophy and associated fibroses of their fibers and tendons. This shortens the working length of the face and manifests in sagging and wrinkling of the face. Premature aging of the face can be brought on by repeated overexposure to the sun as well as habits such as cigarette smoking. Especially damaging to a youthful appearance is the early

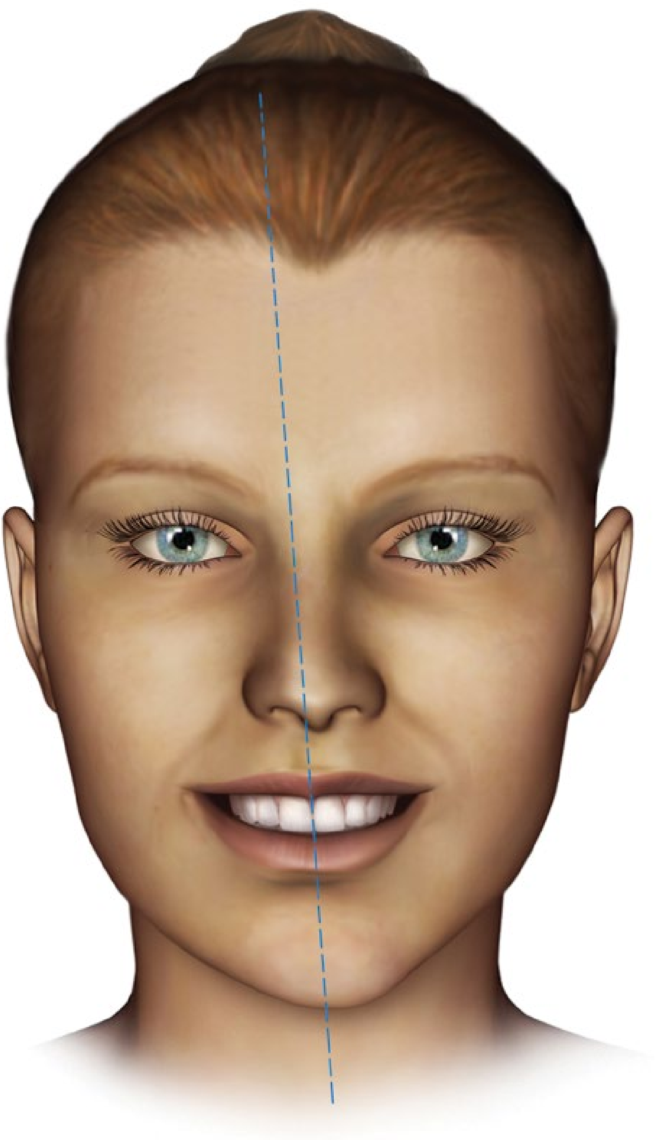

Figure 33.18 **(A)** When the dental midline is canted in the same direction as the nose and chin, some harmony and parallelism are maintained.

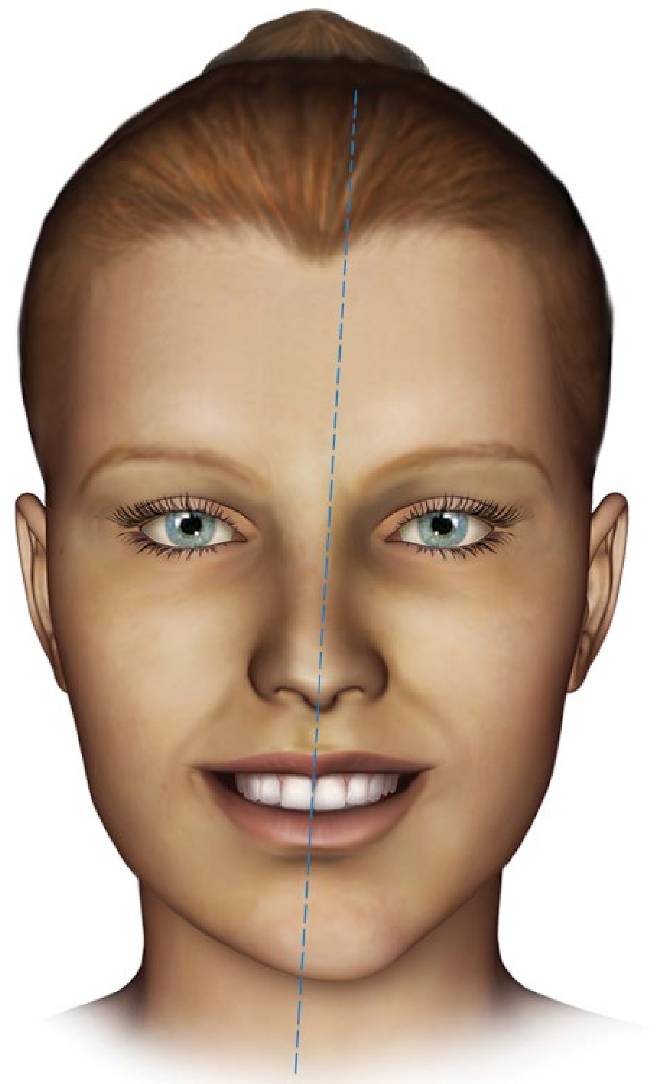

Figure 33.18 **(B)** When the dental midline is canted in the opposite direction of the nose and chin, harmony and parallelism are disrupted.

loss of the dentition, which eventually results in the partial or total resorption of alveolar bone, and leads to the "overclosed" or "collapsed" appearance associated with advanced age (Figure 33.22A–I).

A reduced facial lower third can be caused by tooth wear with loss of vertical dimension or by undereruption of the posterior teeth.[56] In some cases, increasing the vertical dimension can improve facial beauty,[57–60] but it is considerably difficult to achieve large changes in facial lower third height and dramatically transform facial proportions while preserving a correct occlusal relationship.[61,62] When the vertical dimension is increased or decreased, the overjet is also significantly altered; for each 3 mm vertical change in the anterior teeth there is approximately a 2 mm horizontal change in an anterior–posterior dimension, modifying the overjet (Figure 33.23). Therefore, attempting to increase the vertical dimension by 9 mm will result in a 6 mm increase in overjet, making it almost impossible to obtain a correct occlusal relationship unless the patient was initially in Class III occlusion. This is also the reason why it is extremely difficult to correct facial proportions when the lower third height is increased and the vertical dimension needs to be reduced (see Figure 33.24A–D).[61]

Research shows dentists were unable to see the difference in esthetics when discrepancies were caused by vertical dimension changes of 2, 4, and 6 mm. Gross found that until vertical dimension changes reach 8 mm, dentists could not assess the difference in facial features.[61] The reason behind this is that, although VDO is normally evaluated with teeth contacting, most everyday activities are done with teeth apart and thus facial proportion is not affected.[61,62]

The frontal view of the lip position at rest can also be evaluated to assess the vertical dimension and its impact on the face's lower third height; this position should create an optimal facial proportion.[63] At times, closure from this rest position to

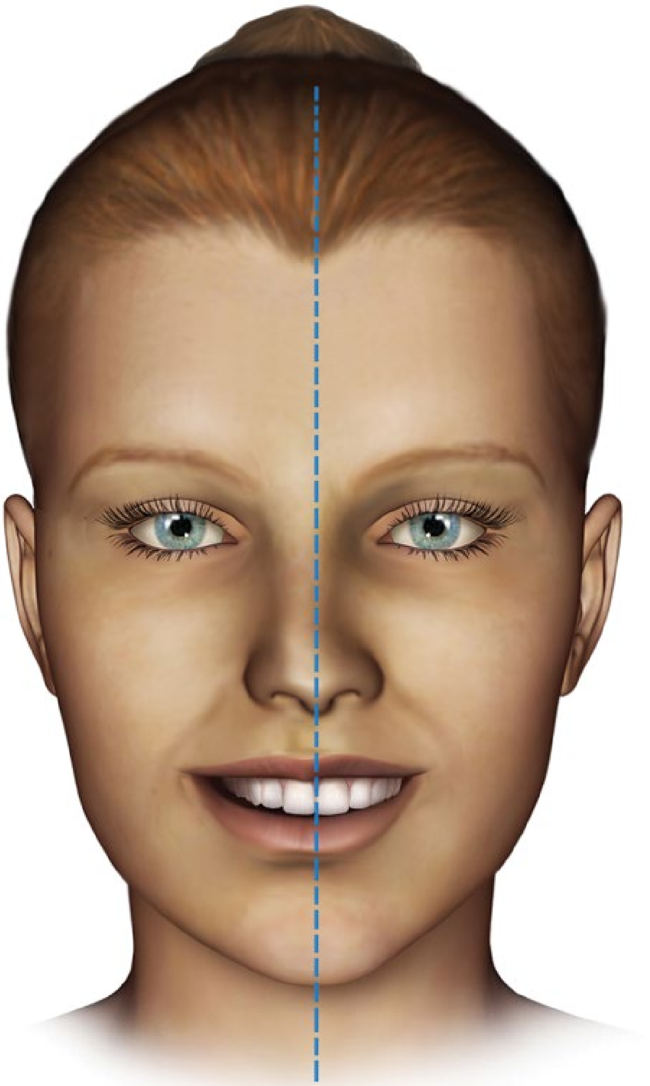

Figure 33.19 (A) This illustration shows how the dental midline is shifted approximately 2 mm in the same direction as the nose tip and chin. Dental midline shifts in the same direction as the facial midline maintain some harmony.

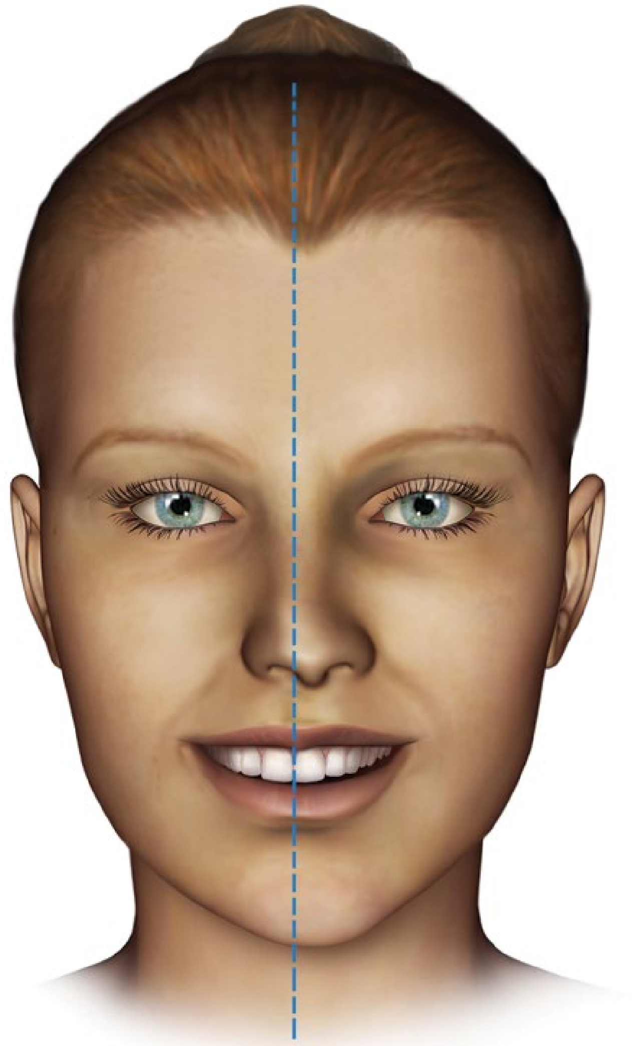

Figure 33.19 (B) When the dental midline is shifted approximately 2 mm in the opposite direction as the nose and chin, harmony is disrupted.

maximum intercuspation reveals a significant decrease in facial height and is esthetically unpleasing due to reduced labial visibility and increased labiomental sulcus depth.[64] This generally indicates an inadequate vertical position of either the maxillary or mandibular occlusal planes. These should also be evaluated with pictures and videos; therefore, picture series in frontal view should include rest and maximum intercuspation positions.

Ideally, there should be minimal effect on facial height and, thus, facial esthetics when the patient closes from the vertical dimension of rest to maximum intercuspation.[11] Usually, when there is a significant difference between these two positions, patients appear to have one of two conditions: deep bite associated with vertical maxillary deficiency and mandibular retrusion (Class II malocclusion)[31] or reduced VDO due to either one of the previously mentioned conditions: significant wear, loss of posterior support due to tooth loss, or underurupted posterior teeth.[63] A composite or acrylic overlay can be placed on the lower back molars (without previous etching) to allow the patient to occlude slightly closer to the vertical dimension of rest; the vertical dimension change and its effect on esthetics and comfort can then be assessed. For further evaluation, a composite overlay can be used to mount the diagnostic casts on an articulator with the new vertical dimension and to do a diagnostic wax-up of the proposed changes. If the mounted casts reveal that altering the teeth to improve facial or dental esthetics would compromise the patient's dentition either biologically or structurally, a multidisciplinary treatment approach should be taken (restorations alone should not be used to treat this case, and orthodontics and orthognathic surgery should be considered).

Clinically, there are many ways of either restoring or altering vertical dimensions in patients. Either fixed or removable temporary restorations can be constructed to provide the planned vertical opening. Perhaps the safest way to make sure your patient will be comfortable with the new opening is to have the

Figure 33.20 **(A, B)** Because of this patient's long, narrow face, she shows muscular strain when trying to close.

patient wear their temporary restorations for 3 months, followed by an extended time in final temporaries once the teeth are prepared. In addition, the anterior teeth can be temporarily bonded with composite resin to also provide the patient with a trial smile so they can approve your esthetic smile design. When there are perceptible abnormalities that bother the patient, such as skeletal asymmetries, a referral may be made to an oral and maxillofacial specialist.[63] Nothing can be done dentally to affect structural changes to the upper two-thirds. Decreased lower-third height cases due to携 undererupted posterior teeth should be referred for orthodontic treatment. These teeth are minimally affected by wear, so restorative treatment alone to increase the vertical dimension would create an unfavorable crown-to-root ratio; it is also possible to cause unnecessary damage to the teeth by preparing them.[56]

Nasal tip and facial midline

According to Ferrario's three-dimensional study,[65] the nasal tip is the most asymmetric midfacial point. The nasal tip position should be assessed beyond the frontal view with the patient's head slightly elevated.

The relation of the nasal tip with the facial midline, philtrum, and dental midline should be registered to reduce the risk of treating the dental midline to a distorted nose. Further studies need to be done to obtain further conclusions about the role that the nasal tip and other midfacial structures play on dental esthetic perception.

Maxillary dental midline and facial midline

The relation between the maxillary dental midline and the midfacial plane should be evaluated in terms of parallelism between them and also to the horizontal plane. Some discrepancies could be caused by dental factors such as missing teeth and crowding or by skeletal maxillary rotation.

A dental symmetrical arrangement is considered a key factor in an esthetically attractive smile[10,19,51,66–68] because patients can easily identify a wrongly positioned midline.[2,19] This idea was accepted into dental practice, albeit without scientific evidence to support it.[9] It was not until the late 1990s when the first studies attempting to quantify midline shifts identifiable by both laypeople and oral health professionals were published. Owens et al.[48,69] concluded that dental midline deviations from the line bisecting the interpupillary line were found in 30% of the population without racial and sex differences; this was subdivided into 22% to the left side and 8% to the right. Miller and Jamison[17] found a 25% midline deviation.

The published studies concluded that a dental midline shifting from the facial midline over 2 mm was easily identified and considered to be hardly esthetic by most people, regardless of their dental education.[7,8] However, some investigations brought up very different results, such as those by Kokich et al.[4] and

Figure 33.21 **(A, B)** In a dolichocephalic face, the lower third is often increased due to a vertical maxillary excess. This problem can be handled by surgically modifying alveolar height and vertical dimension. Now she is a good candidate for restorative esthetic dentistry. (Orthognathic surgery performed by Louis Belinfante.)

Figure 33.21 **(C)** Note how the golden proportion caliper shows a more symmetrical face.

Pinho et al.,[70] who considered that a 4 mm shifting had no impact on the esthetic appearance as judged by a layperson. However, there was a significant difference between the results obtained in these studies. The main difference was that while the 2 mm threshold studies used facial photographs evaluating the entire facial composition, those that obtained higher thresholds used photographs of the two lower facial thirds evaluating the dentofacial composition without taking the eyes, nose, and chin into account. This emphasizes the importance of taking a step back from the traditional dentofacial assessment and a step toward a facially oriented/comprehensive esthetic analysis. Slight inclination of the dental midline does not respect parallelism to the facial midline and is thus considered unattractive, tending to create a degree of visual tension.[2,4,10,12] Frush[71] argued that canting of the dental midline was significantly more critical than its shifting. This means that the inclination of the dental midline is more easily detectable than its deviation, even if it keeps parallelism to the facial midline.[12]

The aforementioned perceptional study came to the conclusion that a 3.5° dental midline cant was easily detected; furthermore, when the dental midline was canted in the same direction as the nose tip and chin, the esthetic ratings were

Figure 33.22 **(A, B)** This patient had temporomandibular joint pain related to her collapsed bite and lack of stable posterior contacts. Although she had a rehabilitation completed in another country, it was determined that her bite had been overclosed.

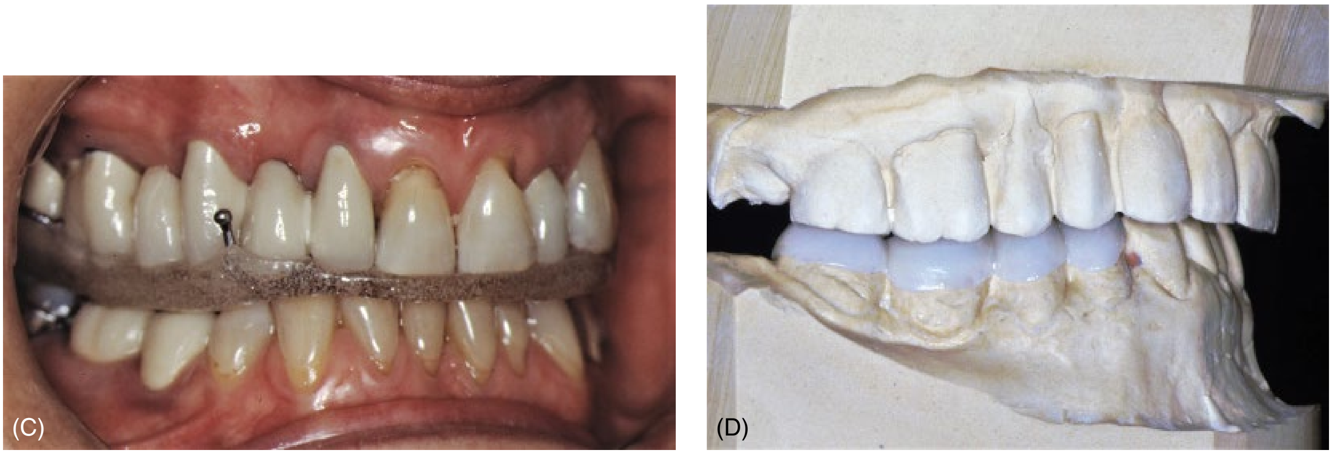

Figure 33.22 **(C)** The occlusion was tested with a full-coverage removable appliance for 3 months. **(D)** Two four-unit overlays were worn for 3 months to see whether the new posterior occlusion achieves the desired comfort and stability.

Figure 33.22 **(E)** The final maxillary and mandibular restoration consisted of ceramo-metal crowns and porcelain veneers.

higher than when the canting was in the opposite direction of the nose and chin deviation (Figure 33.18A and B). This means that each case should be evaluated individually because each face is unique. Moreover, these numbers should not be taken as thresholds of recognition that can be applied to everyone. What seems clear is that some facial structures can have an impact on the perception of some midline discrepancies and thus cannot be neglected during the esthetics diagnosis.

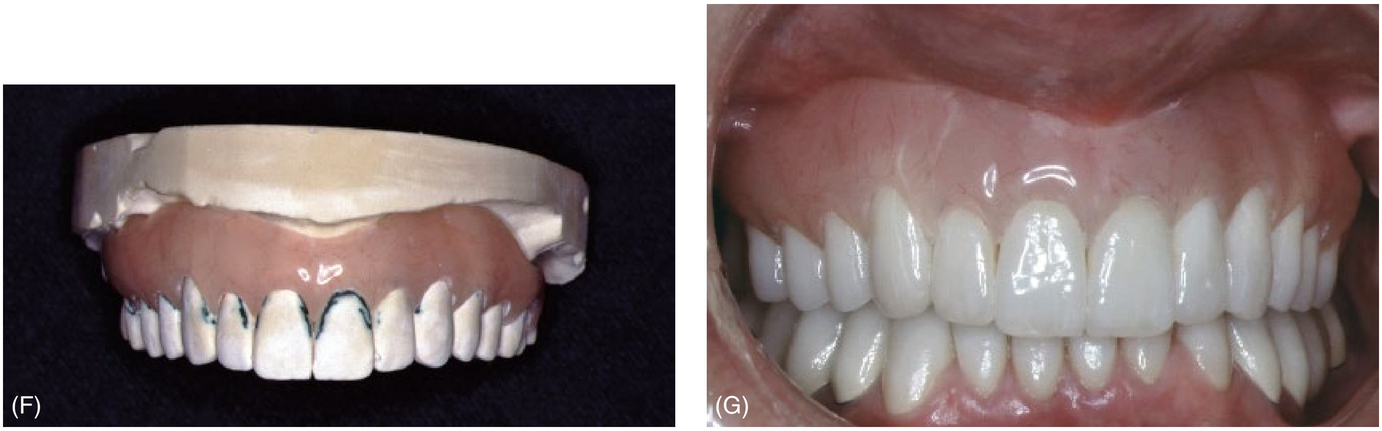

Figure 33.22 **(F–G)** Because the final restoration left open gingival interdental spaces, a removable acrylic artificial gingival appliance was constructed. The removable gingival appliance helped to better proportion the size of her teeth.

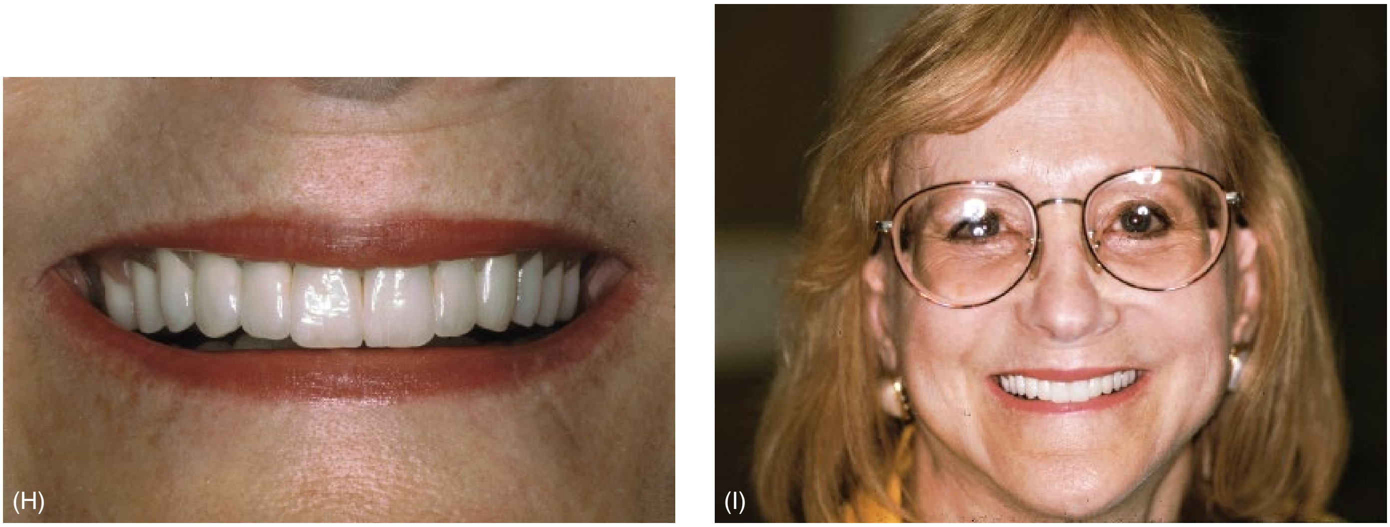

Figure 33.22 **(H–I)** Since the patient lived in a different state, it took considerable time for her to complete her therapy. Nevertheless, the patient felt the final functional teeth result was well worth the extra time and effort involved.

Chin and facial midline

Facial asymmetry can often be limited to the chin. If systematic analysis of facial symmetry reveals normal dental and skeletal midlines and vertical relationships of the maxilla but a lowered facial asymmetry, the asymmetry could possibly be isolated to the chin. Our opinion is that the chin's impact on the perceived facial midline and smile esthetics, as a midfacial structure, is smaller than the nose's tip; nonetheless, the chin cannot be neglected.

Incisal plane and interpupillary line

The incisal plane is a virtual plane that touches the incisal edges of the maxillary incisors and the tips of the cuspids in a frontal view. In this frontal plane, it can also be called the plane of occlusion. The perpendicularity of the incisal plane with the facial midline creates segregation forces that make the mouth the dominant element of the face. It is possible to evaluate the inclination of the incisal plane through a frontal full-smile facial photograph or, to be more precise, through a frontal cephalometry. Taking digital photographs with the half or three-quarter facial view just above the eyes can be very helpful.

Clinically, the interpupillary line usually is the reference line used to evaluate the orientation of the incisal plane, the gingival margin plane, and the maxilla.[12,48] Many facebow transferring systems use this horizontal reference line to relate the position of the maxilla to the cranial base; this is generally done when creating new occlusal guidances and planes of reference. Imbalances or disharmonies between the horizontal facial planes are possible and should be recognized and noted, such as the inter-ear line, interpupillary line, commissural line, and/or the horizontal line of reference.[18] Make sure you evaluate your patient in their natural head position. The best method is to have your patient either sitting straight or standing in front of a striped background with the stripes accurately demarcating the horizontal plane.

A lack of parallelism between the interpupillary line and the horizontal plane should be noted in the early stages; otherwise the facebow registration will be done using an arbitrary plane. This would directly affect the orientation of both the horizontal and vertical planes of reference of the future smile line.[18] If the natural head position is not parallel with the interpupillary line and the horizontal plane, and if the commissural line is parallel to the horizon, the commissural line should be considered as the horizontal plane of reference (Figure 33.25). If this is not corrected when transferred to the articulator, such discrepancies will show in the midline and horizontal planes, resulting in restorations that do not adhere to the principles of parallelism. Yet, if the interpupillary and commissural lines are parallel to one another but not to the horizontal plane, they can still be used as the horizontal plane of reference (Figure 33.26).

To sum up, if the interpupillary and commissural lines are not parallel to one another nor to the horizontal plane, the situation should be discussed with the patient to analyze their individual horizontal plane of conformity to the facial structures. Figure 33.8A–C shows a patient with an attractive smile who presents an interpupillary line not parallel with the commissural lines. However, the incisal plane is parallel to the commissural line, which makes the teeth appear harmonious inside the lip frame. Furthermore, the entire smile fits with the facial asymmetries, making the whole facial expression look very compatible in a natural posed smile.

In these cases, further stages are required to relate the smile to the horizontal plane. First, record the smile with the teeth and lips and reproduce it in the articulated cast to determine the soft-tissue reference. Second, relate the facebow transfer with a bite registration containing a horizontal element that would line up with the horizon. Third, adjust the provisional restorations intraorally to acquire a smile plane that is parallel to the horizontal. Fourth, use cross-mounted interchangeable casts of the provisional restorations with working casts.[18]

Another common mistake is canting the facebow while mounting it. This frequently occurs because the ear plugs of the facebow are positioned on soft tissue, which allows enough small movement to introduce a small cant of 1–2° on the incisal plane. There are two ways to avoid this problem. The first is to make a picture of the patient with the mounted facebow, which allows for detection of any cant and subsequent correction if needed. Another way is to use the digital facebow concept (see Chapter 4), which uses a calibrated and standardized frontal picture and a couple of reference points to mount the upper cast on the articulator according to the real horizontal plane determined from the picture (Figure 33.27A–D).

Some studies show that normal individuals with no pathology can present an average inclination of the occlusal plane in the frontal plane between 2.15° and 2.4°; this was without significant discrepancies between sexes.[20] Evaluating the incisal plane is

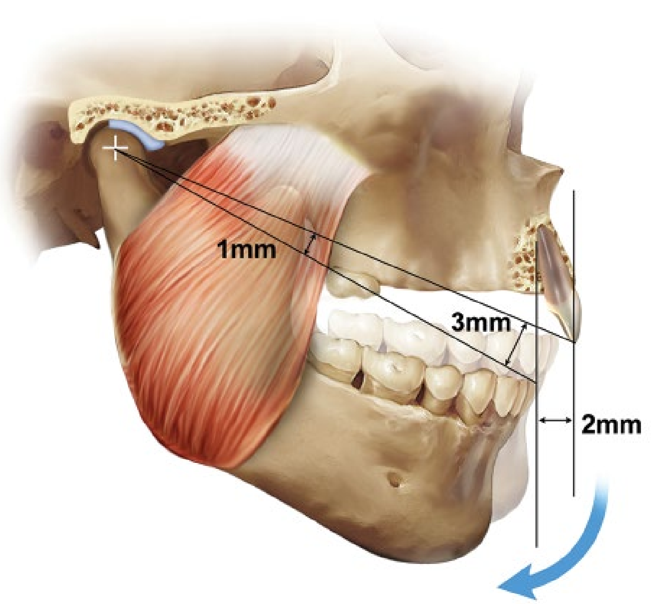

Figure 33.23 Increasing the vertical dimension of occlusion (VDO) by 3 mm in the incisal area means opening approximately 1 mm in the molar region (a 3 : 1 ratio). This 3 mm anterior opening also causes approximately 2 mm of horizontal change in overjet anteroposteriorly (a 3 : 2 ratio).

Figure 33.24 **(A)** In this brachycephalic face, the lower facial third was diminished due to severe wear and malocclusion (deep overbite).

Figure 33.24 **(B)** Orthodontic treatment before final restoration improved the interocclusal relationship, allowing for better esthetics and function.

Figure 33.24 **(C)** Increasing the VDO improved facial balance. In more extreme cases, it may be difficult to achieve large changes in the lower third by only increasing the VDO.

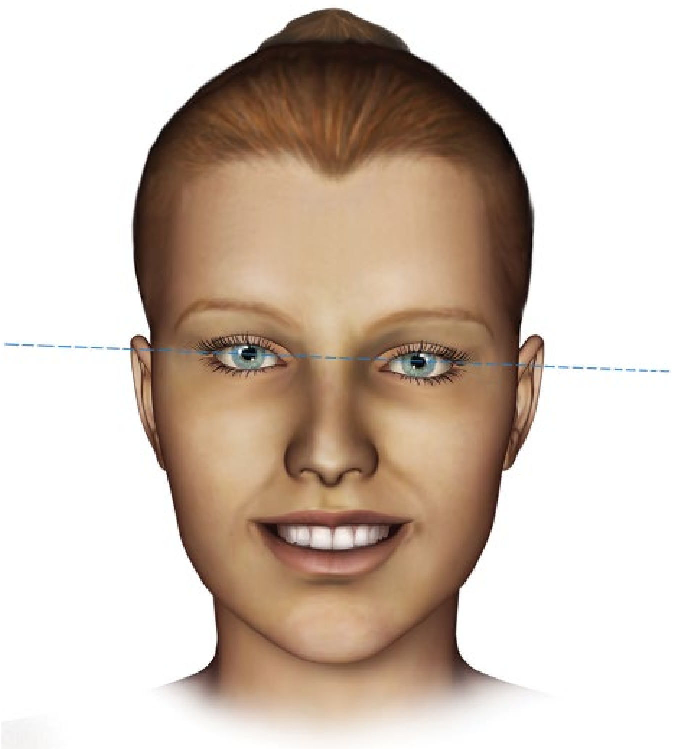

Figure 33.25 Postural head position reveals a lack of parallelism between the interpupillary line and the horizontal plane (horizon). In this situation, a facebow that parallels the interpupillary plane will result in a canted smile line. Instead, if commissural line is parallel to the horizon it should be used as the plane of reference. This must be diagnosed before treatment planning the case, so the maxillary cast can be mounted and waxed up to match the desired reference plane.

Figure 33.24 **(D)** Final full coverage restorations gave the patient the function and smile that she was hoping for.

important in patients with clear facial asymmetries, but also in apparently normal individuals needing extensive dental treatment. Padwa et al.[20] were the first to quantify the inclination of the plane of occlusion in the frontal plane identifiable by both laypeople and dentists. He reached the conclusion that a layperson can identify occlusal plane angulations greater than 4° in

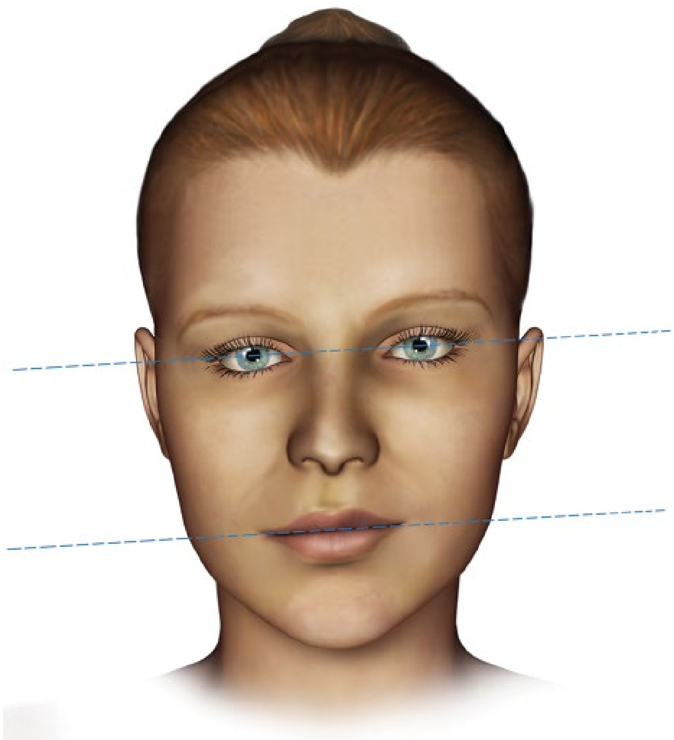

Figure 33.26 In this illustration, interpupillary and commissural lines are parallel to one another, but not parallel to the horizontal. In this situation, a thorough pretreatment diagnosis must be completed to determine the optimal plane of reference.

Figure 33.27 **(A)** Facial frontal picture is oriented according with the natural posture of the head. Two parallel and horizontal lines can be drawn crossing the pupils and the teeth.

Figure 33.27 **(B)** Dentofacial frame is cropped from the facial picture. A digital ruler is calibrated according to the width from the distal to the distal of the two centrals according to what was measured with a caliper in the stone cast.

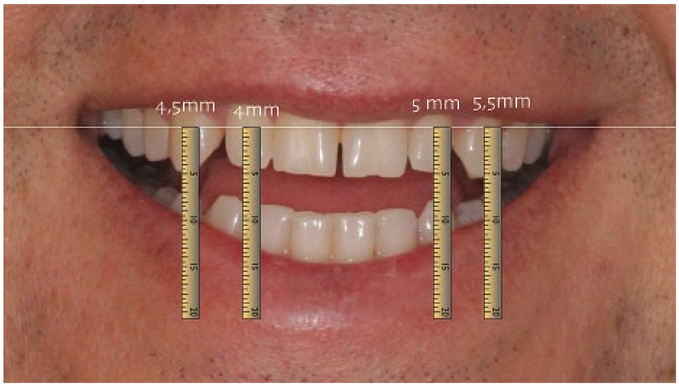

Figure 33.27 **(C)** The digital ruler is now ready to measure the distance from the incisal edges to the horizontal plane in three or four different reference points.

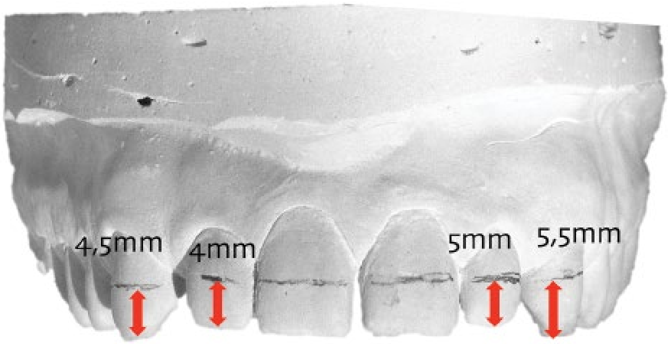

Figure 33.27 **(D)** The points are now transferred to the cast model allowing to the trace line (the real horizontal plane, determined from the facial picture). Now the model is ready to be transferred according with this plane.

90% of cases; this was such the case with 98% of the experts (Figure 33.27E–I). The reported difference between laypeople and expert observers was not statistically significant, which suggests that the clinical identification of occlusal canting depends on the canting degree rather than necessarily on the dental qualification of the observer. According to Padwa et al.'s conclusions,[20] over 50% of the population can recognize an occlusal inclination of just 2°, and apparently symmetric patients can have an occlusal canting that ranges from 0° to 2.4° (Figure 33.27E–I).[20] Finally, it must be noted that transverse tilting of the maxilla is generally accompanied by mandibular asymmetry.

Figure 33.27 **(E)** Incisal plane parallel with the horizontal plane.

Figure 33.27 **(F)** Incisal plane cant 2°.

Figure 33.27 **(G)** Incisal plane cant 3°.

Figure 33.27 **(H)** Incisal plane cant 4°.

Figure 33.27 **(I)** Incisal plane cant 5°.

Lip symmetry

Lip symmetry should be assessed while in both rest and function. It is relatively common to find completely symmetric lips when at rest that lose their symmetry when they perform functions like smiling. These situations are much more frequent nowadays with the increased popularity of Botox or other esthetic lip treatments. These asymmetries are often unesthetic due to the irregular tooth exposure between the right and left sides (Figure 33.28A and B).

Attention should be drawn to labial commissures that do not have the same height, as they will cause one of the main facial reference lines, the commissural line, to be canted. This must be diagnosed from the beginning to avoid using the wrong horizontal reference plane. As was said before, these cases require further steps and discussion with the patient to analyze their individual horizontal plane of conformity to the facial structures. In some cases, it may be appropriate to take the commissural line as a reference point while maintaining the parallelism of the incisal curve with the lip frame, as long as harmony with the other facial structures is not broken (Figure 33.8A–D). In other cases, the interpupillary line, or even a mean between both reference lines, is more indicated. In summation, each case should be individually assessed and supplemented by a good diagnostic wax-up with a mock-up, which immensely aids both clinician and patient in making a decision.

Another phenomenon is the rising of the lip higher on one side than on the other upon smiling (Figure 33.28A and B). This particular patient, however, could use much less lip coloring—or a lighter shade—to deemphasize the mouth. The arch of the lip on the left side should not be accentuated. Rather, coloring should be applied straight across to make the arch much less noticeable.

Lip irregularities combined with arch asymmetry can compound any esthetic restoration. Thus, it is absolutely essential to communicate the problem to the patient so that they thoroughly understand the nature of the deformity and the best options available to correct it. If there are no favorable options available,

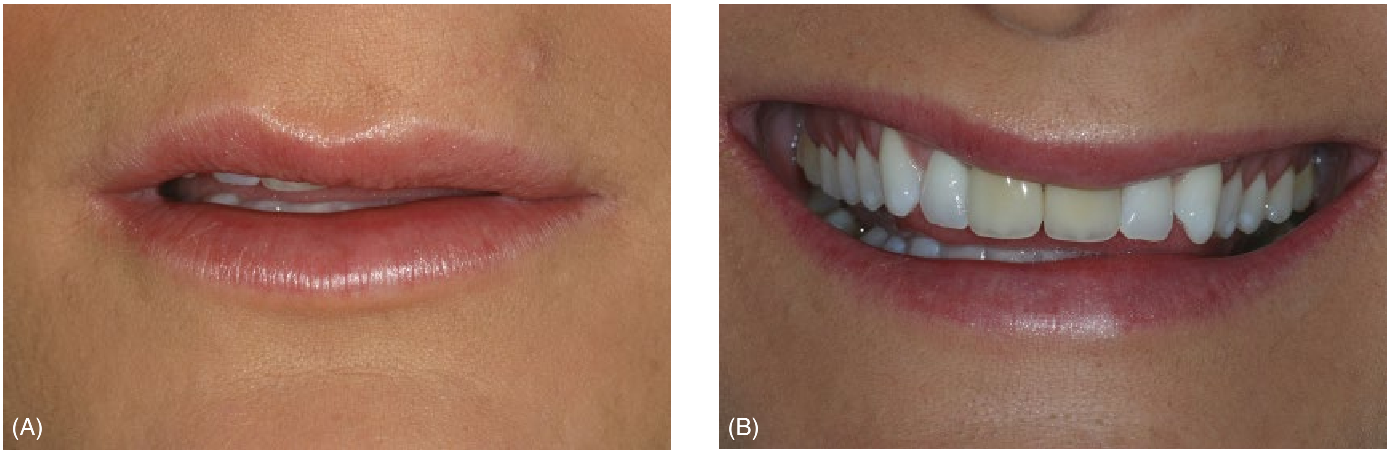

Figure 33.28 **(A, B)** Lip asymmetry at rest and during smiling.

then it is important to let your patient know to what degree you can help them. The result will obviously be an esthetic compromise, and there should be no surprises at the end of the treatment. This is definitely the time to plan one or more methods to let the patient know what to expect. This can be done via esthetic imaging, a pretreatment trial smile, and/or a treatment trial smile. The first two are preferred, since a different option can be easily presented if the patient is not satisfied with the proposed treatment plan. The rule "no treatment is better than the wrong treatment" definitely applies here.

Figure 33.29 **(A)** Excess mucosal tissue on the patient's lip detracts from her smile.

Excess mucosal tissue can make the mouth unattractive (Figure 33.29A); scar tissue can also create an unattractive lip line (Figure 33.29B). Both conditions are treatable by plastic surgery. Patients with this condition should make the eyes the focal point of the face and deemphasize the mouth, achievable by using little or no lip coloring and more eye makeup (Figure 33.29C).

Be sure to carefully document every detail you explain to your patient, as well as everything your patient tells you. This is a good indication for a consultation to be recorded using video so that there can be no misunderstanding about what is and is not promised or even implied.

Lip length

The lengths of the upper and lower lips can aid in establishing a differential diagnosis between an anatomically short upper lip and a vertical maxillary excess. To accurately assess lip length,

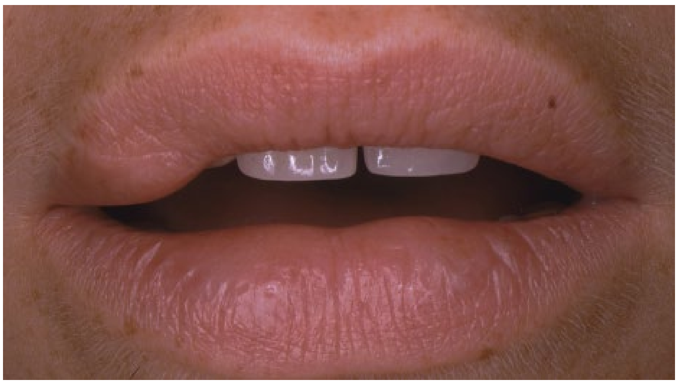

Figure 33.29 **(B)** Scar tissue shows how it affects the lip line.

Figure 33.29 **(C)** An asymmetric lip line affects the appearance of the smile. In this case, the lady would help her appearance if she altered the height of her lipstick.

the lips must be at rest without tooth contact. The lips should be measured separately in a relaxed frontal position. The normal length from the subnasale to the upper lip in a young adult is between 19 and 22 mm.[31] An upper lip of 18 mm or less is considered to be short and is generally accompanied by increased incisor exposure and an interlabial gap with a normal lower facial height.[31] This should not be confused with vertical maxillary excess, where the interlabial gap, incisor exposure, and lower third facial height are increased.[31]

The lower lip is measured from the superior border of the lower lip to the soft-tissue menton point, and it normally measures 38–44 mm. The normal ratio of the upper to lower lip is 1 : 2.[31] The association between an anatomic short lower lip and a Class II malocclusion is frequent and can be verified measuring the lower anterior dental height on the cephalometry (lower incisor tip to hard-tissue menton; women 40 ± 2 mm, and men 44 ± 2 mm).[31] A difference should be made between an anatomically short lower lip and a short lower lip secondary to posture when the upper incisors interfere with the lower lip; this is generally associated with a Class II deep overbite. The plastic surgery procedure known as a genioplasty can be performed to lengthen an anatomic short lip.

Lips at rest position and interlabial gap

The interlabial gap with lips at rest should be 1–5 mm (the distance between the inferior edge of the upper lip and the superior edge of the lower lip). Women usually tend to show a larger gap than men. The interlabial gap may be larger in situations where there is an anatomic short upper lip, vertical maxillary excess, and/or a mandibular protrusion with an open bite due to cusp interferences.[63] A decreased interlabial gap is found with vertical maxillary deficiency, anatomically long upper lip, or mandibular retrusion with a deep bite. In any of these cases, the restorative dentist cannot do much to change the interlabial gap.

Closed lip position

To improve the diagnostic patterns and to be able to detect disharmonies between skeletal, dentition, and soft-tissue length, it is necessary to thoroughly understand the closed lip position. Increased mentalis muscle contraction, lip strain, and alar base narrowing are observed when the vertical dimension is increased far from what is recommended; this can also happen in cases with vertical skeletal excess (Figure 33.21A–C), anatomic short upper lip, and some cases of mandibular protrusion with an open bite. Lip redundancy can be found when patients have lost vertical occlusion; it can also be associated in some cases of mandibular protrusion with a deep bite.

Facial analysis: oblique view

The oblique view provides information that is not obtainable on the frontal view about spatial relations between the maxilla and mandible in a facial three-dimensional context. The occlusal plane can sometimes be canted anteroposteriorly and therefore not be consonant with the inner curvature of the lower lip.

Lip anatomy should be analyzed from both an oblique and a profile view. The height of the philtrum should be noted as short, balanced, or excessive, and the vermillion display can be easily evaluated from this view as excessive, balanced, or thin. This perspective adds valuable data about how teeth relate with perioral tissues at rest and in function (see "Dentofacial analysis" page 1119). Therefore, pictures and video should also be taken in both left and right oblique views, approximately at 45°. This is important to do because in most social encounters we only briefly look at people's faces from a frontal perspective. However, the rest of the time we socialize from different oblique angles.

Facial analysis: profile view

Profile analysis is conducted while the head is in its natural position.[11,30,31,56,64] The patient should be instructed to look straight ahead, possibly looking for their own image in a mirror. The natural head position can be checked using the Frankfort plane (the most inferior orbit point with external auditory meatus) as reference; usually this plane makes an 8° angle with the horizontal.[64]

Profile angle

The facial profiles are evaluated based on the relative sagittal position of the maxilla and mandible with the glabella. The angle formed by the glabella, subnasale, and soft-tissue pogonion allows the appraisal of general harmony of the lower third.[11,30,31,56,64] Class I dental and skeletal relationships present an angle range of 165–175° with a slightly convex facial plane. Class II angles are less than 165°, giving a greater convex appearance. Those characteristics of Class III are greater than 175° and show a concave relationship of these three points.[30,31] Class II angulation includes maxillary protrusion (rare), vertical maxillary excess (common), and mandibular retrusion (common). Class III relationship includes maxillary retrusion (common), vertical maxillary deficiency (rare), and mandibular protrusion. Several studies have analyzed the profile differences among races[48] and have found that North Europeans tend to show posterior divergence while Native Americans frequently present anterior divergence.[48]

In order to produce a more comfortable intercuspation position, it is crucial to first establish a differential diagnosis of a Class III VDO (due to skeletal relationship) or a pseudo-Class III (secondary to dental interference or lack of posterior teeth) which leads to an anterior mandibular rotation. Some patients with loss of VDO can exhibit a concave profile that resembles a skeletal Class III relationship for the same reason as a pseudo-Class III: the anterior rotation of the mandible into maximum intercuspation. In these cases, restoring the VDO will decrease the overbite and increase the overjet as the mandible rotates back to centric relation, creating space for lengthening the teeth. This can be clinically checked before treatment using a composite resin mock-up and assessment of phonetics, occlusion, and facial esthetics (Figure 33.30A–D).

Excessive convex and concave facial profiles cannot be changed restoratively. Patients who seek esthetic treatment to change these conditions should be referred to an orthodontist or an oral surgeon.

Figure 33.30 **(A, B)** This young lady had a convex profile complicated by her lingually slanted maxillary interiors.

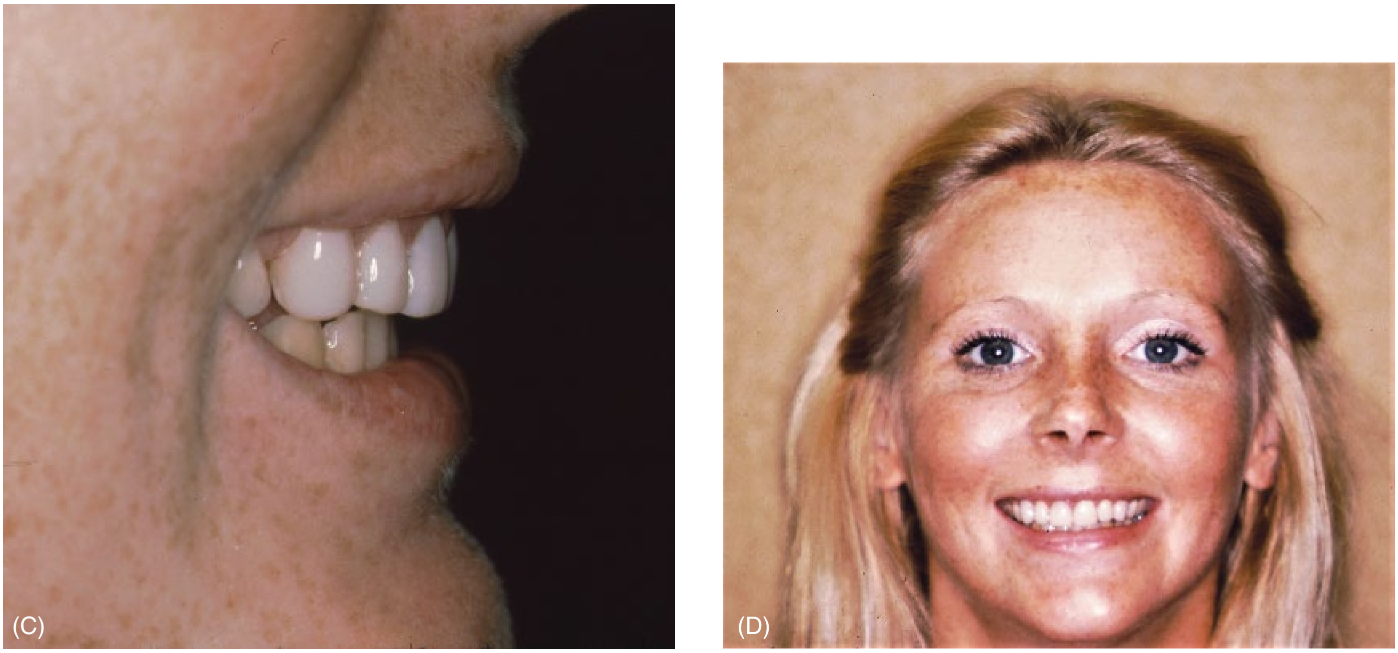

Figure 33.30 **(C, D)** Orthodontic therapy plus final direct-bond composite veneers helped improve the patient's facial appearance.

Nasolabial angle

Figure 33.31 shows the nasolabial angle, formed by connecting the columella to the subnasale and upper lip anterior point. It allows for the evaluation of the lip position on a sagittal plane and also gives some information about skeletal and dental relationships. There are significant sex differences: female patients usually show a more obtuse angle (100–105°) than males (90–95°). Some authors have found significant differences between Caucasians (who presented mean values between 102° and 110°) and Koreans (93°), Chinese (92°), and African Americans (90°), who presented significant inferior values for the nasolabial angle.[48]

Restorative dentistry alone can have a slight effect on the nasolabial angle and lip position because both are determined by several factors: the anteroposterior position of the maxilla, anteroposterior position of the maxillary incisors, vertical position or rotation of the nasal tip, and soft-tissue thickness of the maxillary lip, which contributes to the nasolabial angle. Restorative

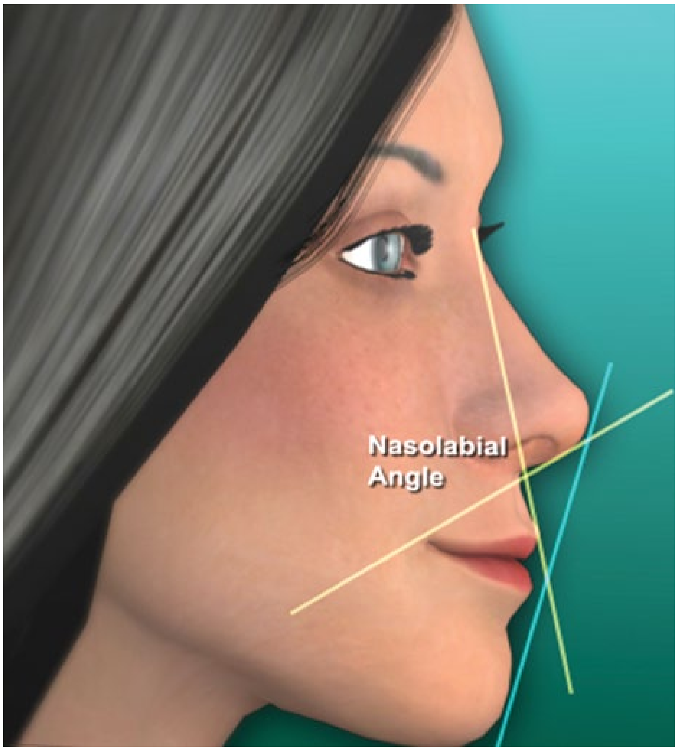

Figure 33.31 The nasolabial angle is formed by connecting columella to subnasale and upper lip anterior point. It allows the evaluation of the lip position on a sagittal plane, and also gives some information about skeletal and dental relationships.

dentistry can only change one factor: the anteroposterior tooth position. It is important to know that the lower half of the upper lip is supported by alveolar bone and by the gingival two-thirds of the maxillary incisors; this means that the incisal third and the incisal edge position have a minimal effect on lip position.

The patient's profile, nasolabial angle, and lip position can suggest the size/dominance of maxillary anterior restorations. If the maxilla is prominent and the nasolabial angle is less than 85°, or the profile is convex, consider using smaller and less dominant anterior restorations to naturally balance the esthetic convexity of the patient's profile.[64] On the contrary, more dominant anterior restorations can have an esthetic impact on concave profiles.[64] Whereas orthognathic or plastic surgery combined with orthodontics is usually the ideal treatment, orthodontics plus lighter shaded direct composite resin bonding can make an improved facial appearance (Figure 33.30A–D).

Orthodontic and orthognathic treatments are the only means to achieve major lip repositioning. Plastic surgery can be used to fill out lip contour and decrease the nasolabial angle or to correct an inferior border of the nose that gives an abnormal nasolabial angle. In an esthetic face, the inferior border of the nose is canted slightly above the horizontal from the base of the nose to the tip. In circumstances where the nose tip cants downward below the horizontal, changes to the nasolabial angle may be desired, in which case plastic surgery is the appropriate treatment.

A profile dominated by a disharmonious nose shape or size can seriously limit esthetic improvement by dental intervention, and therefore should be evaluated for correction by the plastic surgeon. However, there are patients who prefer the strong influence of the shape of their nose; thus, any change in the arch alignment may negatively alter the facial balance. In this situation, the patient must be thoroughly informed about all the treatment possibilities and variances. Figure 33.32A–C shows the profile of a young lady who was concerned about her slightly protruding porcelain laminates but who liked the shape of her nose. Although orthodontic treatment would ordinarily be the choice of correction, computer imaging revealed that her nose would be out of proportion to her face after orthodontic correction. Unless she had both the teeth and nose treated, she would be better off without any correction.

Lip position and projection

The esthetic nature of the face is such that the lips play a major role. Lip position not only controls facial expression but also influences the beauty of the face. Several factors influence the appearance of the lips. To begin with, the size of the lips can influence the patient's perception of the selected tooth shade. For instance, when patients with very large thick lips speak or smile slightly, there is a shadow created by the lip that can make a light tooth appear darker. This also means it is imperative to know if a patient with thin lips has any desire to have the lips enhanced. If so, suggest a lighter shade than you would normally do and let the patient know why.

People display their teeth in four basic ways when they smile. They may show only their maxillary teeth, only their mandibular teeth, both, or neither. To restore esthetics, it is important to attempt to preserve or restore the patient's best smiling position. The appearance of the entire face is affected by lip position. For example, the relative prominence of the chin can be influenced by lip position. If the lower lip protrudes, the prominence of the chin is diminished. The converse is also true. If the lower lip is retrusive, the chin appears more prominent. The prominence of the nose is affected in the same way, but by the position of the upper lip. The patient may have acquired abnormal lip mannerisms in speaking or smiling for any of the following reasons: in an attempt to hide bad teeth, because of a collapsed bite, or because of lost or reduced occlusion or other type of malocclusion. These habits affect how the teeth are viewed and may not disappear, even with complete occlusal rehabilitation (Figure 33.33A–F). Patients may also develop unnatural occlusal relationships to hide a retrusive or rather asymmetrical jaw. They develop these detrimental habits because they either consciously or unconsciously see improved facial shape by doing so; furthermore, it is not uncommon to find temporomandibular joint problems in these patients.

Sagittal lip position can be esthetically evaluated using one of the published reference lines[3,12,30,31,42,44,64] (Figure 33.33G). "The relationship of the lips relative to these lines can be helpful in the diagnosis and treatment planning of the position of anterior teeth and the alveolus. The use of these lines will demonstrate if the lips are anterior or posterior to the ideal, giving an indication as to the positioning of the underlying teeth and alveolus. Lips that appear anterior to the reference lines generally require retraction of the teeth and/or the alveolus."[56]

Figure 33.32 **(A)** This patient wanted to have porcelain veneers to build out her teeth, but was advised the veneers would be too thick unless orthodontic treatment was done before. **(B)** This image shows the patient that if orthodontic therapy was done it would make her nose disproportionate to her face. **(C)** Unless the patient was willing to commit to surgical correction of the nose along with orthodontic intervention, she would be better off without the orthodontic change. This photo shows the patient what the combined orthodontic, veneers, and surgical correction to her nose would look like. Since she loved her "Roman-shaped" nose, she declined any treatment.

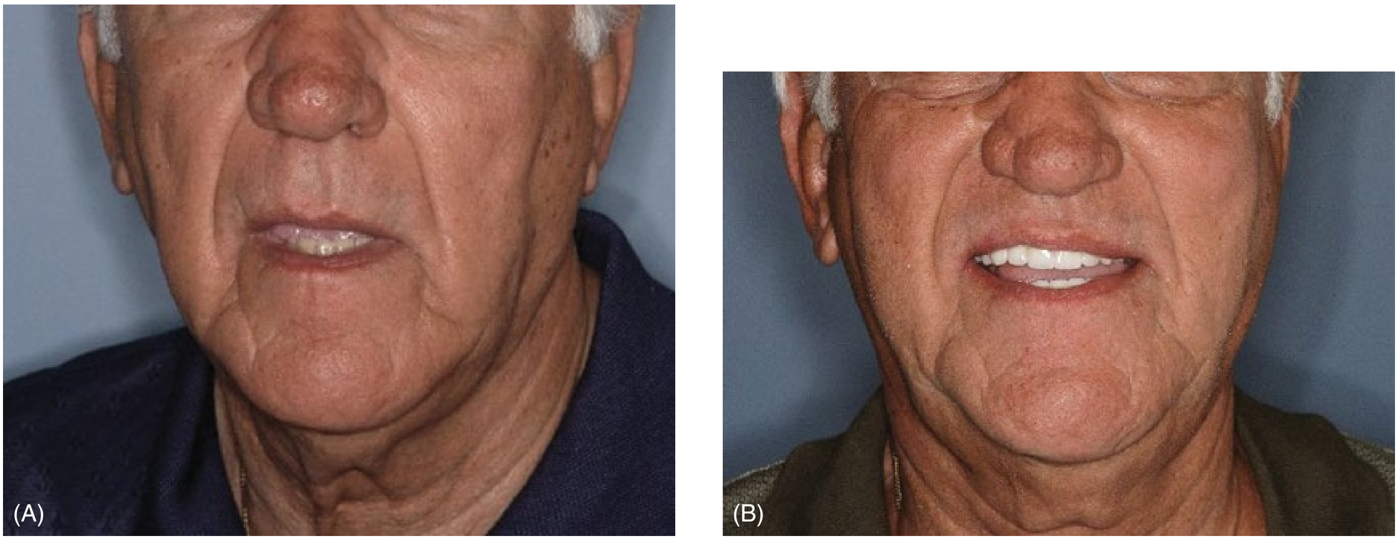

Figure 33.33 **(A, B)** This patient developed a habit of hiding his upper teeth when speaking or smiling in order to hide his Class III occlusion plus discolored and failing dental treatment.

Figure 33.33 **(C)** Since the patient declined orthodontic or surgical treatment, a full mouth rehabilitation was required to stabilize function and improve esthetics.

Figure 33.33 **(D–F)** With his new restorations, over time he grew more comfortable and was able to smile and speak with confidence.

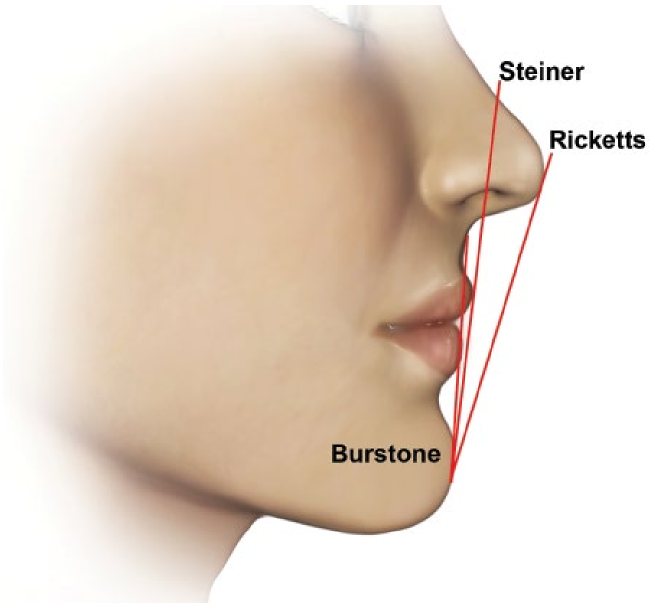

Figure 33.33 **(G)** Sagittal lip position can be esthetically evaluated using one of the published reference lines suggested by Ricketts, Steiner, and Burstone.

Ricketts[42] established the E-plane from the nasal tip to the chin, where in an ideal profile the upper lip should be 4 mm from this plane and lower lip 2 mm.[3,12,30,64] We recognized that significant differences may exist between sexes. Recent research[48] studied this relationship among different races and reached the conclusion that the majority of races studied (Japanese, Chinese, Korean, Hispanic) obey the Ricketts principle. However, Caucasians have shown a particularly different mean distance from the E-plane: 7.5 mm for the upper lip and 5.2 mm for the lower. Furthermore, African American lips are usually found to be anterior to the E-plane and the lower lip is more prominent than the upper lip: 0.3 mm and 2.9 mm anterior to the E-plane respectively. According to Steiner, the upper and the lower lip touch the line that connects the nose midpoint to the chin.[43] Finally, Burstone[44] established that the upper and lower lip should be 3.5 mm and 2.2 mm respectively farther from the line that connects the subnasale point to the pogonion point.

In cases where the lips seem excessively posterior to these lines, advancement of the maxilla or mandible may be required, and a referral to the orthodontist or the maxillofacial surgeon should be considered.[56] As mentioned previously, some authors argue that, in 70% of cases, lip support comes from the cervical two-thirds of the maxillary incisors. In addition, the upper lip position is determined by tooth position instead of incisal edge positioning.[72]

Ridge replacement

The location of the alveolar ridge contributes to lip support and facial appearance. Most facial deformities stem from malformations of alveolar processes, which can cause malpositioning of the teeth, lips, and cheeks. If the alveolar ridge is in a protruded or anterior position that makes the lip overextend, the removal or loss of a tooth will not provide an esthetic solution. A prominent alveolar ridge can interfere with the esthetics of any anterior restoration because the patient will show too much gingival tissue, resulting in an unpleasant smile, even if all teeth are present. In this situation, any fabricated anterior restoration will usually be prominent and noticeable. When correcting a ridge deformity, orthodontic treatment or orthognathic surgery may also be necessary to successfully create an esthetically balanced appearance.

Just as the protruded ridge causes a problem, so does the retrusive ridge. Early tooth loss can also cause ridge resorption over a period of years. When this occurs, the position of teeth in a prosthesis becomes important. It may be necessary to position the teeth anterior to the ridge to gain good lip support. Alternatively, it may be necessary to position the teeth in a labial inclination, depending on the relationship of the anterior teeth to the lips. Adequate lip support is essential to compensate for the retruded position of the ridges and the subsequent facial profile around the area of the oral cavity. Figure 33.34 shows the labial inclination of the maxillary anterior teeth that achieves an esthetic lip position in the Class III patient.

A major alternative treatment for ridge resorption is ridge augmentation surgery. Several types of surgical procedures can be attempted. The ridge should be viewed from two perspectives: horizontal and vertical. Horizontally, it is rather facile to see where the ideal ridge position should be. Much harder to see is the “trench-like” deformity left by tooth extraction that can best be seen by looking from the incisal aspect. Both deformities can be repaired through ridge augmentation (see Chapter 37).

Tooth position

Relative tooth position in the arch is a determinant of lip position. A change in the teeth—occlusion, type, size, position, or vertical or horizontal overlap—may alter the facial appearance. A dramatic example is one of a patient who cannot close their lips when the teeth are at rest or in centric relation or severe protrusion (Figure 33.4A and B).

The relationship between the upper and lower lips is also influenced by the degree of overjet and overbite. Excessive overjet can make the lips protrude. Excessive overbite can contribute to the loss of vertical facial height, collapse of the lips, and wrinkling around the corners of the mouth.

Labiomental angle

Defined by the curve of soft tissue between the lower lip and the chin, the labiomental angle can vary greatly in form and depth.[11,31] The mandibular sulcus contour can be affected by the

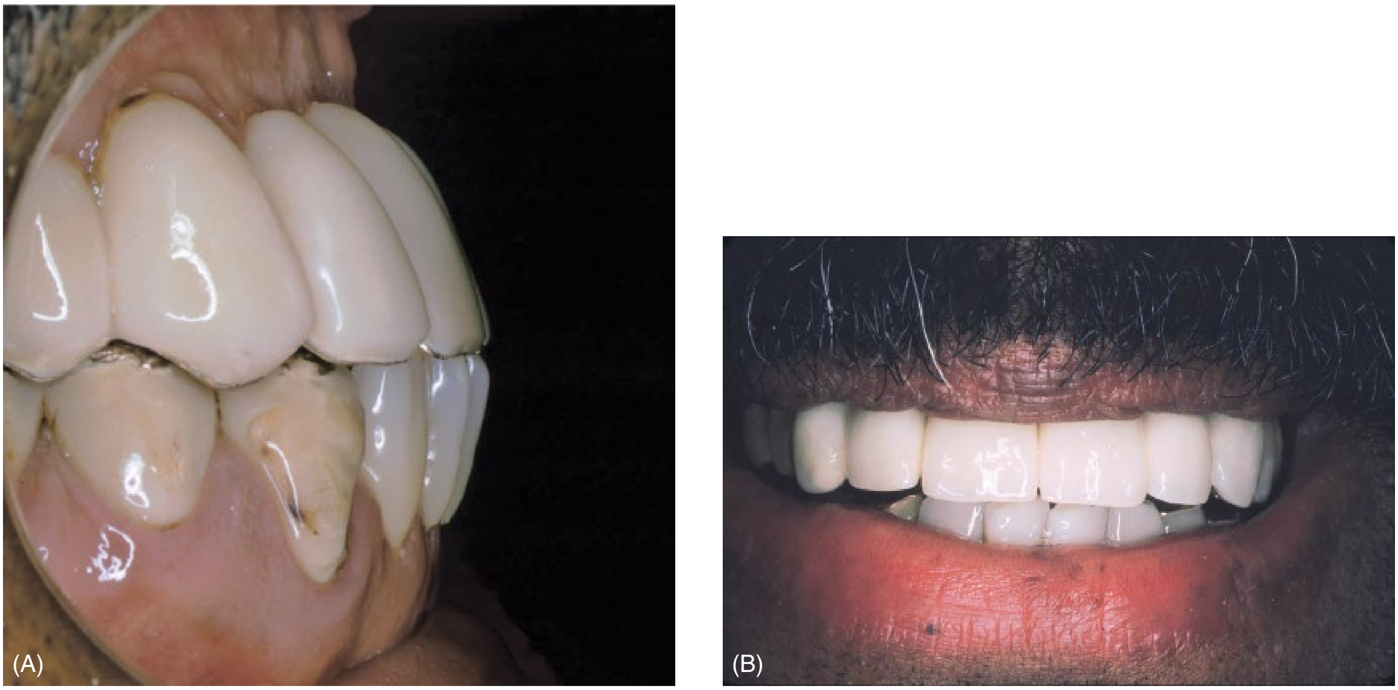

Figure 33.34 **(A, B)** In this gentleman’s dental rehabilitation, a labial inclination of the maxillary incisors makes up for a deficient alveolar ridge. This provides lip support, as well as an esthetic relationship between the maxillary and mandibular dentition. However, other surgical and orthodontic treatments should also be considered when treatment planning a case such as this.

lower incisor position and lower facial height.[11] Upright incisors will result in a shallow labiomental angle due to the lack of lower lip support; on the contrary, excessive proclination of lower incisors will deepen the contour. If the lower facial height is decreased for any of the aforementioned reasons, the result will usually be a deeper labiomental fold.[11]

Dentofacial analysis

The relationship between the incisal edges of the upper incisors, the lower and upper lips, and the gingival margins of the maxillary incisors is a key feature of facial esthetics. The natural postural head position should also be used in dentofacial analysis.

Tooth exposure at rest

The amount of tooth exposure at rest should be evaluated from a frontal view with the patient standing in an upright position. The mandible should be at rest, lips slightly apart in the rest position, and teeth not touching. Sometimes it is difficult getting the patient into the rest position while being able to take a good picture. For this reason, video is definitely the best method to evaluate how the patient gets into rest position in a completely natural matter. A rehabilitation plan involving tooth position references that have been lost requires considerations of the upper and the lower lips and the incisor exposure as reference points.

The incisor exposure at rest is one of the main factors that can be used to determine incisal edge position. This will be determined by considering the age and sex of the patient, the length and curvature of the upper lip, and the clinical crown length.[73] The average anatomic crown length values for the maxillary central incisor are 10.5 ± 1 mm.[74] A central incisor that can be seen when smiling but not at rest will give the appearance of an older face (Figure 33.35A–B).

Vig and Brundo[75] demonstrated how the degree of dental exposure is a dynamic element throughout life. The clinician should be aware that the amount of maxillary teeth exposure at rest decreases throughout life, while mandibular teeth exposure increases. Vig and Brundo[75] studied the relationship between the incisor exposure through resting lips with aging and came to the conclusion that time is a major factor on the amount of this exposure. The average 20-year-old exposes 3.5 mm of the maxillary incisors and none or very little of the mandibular teeth. The muscles and perioral tissues become increasingly lax with age, reducing the amount of maxillary incisors displayed and increasing the visibility of the mandibular incisors. The laxness starts

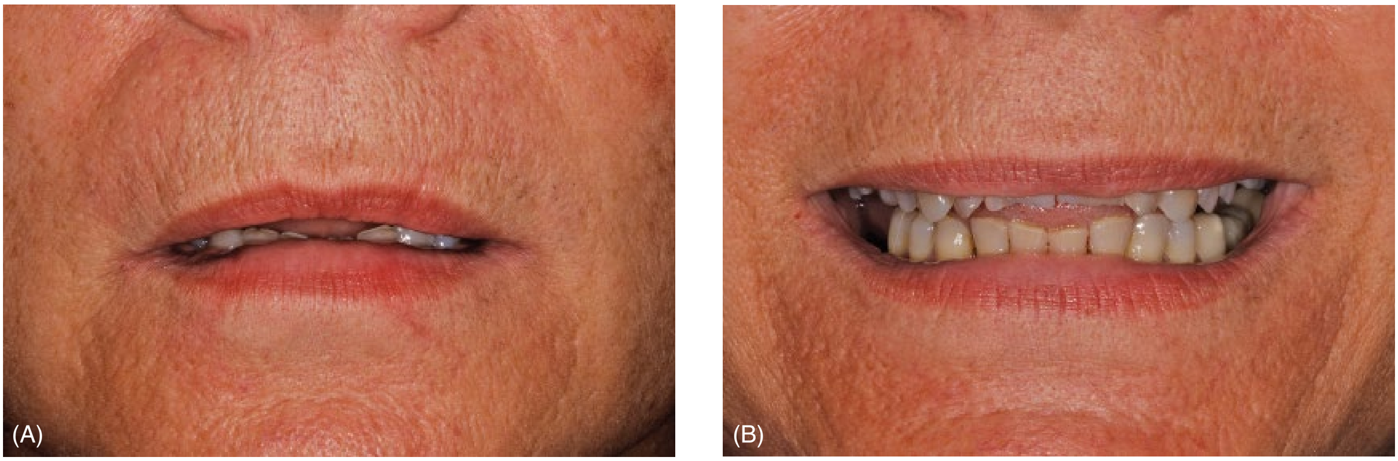

Figure 33.35 **(A–B)** Reduced visibility of the maxillary incisors both at rest and smiling due to extreme tooth wear.

Figure 33.35 **(C)** Quick direct composite mock-up on teeth (#8 and #9), without etching the teeth to assess the incisal edge lengthening esthetically and functionally (phonetics).

Figure 33.35 **(D–E)** Comparing the before smile on this patient, it is easy to see why she was so pleased with her new look.

around the age of 30–40 years, causing the maxillary incisor exposure average to decrease to less than half. Afterward, the maxillary incisor exposure is further reduced 0.5 mm on average for each decade, such that by the age of 70 years they are no longer visible.

Dickens et al.[76] conducted a study demonstrating that the heights of both the philtrums and the commissures increase with time and lead to a decreased display of teeth with increasing age. Furthermore, the philtrum's lengthening rate is greater than that of the commissure's; this is the responsible factor for flattening the "M" that is characteristic of the vermillion border of the upper lip in older patients compared with young people (Figure 33.35I and J).

Different conditions can reduce the amount of incisors shown at rest, such as excessive wear. The compensatory eruption that occurs in some patients suffering from incisal attrition is not fast enough to compensate for the loss of tooth structure, leading to a reduced visibility of the maxillary incisors both at rest and smiling (Figure 33.35A–B). In these situations, plan on a quick direct composite mock-up on teeth #8 and #9. This must be done without etching the teeth to esthetically and functionally assess the incisal edge lengthening (phonetics) (Figure 33.35C). Photographs and videos should be done in both frontal and oblique perspectives; and if the patient is comfortable and esthetics are favorable, the incisal edge index registration can be done with polyvinyl siloxane putty. The lab technician can easily transfer the preset incisal edge position by repositioning the index on the mounting casts before starting the diagnostic wax-up. The final result can be seen in Figure 33.35D–H.

The delayed eruption of the maxillary permanent incisors due to early loss of the primary maxillary incisors (As and Bs) before the complete development and eruption of the permanent teeth (generally due to caries or trauma) can allow the mandibular incisors to overerupt. This supereruption creates an unfavorable edge-to-edge occlusal position and a reduced maxillary incisor exposure.

Finally, the anterior teeth exposure can also be affected by the length and thickness of the upper lip, with longer and thicker lips reducing the tooth exposure.

Incisal edges and the lower lip

The relationship between the incisal edges of the maxillary anterior teeth and the lower lip, in both a posed and spontaneous smile, is another reference that can be used to determine the incisal edge position anteroposteriorly and midfacially. Attention

Figure 33.35 **(F–H)** Upper arch rehabilitation was performed, with a small increase of VDO, to restore the incisal curve, tooth exposure at rest, and smiling, giving the patient a much younger look.

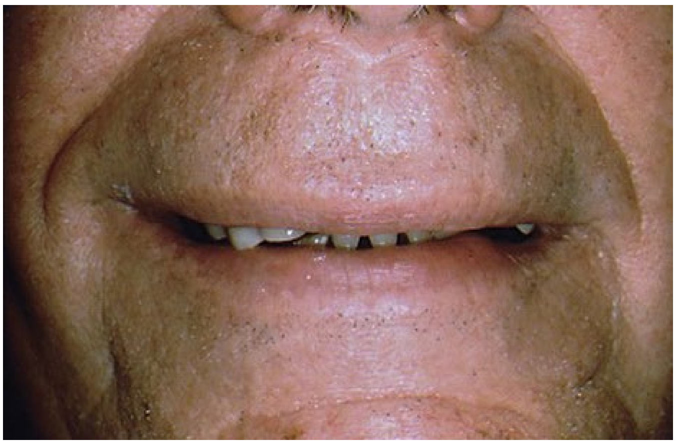

Figure 33.35 **(I)** This 78-year-old man's smile illustrates a decreased display of teeth, resulting in an older-looking appearance.

Figure 33.35 **(J)** Restoration consisted of restoring vertical dimension and lengthening his maxillary teeth that resulted in a much younger look.

should be made when taking photographic records to evaluate this parameter; this is because sometimes patients force a posed smile by placing the lower lip against the incisal edges, giving the illusion that there is no space between them. As such, the clinician should evaluate this parameter while talking with the patient to make an accurate diagnosis. Dynamic records should be taken in frontal, oblique, and profile perspectives to allow a sufficiently three-dimensional evaluation of this parameter.

From the frontal perspective of a smile, the maxillary incisal curve (defined by the incisal edges of the maxillary incisors) and the buccal cusp tips of the posterior maxillary teeth inscribe a convexity that follows the inner curve of the lower lip. Tjan et al.[51] found that parallelism between the upper incisal curve and the lower lip existed in 85% of the population, while Owens et al.[69] found 74% in an interracial study with no race or sex differences.

Frush[71] first described the reverse smile line (when the cuspids drop lower than the incisors) as being unattractive. White ivory wax was used to show the patient the proposed result. In this case, four full porcelain crowns were constructed to correct the problem (Figure 33.36A–C).

In other situations it may be possible to cosmetically contour the cuspids and the posterior teeth to lessen, or even eliminate, the reverse smile. The best approach is to use a black alcohol marker (Masel) and black out the areas of the teeth that could be contoured. Next, take a digital full-face picture with the patient smiling; then erase the marker and add composite or wax to lengthen the maxillary anterior teeth to their ideal position. Finally, take another digital full-face picture to compare the two treatment possibilities on the monitor; this will help the patient determine which treatment option would be most desired (Figure 33.37A–C).

Excessive incisal abrasion can flatten the maxillary incisal curve, or in more severe cases reverse this curvature. The esthetic result would be a reverse incisal curve, or a reverse smile line, where the canines stand out as the dominant smile element, giving an aggressive and older look to the facial expression. Figure 33.35I and J shows a patient with a reverse smile line due to a combination of attrition and erosion. The canines stand out upon smiling, making the smile less attractive. No tooth exposure at rest was observed, and visibility of the maxillary incisors at smiling was reduced. Upper arch rehabilitation was performed with a small increase of VDO to restore the incisal curve and tooth exposure, ultimately giving the patient a much younger look. Besides abrasion, an anterior open bite can cause loss of symmetry between the incisal curve and lower lip. A differential diagnosis should be made at the first stages to help plan the treatment.

As mentioned before (see "Lip symmetry" section), the lower lip is not always symmetric. In these cases, note that the inner curvature of the lower lip should not be used as a reference line for incisal curvature in the restorations.

Many authors suggest that the maxillary canines should come very close to touching or should actually touch the lower lip when smiling. Furthermore, the maxillary incisors should come about 2–4 mm short from touching the lower lip inside the vermillion border.[11] In their research about the position of the incisal curve relative to the lower lip, Tjan et al. reported that 47% of the population showed the maxillary anterior teeth touching the lower lip, 35% showed them not touching, and 17% had the incisal edges completely covered by the lower lip.[51] Tjan et al. used posed smile photographs; we believe that these results could change dramatically if they were to use dynamic records with spontaneous smiling. According to Van der Geld et al.,[47] the teeth are less covered by the lower lip when a person smiles spontaneously than when the smile is posed. He also concluded that, from an esthetic point of view, the differences between a spontaneous and posed smile were the most relevant for anterior mandibular teeth.

Smile line

The smile line refers to the position of the inner border of the upper lip during smiling, and thereby determines the tooth and gingival exposure. The smile line can be divided into three

Figure 33.36 **(A)** This man had a reverse smile line with the cuspids much longer than the lateral and central incisors. **(B)** Ivory wax is added to the incisal edges so the patient can see how added length to the maxillary central and lateral incisors improved the smile. **(C)** Four porcelain crowns plus new posterior restorations helped provide a more attractive smile line.

Figure 33.37 **(A)** This man wanted to correct his reverse smile line. **(B)** A Masel alcohol marker was used to show what the smile would look like if the teeth were contoured. **(C)** Ivory-colored wax was added to show what the smile would look like if the teeth were lengthened to correct it.

Figure 33.38 **(A)** Example of a high lip line.

Figure 33.38 **(B)** This smile illustrates a medium lip line.

Figure 33.38 **(C)** Example of a low lip line.

categories: a high smile line, when the clinical crown and gingiva of the anterior maxillary teeth are exposed (Figure 33.38A); an average smile line, when 75–100% of the clinical crown length of the maxillary anterior teeth are exposed in addition to the gingival embrasures (Figure 33.38B); and a low smile line, when the clinical crown display of anterior maxillary teeth is less than 75% of their length, and little or no maxillary teeth are exposed (Figure 33.38C).

Authors seem to agree that the most esthetically pleasing smile should not show more than 3 mm of gingiva.[56,64] Tjan et al. found that 10.5% of subjects had a high smile line, whereas 69% presented an average smile line, and 20.5% a low smile line. Significant differences were found between sexes: women presented twice as high a smile line than men did.[51] These findings were confirmed later by Owens et al.,[48] who found significant differences in gingival display between races: African American and Caucasians presented the greatest amount of gingival tissue exposure. However, we believe that these findings could change dramatically if dynamic records had been taken instead and, according to Van der Geld et al.'s conclusions, the prevalence of a high smile line would be much greater.[47]

A "gummy" smile, or excessive gingival display, consistent with a high smile line, may be considered an unesthetic characteristic by many patients. "The decision as to whether the amount of gingival display is an esthetic problem for which treatment is desirable is a personal choice."[11] This condition can have multiple etiologies, which should be identified early on: altered eruption, incisal attrition with compensatory eruption, and vertical maxillary excess. The diagnosis of vertical maxillary excess can be confirmed by facial analysis that shows any of the following: a long lower face, lip incompetence, or excessive incisor display at rest and smiling. These patients should be referred to an orthodontist and a maxillofacial surgeon. Altered eruption can be diagnosed by probing the facial bone crest, and crown lengthening can be done if necessary in these situations. A differential diagnosis between passive and active altered eruption must be done before periodontal surgery.

When discolored or nonvital teeth must be restored, a high smile line can pose the greatest difficulty (Figure 33.38A). If the gingiva recedes following placement of a veneer or full crown, the darkness of the root will be revealed, displeasing the patient. Another esthetic failure can result if the cervical margin of an anterior tooth is above the matching tooth in the quadrant; therefore, cosmetic periodontal treatment becomes much more important in the case of a patient with a high lip line.

If the patient has a so-called short upper lip and a high smile line, it is sometimes possible to shorten the teeth and raise the gingival level. However, if enough attached gingiva is present, gingivoplasty or gingivectomy may provide some improvement.

A true long or low smile line may be seen in Figure 33.40. When a patient has this type of smile line, it is possible to use any dental procedure without showing the cervical margin of the teeth. The patient may complain about not showing teeth, which can be remedied by orthodontics, bonding, veneers, crowns, or some other type of restorative procedure to lengthen the teeth. Figure 33.39A–D shows correction of this problem in a patient who needed full mouth reconstruction. In this case, the vertical dimension was restored and the incisors were lengthened through a combination of orthodontics and full mouth reconstruction of both arches. Note the improved smile line in Figure 33.39C.

Individuals with incisal wear can give the appearance of a low smile line. Figure 33.40 shows a patient with a short upper lip complicated by mandibular prognathism. In this case, the incisal level of the lower arch could have been adjusted when the mandibular reconstruction was performed to improve the facial appearance. Figure 33.33A and C shows the appearance of a low lip line in a Class III patient. A low lip line can be caused by a bad habit, such as a conscious attempt to hide an unsightly oral condition, leading to the development of muscle control into an unconscious response. Even after this disagreeable condition has been corrected, it will take additional time and reassurance before this bad habit can be broken so that the patient can have a relaxed smile.

Finally, the loss of tooth structure is physiologic, and is a natural consequence of aging and wear. In physiologic tooth structure loss, vertical dimension is maintained by modeling of the alveolar bone (compensatory eruption) and the facial height remains constant. If the tooth loss is excessive, there is a high probability that the facial height will decrease due to the loss of VDO.[77]

Papilla display during smiling

Hochman et al.[78] studied the interproximal papillae exposure when smiling. This seems to be a critical issue to consider during the diagnosis in any esthetic restorative procedure. This research evaluated subjects with ages ranging from thirties to those in their eighties. The conclusion was that 91% of subjects showed interproximal gingiva when smiling. One of the most interesting

Figure 33.39 **(A–D)** This woman was concerned about not showing teeth when she smiled, as well as their dark color. There was insufficient tooth display due to her low lip line. A combination of orthodontic treatment and a full reconstruction of her upper and lower arches with a brighter tooth shade achieved the esthetics she desired.

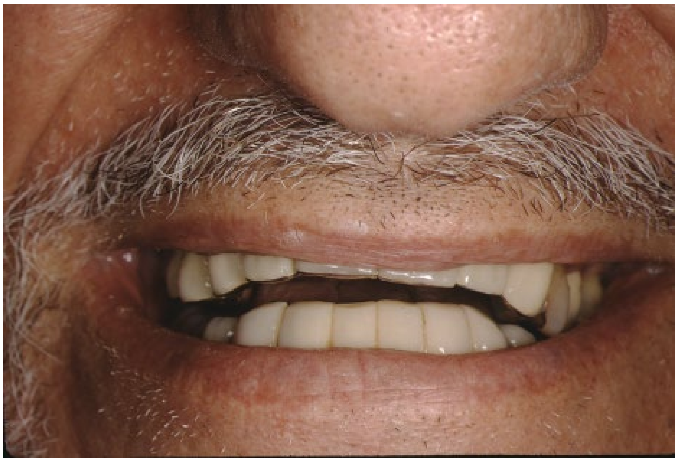

Figure 33.40 This patient had incisal wear and a short upper lip, complicated by mandibular prognathism. His smile could have been significantly improved if the mandibular teeth had been contoured at the time of his lower arch reconstruction.

findings of this study is the high prevalence (87%) of individuals with a low smile line who also displayed interdental papillae upon smiling. Clinically, this means that, even when treating adult patients with medium or low smile lines, the interdental papillae should be considered during the diagnostic and treatment planning process. This can make the difference between natural- and esthetic-looking restorations, versus artificial ones with increased interproximal contact surfaces between the teeth.

Smile width

Smile width refers to the number of teeth displayed in a smile and is directly related to arch form. A narrow or collapsed arch usually results in a narrow and unattractive smile; orthodontic and, possibly, surgical intervention are required to correct this. The smile width is determined by different factors: arch form, intercommissure length, facial muscle tone, and position of the buccal surfaces of the posterior upper teeth. Clinically, in posterior crown preparations, the margin location can be an esthetic issue when treating broad arches. The smile width is especially important when treating discolored teeth, as a misdiagnosis can lead to unesthetic situations. Sometimes the esthetic impact of a narrow arch can be reduced by building out the surfaces of premolars with bonding, veneers, or crowns (Figure 33.41A and B). Tjan et al.[51] has reported the number of teeth displayed in a smile: 7% of people show the six anterior teeth, 48% the six anterior and first premolars, 41% the six anterior and first and second premolars, and 4% the first molar. Van der Geld et al.[47] came to the conclusion that the posterior tooth display increased around 30% from a posed to a spontaneous smile. This can be explained by a significant reduction in intercommissure length in posed smiles compared with spontaneous smiles. We believe that the numbers reported by Tjan et al. could change if the spontaneous smile and the oblique prospective are evaluated instead of the posed smile.

Buccal corridors

The term buccal corridor was initially added by Frush to dental terminology in the late 1950s.[71] The buccal corridor refers to the dark space (negative space) created between the commissures of the mouth and the buccal surfaces of the maxillary posterior teeth that can be seen during a smile. Buccal corridors and smile width depend on the same factors and are inversely related. As the smile width decreases, the buccal corridors increase. Any discrepancy between the values (color) of the premolar and six anterior teeth can increase the darkness and prominence of the buccal corridors. A small amount of darkness is always present in esthetically pleasing smiles, although it can be increased in several situations, as described earlier. The absence of negative space due to, for example, overcontoured crowns has an unesthetic effect on changing the natural smile progression, creating an artificial look. Thus, attention should also be made not to obliterate the buccal corridors (refer to Figure 36.11C and D).

Figure 33.41 **(A, B)** This actress and model was displeased with the dark spaces (she called them "caves") that she saw on each side of her mouth when she smiled. The solution to this cosmetic problem involved building out both the front and back teeth with lighter-colored porcelain veneers. Lighter-colored teeth appear to stand out, whereas darkly stained teeth appear to recede.

Conclusion

Treatment planning a new patient may appear at first glance to be routine, especially if you have had years of clinical experience. However, your next new patient could be your first esthetic failure, which can be extremely stressful as well as costly. The reason? Failure to adequately spend the time to evaluate the various aspects covered in this chapter. Never take anything for granted. Even if your patient states they just want four anterior teeth crowned or veneered, the reality is it may not provide the patient with what they envision esthetically. Instead, the more you analyze and become aware of how all the facial considerations can affect your result, the greater your chance for esthetic success.

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Chapter 34 Plastic Surgery Related to Esthetic Dentistry

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Chapter Outline

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Although there are individual preferences as to what constitutes beauty, it seems almost universally accepted that society values a youthful face. Alterations in normal facial anatomy, be it post-traumatic, congenital, or secondary to aging, can have negative social and psychological repercussions for the individual affected. Having a balanced facial physique is inherently important in developing social interactions, maintaining self-confidence, and even securing gainful employment. By creating facial harmony, esthetic surgery procedures have become important adjuncts in restoring patient self-esteem and functionality.

Beauty is subjective, and there is no single formula that defines facial beauty. The concept of facial esthetics is a complex one involving interplay between underlying skeletal framework, soft tissues, and external anatomic structures. Although no single measurement, reference line, or angle completely translates to an esthetic ideal, there are some fundamental features that optimize outward appearance. The concept of balance from one side to the other is one such feature. While some asymmetries individualize a face, they should be minor enough to not disfigure or draw attention. Notions of harmony and proportion are important. Even, flowing curves from the upper to lower face create a harmonious, pleasing profile. Neonatal features, such as large eyes, small nose, round cheeks, and smooth skin, are usually deemed attractive.

Several medical specialties are involved in enhancing facial appearance. Esthetic dentistry focuses on the mouth, with the intent to optimize the quality of the teeth and smile. Altering the jaw and dentition invariably influences nearby structures and becomes intimately related to other procedures affecting facial form. There are numerous plastic surgery procedures that, although not specifically related to the mouth, have a definite relationship to cosmetic dentistry. A variety of both surgical and nonsurgical procedures exist to address the eyelids, nose, cheeks, chin, and neck. Esthetic plastic surgery, therefore, becomes an appropriate complement to esthetic dentistry, and often a combination of both yields optimal results.

To understand the range of surgical techniques available is to understand specific changes in the face as they occur over time.

Ronald E. Goldstein's Esthetics in Dentistry, Third Edition. Edited by Ronald E. Goldstein, Stephen J. Chu, Ernesto A. Lee, and Christian F.J. Stappert.

Erroneous assessment of facial features and the anatomy underscoring those traits may lead to inappropriate treatment and a disappointed patient. A comprehensive approach requires analysis of the face according to the upper, middle, and lower thirds. By evaluating these areas in an orderly fashion and taking into account the patient's personal desires, the plastic surgeon formulates a comprehensive plan to achieve desirable results.

Upper face

Browlift

The brow is usually arched with smooth, taut skin constituting the forehead. Over time, the skin from the hairline to the eyebrows can sag, causing drooping of the brows and skin redundancy in the upper eyelid area. Particularly along the outer portion of the brow, this can lead to hooding and an aged appearance reducing eye size. Muscles in the forehead and between the brows contract in an attempt to elevate the skin, resulting in horizontal and vertical forehead wrinkles. A browlift procedure releases this sagging tissue, resuspends it, and secures it in its newly elevated position. This can be achieved either through a series of small incisions located in the hair-bearing scalp, or through an incision located just behind the anterior hairline. In either case, scars are usually well camouflaged. The procedure may require general anesthesia, and recovery time averages a week or two secondary to both pain and periorbital bruising. Browlift procedures lift the eyebrow arch, minimize skin redundancy along the upper eyelid region, and smooth out the etched wrinkles that are seen between the brows and in the central forehead. The procedure is often combined with eyelid surgery (Figure 34.1A–D).

Blepharoplasty

Predictable changes occur in the periorbita over time. At the most superficial level, thin eyelid skin is subject to actinic damage and becomes wrinkled or "crepey." Retaining ligaments lose their consistency and weaken, with resultant sagging of skin and cheekbone complexes. The orbital septum, which normally contains the lower eyelid fat pads, relaxes, allowing herniation of the fat and appearance of lower lid "bags." In the lateral canthal region, the lateral canthal tendons elongate and loosen, producing a downward slant to the corners of the eyes (Figure 34.2).

These aging changes are surgically addressed with an upper and lower lid blepharoplasty (Figure 34.3). In the upper lid region, an incision is hidden along the natural upper lid crease. Through this, excess skin is removed and a sharp crease is defined and pretarsal or "eye shadow" space is recreated.

Figure 34.1 **(A, B)** Anteroposterior and lateral views of the patient prior to brow and eyelid surgery.

Figure 34.1 **(C, D)** Same patient after undergoing endoscopic browlift and upper lid blepharoplasty. Note the decreased hooding of the brow, which helps to open up the upper eyelid region and recreate a pretarsal space. The glabellar frown lines have also been substantially softened by the procedure.

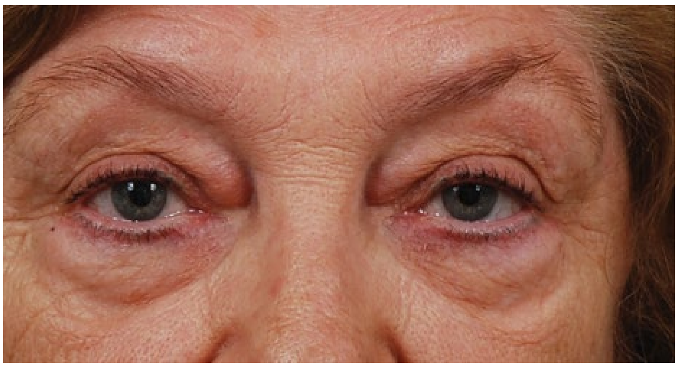

Figure 34.2 Typical changes in the eyelid region, including redundant upper lid skin, prominence of the upper and lower lid fat pads, and loss of the normal upslant along the lower eyelid margin.

Similarly, along the lower lid, an incision is made just below the lash margin. Through this, skin is elevated and redraped, and prominent fat pads are contoured or trimmed. Additionally, the lax canthal tendons can be tightened with either a canthopexy or canthoplasty. This positions the lower lid tightly to the globe at the level of the lower limbus, reestablishing a positive canthal tilt, or upward slant to the corner of the eye.

In most cases of upper blepharoplasty only, local or monitored anesthesia care suffices. General anesthesia is usually more appropriate for patients undergoing quad blepharoplasty. While not terribly painful, there is often a fair amount of postoperative ecchymosis and swelling that can take 14 days or more for resolution. There may also be a transient period of dry eyes, necessitating ocular lubricants. Patients are typically advised to refrain from strenuous activity for 4 weeks following surgery (Figure 34.4A–D).

Midface

Midface lift

Recently, there has been an expanding appreciation for the changes that occur in the malar region. In youth, the cheek is characterized by a smooth convexity from the lower lid to the area below the infraorbital rim. With aging, the midface musculature and malar fat pad descend. This is accompanied by volume loss, which has a deflationary effect and exacerbates midface descent. The result is loss of cheekbone prominence and lengthening of the distance between the lower eyelid and cheek.

Figure 34.3 **(A)** This middle-aged woman has laxity of her brows, and puffy upper and lower eyelids. She underwent a minimally invasive (endoscopic) brow lift combined with upper and lower eyelid surgery. **(B)** After the operation she has a much more alert and less tired look and the puffiness of the eyelids has been improved. *Source:* Nahai 2011 from *The Art of Aesthetic Surgery: Principles*. Reproduced with permission of Taylor and Francis Group LLC.[1]

Hollowing occurs in the infraorbital region with development of tear troughs and nasojugal grooves. The nasolabial fold deepens as soft tissues push downward against the relatively fixed nasolabial retaining ligaments (Figure 34.5A and B).

A midface lift reverses these changes by releasing midface soft tissues and vertically elevating them to restore a natural lid–cheek junction. The result is correction of nasojugal grooves, restoration of malar projection, and softening of the nasolabial lines. The technique involves a subciliary incision, subperiosteal dissection from the inferior orbital rim to the lower border of the malar bone, with elevation and suspension of the mobilized malar soft tissue complex over the infraorbital rim. Lateral canthal fixation in the form of a canthopexy or canthoplasty is essential to reestablish lid tone and counteract the cicatricial forces of midface descent that can occur in the early postoperative period. A midface lift is performed under general anesthesia and can be combined with other surgical procedures to correct changes in the upper and lower face.

Rhinoplasty

There is a wide variability as to what constitutes an esthetic nose. A pleasing nose is influenced by gender, race, skin quality, and the dimensions of other facial features. Typical ideals include a straight and midline nasal dorsum, a refined tip with defined nasal tip points, smooth alar contours without flaring, and a nasolabial angle of 90–95° in men and 95–100° in women.

More so than these specifics, rhinoplasty strives to reshape the nose so that it is in balance with other facial features and to correct nasal irregularities. Possible intraoperative changes can include modifications to the width of the nose at the bridge or base. Techniques exist to remove bony humps often seen on profile. A rhinoplasty can incorporate steps to contour the nasal tip such that it is narrow and slightly upturned. Nostril reshaping may also be performed for wide or flaring nostrils.

Rhinoplasty surgery is typically done under general anesthesia. Incisions are made across the columella, the tissue between the nostrils, as well as intranasally. The soft tissues are elevated off of the nasal framework. This combination of bony and cartilage structures can then be appropriately contoured to achieve desired results.

Recovery includes a 7–14-day period of bruising and nasal congestion. Dressings can include both an external nasal splint and intranasal packing. Swelling can persist for several weeks, but changes should be noticeable after the first week or so. Any need for revisions is delayed for a significant period of time, usually a minimum of 1 year, to allow full resolution of swelling and stability of form (Figure 34.6).

Figure 34.4 **(A, B)** A 58-year-old patient with evidence of lower lid skin laxity and rhytids.

Figure 34.4 **(C, D)** Following lower lid blepharoplasty, the infraorbital region is now smooth and the lower lid position is maintained.

Figure 34.5 **(A, B)** Aging in the midface includes descent of the malar triangle, manifest as a well-demarcated lid–cheek junction, hollowing below the lower lid, loss of cheekbone prominence, and formation of a nasolabial fold. The step off between the lower lid region and the upper cheek is clearly apparent on the lateral view.

Figure 34.6 **(A)** Pre- and **(B)** postoperative photos of a 29-year-old rhinoplasty patient. The procedure has elevated her nasal tip and refined the slope of the nasal dorsum.

Lower face

Genioplasty

There is an inherent and proportional relationship between the nose and the chin, and in combination they strongly influence the facial profile. Typically, the nose, lips, and chin are in alignment on side or profile view. A common finding seen in rhinoplasty patients is that of a concurrent receding chin or microgenia. The chin is recontoured with insertion of a chin implant, through an intraoral or submental incision. Alloplastic implant augmentation is excellent for minor deficiencies. In situations requiring more significant advancement, an osseous genioplasty can be performed. The approach for a genioplasty is either intraoral or an external submental incision. Recovery time averages 1 week or more.

Rhytidectomy

In youth, the skin of the lower face is firmly draped over the lower mandibular border and submental soft tissues. Changes usually start in the fourth and fifth decades. Although externally viewed as loose, redundant skin, the true etiology of lower facial aging is attenuation of the supportive fascial layers. The superficial musculoaponeurotic system envelops the facial mimetic muscles and is contiguous with the platysma overlying the neck muscles. In the process of facial aging, these structures become subject to gravity and downward-pulling vectors. Retaining ligaments, which normally maintain the skin over the bony periosteum, relax over time. Clinical manifestations of these processes include jowling across the mandibular line, marionette and nasolabial line formation, and loose skin across the anterior neck with an obtuse cervicomental angle (Figure 34.7).

A rhytidectomy, or facelift, addresses these changes not only by excising redundant skin, but more importantly by tightening the underlying connective tissue layers in the face and neck. By elevating and plicating these layers with sutures, sagging facial tissues are resuspended. Midface descent, ptotic jowls, and neck laxity are corrected and fixed at the deeper tissue level. Skin is redraped on this foundation and trimmed in the temporal scalp and along the anterior and posterior aspects of the ear. With tension directed toward the deeper layers and away from the skin, the result is a more natural, well-contoured look with less of a "windswept" appearance and "operated look" (Figure 34.8).

A drain is placed and removed within the first few days postoperatively. Patients are maintained in a removable chin strap to counteract swelling and facilitate skin retraction. Neck flexing should be minimized and blood pressure is well controlled to prevent hematoma formation. Recovery in terms of pain, swelling, and bruising ranges from 1 to 2 weeks.

Nonsurgical

The long-standing gold standard for achieving significant and durable changes in facial appearance is surgery. Injectable, nonsurgical treatments are recent options. According to the American Society for Aesthetic Plastic Surgery 2015 statistics, over 6.6 million injectable procedures were performed in 2015.[2] Although in most cases the results achieved with injectables are temporary and require repeat treatment, there are other advantages that make them highly appealing alternatives or, in some cases, adjuncts to surgery. Treatments are performed with or without local or topical anesthesia in an office setting. Recovery time is brief, with the most notable sequelae being the possibility of several days of bruising. Results are often immediate without incurring surgical scars. Cost is reasonable and much less than surgical procedures, but the cost is accumulative. For patients with medical comorbidities that preclude surgery, there is usually no contraindication to facial injections.

Neurotoxins

Most facial wrinkles are the result of underlying muscle activity. This is particularly true in the upper face, where dynamic muscles result in expression lines commonly known as "frown lines" between the eyebrows, "crows feet" around the eyes, and transverse forehead lines. Neurotoxins limit hyperactive muscle activity with softening of wrinkles and furrows. By eliminating muscle contractions, neurotoxins improve the appearance of established wrinkles and prevent the development of new ones. These injections may also be therapeutic in cases of facial asymmetry, such as facial paralysis, where treating muscle imbalance improves overall facial appearance. Results of neurotoxin injections typically manifest 2–7 days after treatment. Duration of results can vary from individual to individual but is most commonly in the 3–4 months range.

Soft tissue fillers

Facial hollows and depressions are the stigmata of aging, trauma, and occasionally surgery. The last two decades have seen a surge in techniques and products to fill facial wrinkles and augment folds. Dermal fillers are designed to restore volume, whether to a wrinkle line, a larger area, or a specific structure. Traditionally, fillers have been injected in the area around the nose and mouth, but more recently the areas for treatment have expanded. Fillers improve the nasolabial folds that arc from the alar base of the nose to the mouth and the marionette lines that extend from the corner of the mouth to the chin. Filler volume can also camouflage depressions such as the prejowl sulcus along the mandibular border, posttraumatic scars, or irregularities following rhinoplasty. They can enhance shape and definition when injected into the lips. Temporal hollowing, under-eye tear troughs, and malar volume depletion may also be treated with dermal fillers, resulting in some improvement and restoration of convexity. Fillers can also be used to enhance otherwise normal structures where volume and fullness are desired. Lip augmentation and cheekbone definition are examples of this (Figure 34.9).

There are a variety of fillers available, varying in chemical composition, duration, and applicability. Some are temporary, lasting in the region of 6 months, some are longer lasting, in the region of 2 years, and others are permanent. Not every filler is appropriate for every facial region. An experienced injector is well versed in assessing the facial contours, determining what product will be most efficacious, and utilizing injection techniques that minimize the risk of complications.

Figure 34.7 **(A, B)** This 56-year-old patient has age-associated changes in her brows, around the eyes, cheeks, jaw line, and neck. She underwent a minimally invasive (endoscopic) brow lift, upper and lower blepharoplasty and full face and neck lift. **(C, D)** Postoperatively she looks refreshed and less tired. Note the softening of the lid/cheek junction below the eyes, improvement in the marionette lines, and tightening across the mandibular jawline. *Source:* Nahai 2011 from *The Art of Aesthetic Surgery: Principles*. Reproduced with permission of Taylor and Francis Group LLC.[1]

Figure 34.8 **(A, B)** A 58-year-old patient desiring facial rejuvenation. **(C, D)** Patient following rhytidectomy and four-lid blepharoplasty. Patient appears younger without the stigmata of an "operated appearance."

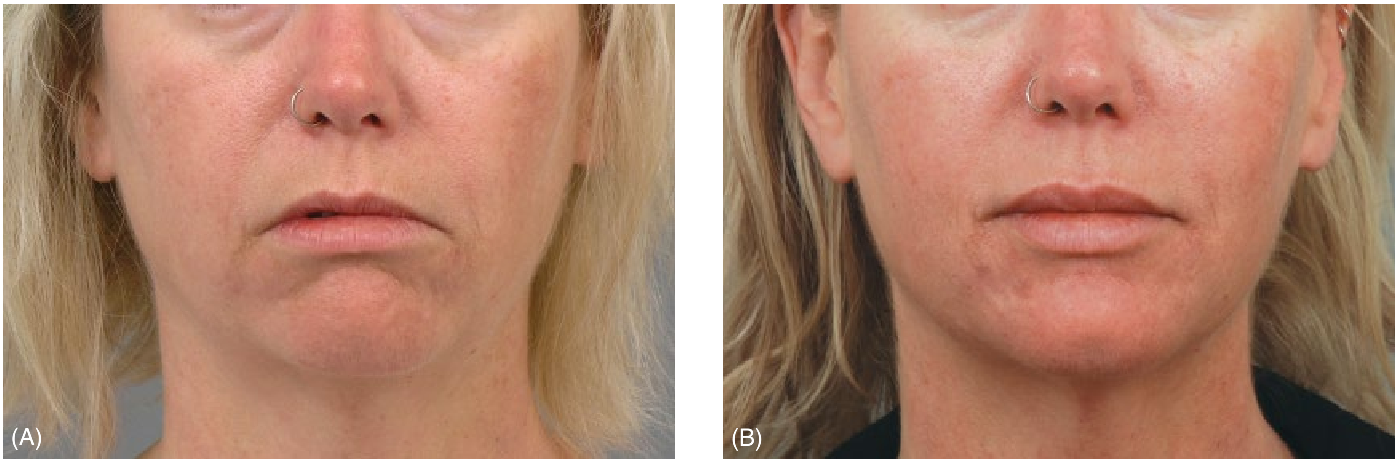

Figure 34.9 **(A, B)** Patient with soft-tissue fillers placed in her lips and lower face. The volume improves her symmetry and softens her overall appearance.

Facial resurfacing

Facial and neck skin undergo changes as a result of aging and photodamage. Although surgical techniques can correct structural changes that occur over time, they do little to address the textural changes seen in the skin. Deep perioral wrinkles or established crows feet often persist after facial surgery. Clinical improvement in skin quality and appearance is more readily achieved with nonsurgical techniques. Skin resurfacing softens wrinkles, erases sun-induced dyschromia, and tightens skin laxity. Lasers direct thermal energy to replace a damaged dermis with new collagen that results in wrinkle removal and skin tightening. Chemical peels essentially remove outer skin layers to improve irregular pigmentation and soften wrinkles. Dermabrasion remains useful to treat particularly deep or resistant wrinkles, such as "lipstick lines," acne scars, or posttraumatic scars.

Despite being noninvasive in nature, these resurfacing techniques do have some associated recovery time while reepithelialization is occurring. Immediate aftertreatment often involves maintaining skin moisture with occlusive dressings until epithelialization is complete. Long term skin improvement will be enhanced with adoption of a comprehensive skin care regimen and sun avoidance.

Patient safety

Any decision about what plastic surgery may be beneficial begins with an evaluation and consultation by a board certified plastic surgeon with expertise in esthetic surgery and cosmetic medicine. Because state laws permit any licensed physician to call themselves a "plastic" or "cosmetic" surgeon, prospective patients must select their doctor carefully. There are many physicians today practicing esthetic plastic surgery who have received their formal training in another specialty, often a nonsurgical specialty. A board certified plastic surgeon is certified by the American Board of Plastic Surgery (ABPS). ABPS is the only board recognized by the American Board of Medical Specialties to certify physicians in the full range of plastic and reconstructive procedures. To be certified by the ABPS, a physician must have at least 6 years of approved surgical training, including a residency in plastic surgery. They must also pass comprehensive written and oral exams in plastic surgery. A qualified physician is usually a member of a national plastic surgery organization, such as the American Society for Aesthetic Plastic Surgery or the American Society of Plastic Surgeons. With an emphasis on patient safety, the surgeon should be performing procedures in an accredited hospital or outpatient surgery center.

Conclusion

The goal of esthetic plastic surgery is to remodel normal structures to improve appearance. In facial surgery alone, many procedures are available to achieve just this. A skilled plastic surgeon is not only well versed in performing the technical aspects of these operations, but also in preoperatively assessing the possibility of achieving desired results. Accurately setting realistic expectations for the patient becomes a crucial component of achieving postoperative patient satisfaction.

Esthetic plastic surgery remains particularly relevant in the realm of dental esthetics by complementing work that is done to the jaw, teeth, and perioral region. Both disciplines are in constant evolution with the development of new products and techniques to improve outcomes and optimize patient safety. Although it is impossible to predict what innovations may occur in these specialties in ensuing decades, the link between esthetic dentistry and esthetic plastic surgery is a well-forged one that will persist.

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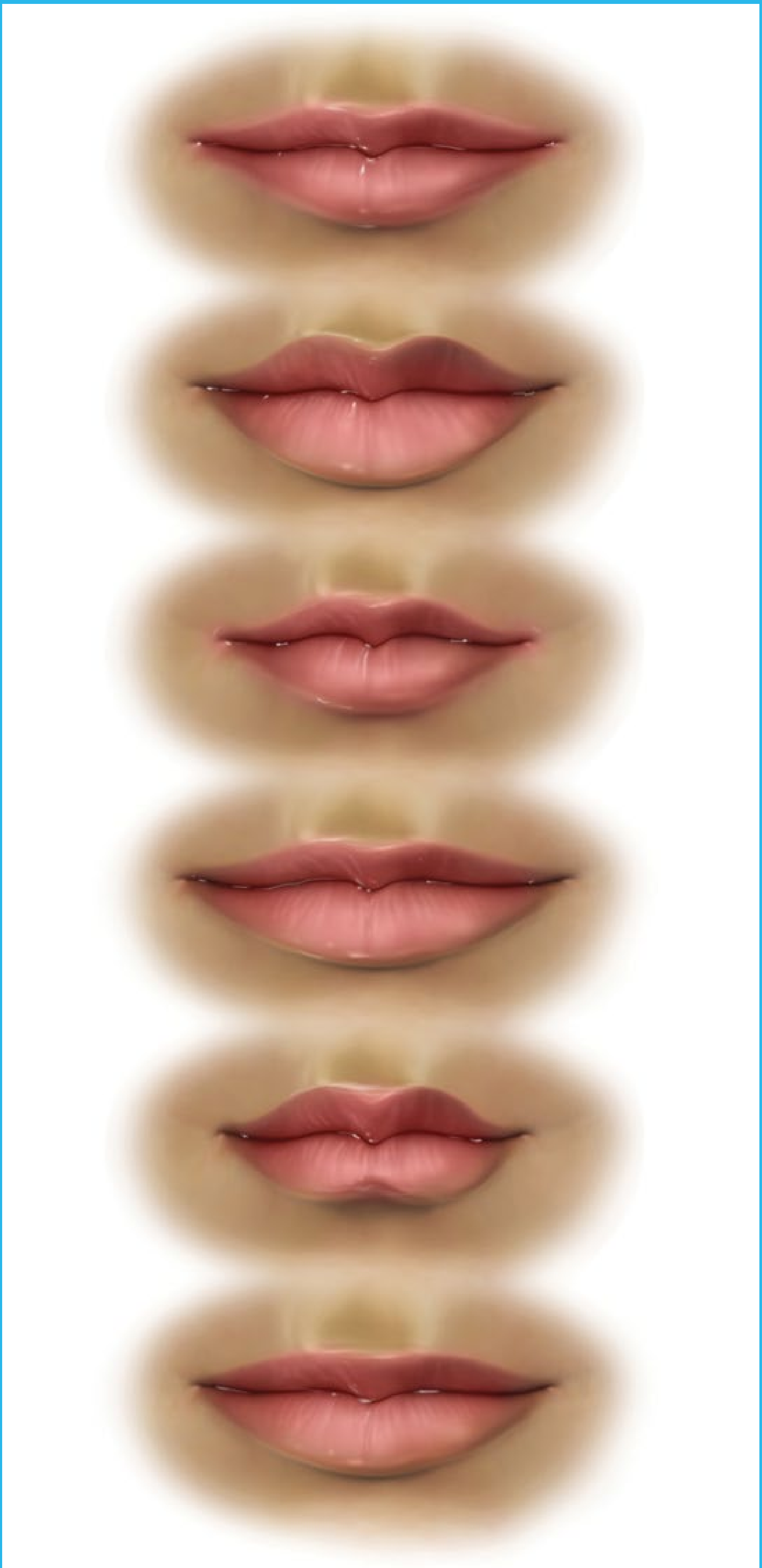

Chapter 35 Cosmetic Adjuncts

Ronald E. Goldstein, DDS, Richard Davis,
and Marvin Westmore

Chapter Outline

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The main goal of the cosmetologist, makeup artist, hairstylist, and plastic surgeon is the same as the cosmetic dentist: to help the person look their best. What the dentist needs to be aware of is that different facial shapes may require different sizes, shapes, color, and arrangement of teeth to help achieve the best look for that type of face. Thus, a partnership with the professional hairstylist, makeup artist, cosmetologist, or plastic surgeon can play an important role.

Since facial diagnosis plays such an important part in smile design, I have my dental assistants take a full series of digital photographs, including adequate full-face photos as outlined in Chapter 3. The photos are immediately downloaded in the computer, so both my patient and I can study them during the consultation. If I feel that one or more auxiliary facial treatments will improve the overall esthetic outcome, a discussion with the patient will take place during this or the next consultation appointment. I have never had a problem explaining possibilities once my patient asks my advice. In fact, when I plan a full mouth smile makeover, I will frequently include a complimentary "day at one of the best hair salons in Atlanta." Usually, I suggest a new hairstyle and makeup session with the salon. Most patients cannot wait for this day to take place and never let me forget it!

The question most dentists ask me is how can they bring up the subject without insulting the patient? I preempt my discussion with an explanation to the patient that "I design the smile based on how it will look best with your face so I need to know a few things about your future plans. First, do you ever change your hairstyle or are you open to change? And second, are you planning any facial surgery in the future? Your answer may well influence the type of smile design I create."

Obviously, it is wise to discuss cosmetic adjuncts with patients who are really looking for a new smile to help "change their life" or to look much younger. These types of patients generally appreciate my advice and ask who I would refer them to for a makeup artist and plastic surgeon. And if a plastic surgeon is desired, I offer several names I have worked with.

Ronald E. Goldstein's Esthetics in Dentistry, Third Edition. Edited by Ronald E. Goldstein, Stephen J. Chu, Ernesto A. Lee, and Christian F.J. Stappert.

I actually began my study of the topic early on in my career when I examined thousands of male and female faces and even formed the first interdisciplinary esthetics study club that consisted of a plastic surgeon, hairstylist, and makeup artist among other dental specialists. We learned from each other with our biweekly meetings, usually with live patents as well as slide presentations.

The bottom line is the more you study the possibilities of what can be accomplished with plastic surgery, makeup, and hairstyle, the more qualified you will be not only in smile design but also in helping your patients get the most out of their life.

Hairstyling can be a positive asset to enhancing one's appearance. The length and texture of the hair as well as the color and style all have an influence on a person's self-image. A hairstyle frames the face and can minimize or conceal protruding ears or an overly round face as well as a prominent forehead. On the other hand, the hairstyle can draw attention to negative facial features. Thus, a hairstyle can play a major role in the balance and symmetry around the face. Hair design utilizes illusions that not only can enhance the face but also help the dentist achieve a more satisfied patient with their new smile.

The hair design that a person may choose can improve or take away from their overall appearance and the treatment that has been completed on their smile. For instance, an excessively short hair design could be very flattering on a perfect oval or square face but could be unflattering on a long or triangular face. Hair that frames the face can draw attention to specific areas or it can be used to change the area of exposed face to give a more pleasing shape. Care must be taken in determining the hair design, so as to enhance the positive aspects of the face. A hair design that an individual may choose could be determined by many factors: personal desire, lifestyle, ease of care, type of hair (i.e., coarse thin/thick, etc.) current fashion trends, or peer influence.

The most important factor, though, should be the proper balance with the facial features and bone structure. The ideal solution for a dental practice is to seek out a professional hair designer/hairstylist who has a reputation for creating complimentary and flattering hair design for improving esthetic appearance. Websites are usually quite helpful to see just how successful a hairstylist has been with previous clients or models.

A hair designer will work with several different facial shapes, as shown later, but most people fall into five basic facial shapes: oval, round, square, long, heart shape. Ideally, all angles of the face need to be considered when making a hairstyle selection.

Facial shape for women

The ideal illusion most often sought after by stylists is the oval face. To distinguish an oval face, the length of the face should be one and a half times the width, as in Figure 35.1. Oval faces can be the most proportionate, meaning they can wear any kind of cut or style (short, medium long, sharp, and full). There are several styling suggestions for working with an oval face. For example, if the face looks long, having the stylist create bangs across the brow line can break up the length and also add width to the face.

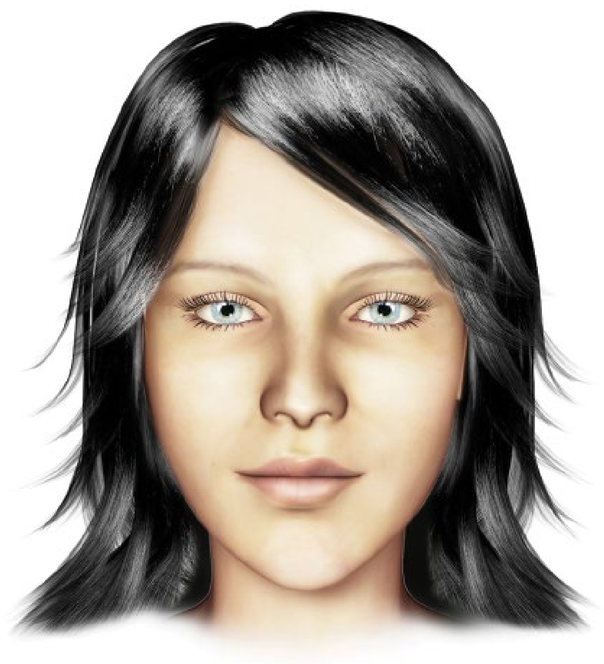

Figure 35.1 This illustration demonstrates how the oval face can look good with most any hair type or style.

Another suggestion is creating a short cut with side swept hair across the forehead which can show off the neck and collarbone. It can also break up a long face.

The round face is as wide as it is long (Figure 35.2A and B). A great design would be a layered cut with a swooping side bang. Avoid super-short designs unless there are longer layers around the face, to keep the face as slim as possible. Another technique is creating a sleek up-style above the ears which will create greater facial definition. This will make the cheekbones appear longer, and with the height it will even out the rounder dimensions. Another suggestion is a pixie cut that can emphasize the cheekbones and eyes. A round face also looks great with an uneven cut which has a mix of different lengths. The face will look slimmer if the hair is side swept across the forehead.

A square face has angular cheeks and jaw (Figure 35.3A). In having a square face, the goal is to play down the strong angular jaw. To soften these features, curls or frayed ends can be added. Layering is another technique the stylist can use. This type of face can also wear a short, spiked look or a long sleek design with soft layers starting around the jawline. A tousled short shag cut with body can deemphasize the square shape of the face (Figure 35.3B).

Principles of esthetics

The heart-shaped face, has a narrow jaw with wider cheek bones, and sometimes a wider forehead (Figure 35.4A–D) This shape may be able to sport shoulder-length hair and long waves. They can also wear shorter hair, but should always have either full or longer bangs swept across to cover the wider forehead. The goal is to emphasize the eyes.

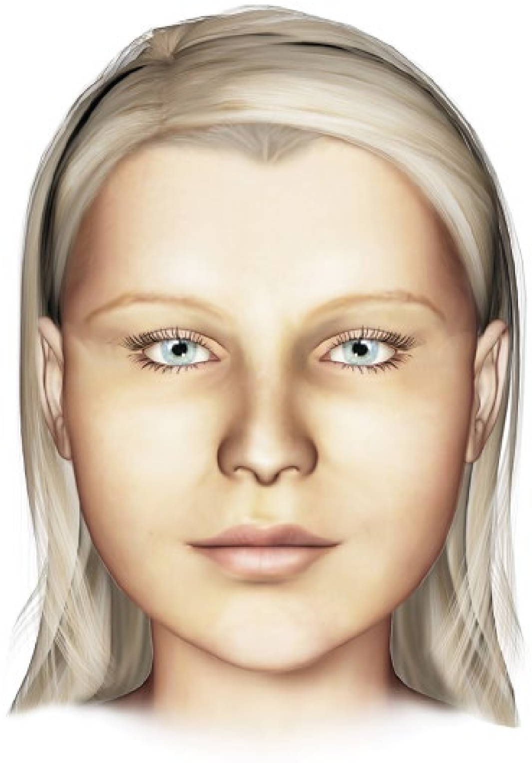

Figure 35.2 **(A)** This illustration of a female with a round face emphasizes the roundness when the hair is pulled back behind the ears.

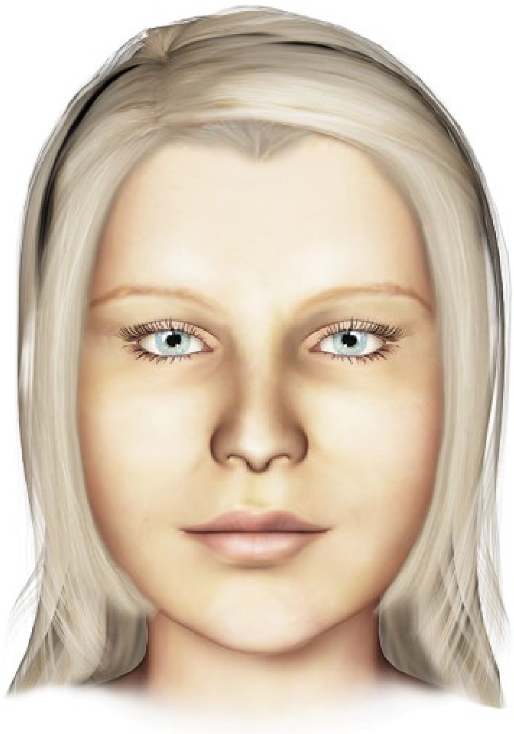

Figure 35.2 **(B)** The face would look slimmer if the hair was pulled over the ears, thus slimming the face.

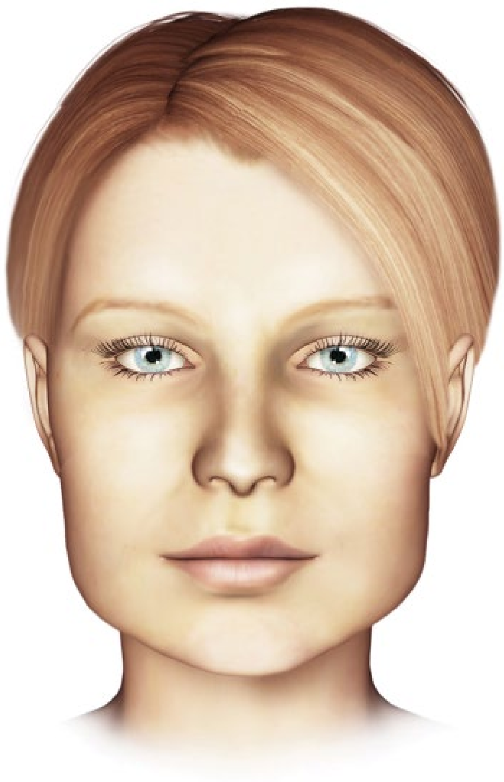

Figure 35.3 **(A)** This illustration shows how the angular jaw contributes to a more square - looking face.

Figure 35.3 **(B)** Note how a hairstyle that covers the angular part of the face helps soften the square look.

(A) (B)

Figure 35.4 **(A, B)** The heart-shaped face calls for masking a wide forehead, plus a better hairstyle, which helps the face appear more oval.

Figure 35.4 **(C, D)** This woman has a heart-shaped face, so the goal of the makeover was to balance her narrow chin with the width of the upper part of her face. The makeup artist applied a crème foundation lighter than her natural skin tone as a highlight on her chin to diminish its sharpness and softened her forehead and cheek areas with darker shades of powder and blush. The hairstylist gave her long layers to add fullness around her chin line and just a wisp of bangs to give her a more balanced look. (Makeup by Rhonda Barrymore; hair by Richard Davis.) *Source:* Goldstein 2009, from *Change Your Smile*, 4th edition. Reproduced with permission of Quintessence Publishing Co. Inc., Chicago.[1]

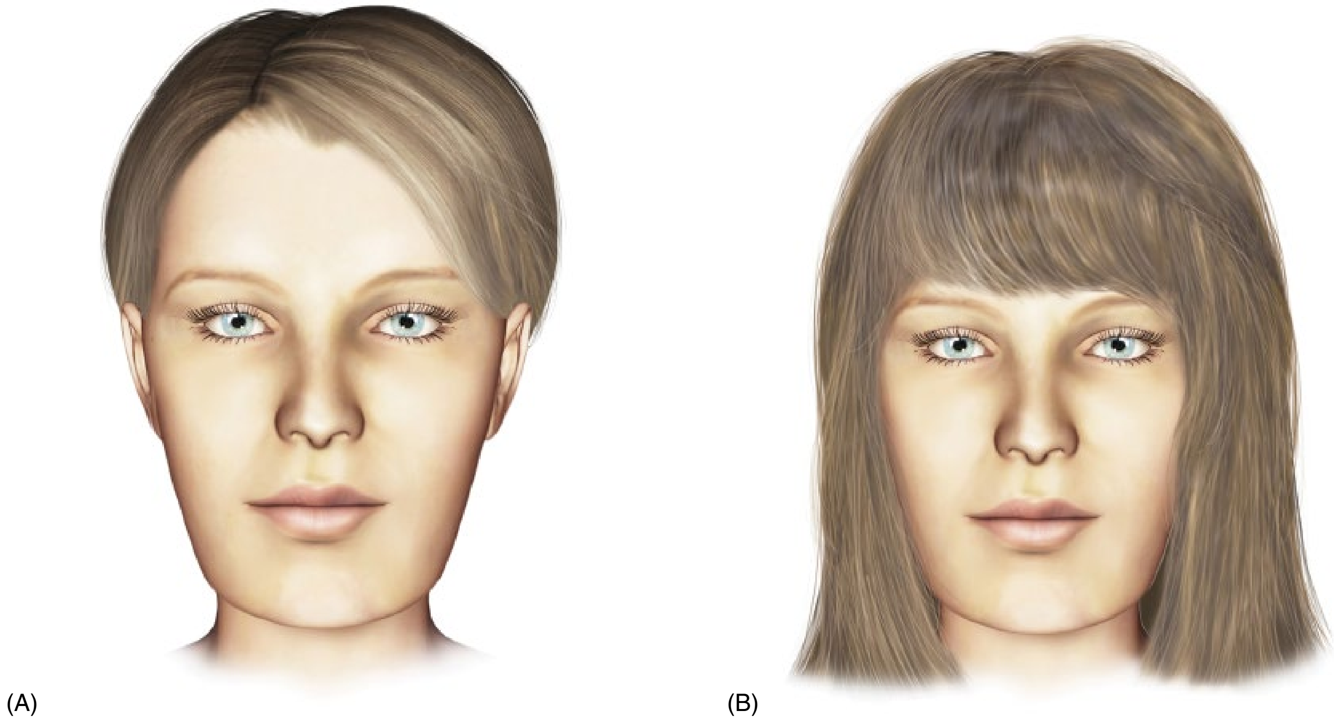

Figure 35.5 **(A, B)** The long face can be masked somewhat by the use of bangs in the hairstyle.

A middle part is one style to avoid because it can appear unflattering.

A long face is similar to a round face but narrower (Figure 35.5). Designs can vary from short, medium, to long. A wedge or graduated short haircut shaping the face would work very well, adding width to the face and adding straight across bangs with a side part.

Other styles that work well are longer layers and designs at the chin or shoulders turning under or with a flip. Stay away from short layers on the top, as this would add height and extend the length of the face more, as well as a middle part.

Hair color

Hair coloring can also be very helpful in creating illusions, or just adding a more youthful look to the face. A woman with gray hair can have an aging appearance if the skin tone is milky white. A short cut can be very attractive, but the majority of the time it will cause an aging effect. In doing a complete new color for this person, the designer should stay one or two shade's lighter than the client's original color. The designer could also decide to add lowlights or highlights if the person has premature gray hair instead of all-over color. These techniques would also benefit a woman with a dull drab color, giving the hair more life and dimension. For a quick fix, a mess-proof marker and mascara-like brushes offer instant gray root coverage between salon visits.

Tooth shade plays an important role when deciding on hair color. A patient with gray hair would look best with bright white teeth. A person with brown hair which is highlighted can make the teeth look more yellow.

Paying attention to lipstick color can also help to downplay yellow teeth or highlight white teeth. For example, a bold red shade will draw attention to white teeth, but make yellow teeth stand out more. On the other hand, a nude color lipstick will draw attention away from yellowed or stained teeth.

Highlights are the use of a lighter shade of color than the natural hair, where lowlights create just the opposite. In addition, highlights of blonde or caramel, or red tones for warmth, can bring life and dimension to the hair as well as frame the face. Natural-looking highlights are a great way to add age-defying definition. In understanding the different shades of hair, just as in makeup, a stylist can hide various flaws in the facial shape and an improved total facial look can be created.

Facial shape for men

Men, as with women, have a need for a hairstyle that works with their facial shape to provide an illusion that will improve their appearance. Men tend to have a hairstyle they feel works best for their chosen profession, as well as what makes them feel comfortable. They may be losing their hair and feel insecure and try to hide the fact, or just wear the style that their spouse, girlfriend, or partner likes best. The kindest advice is to suggest to your patient that he might want to talk to a hair professional to suggest a style that can enhance his new smile. Basic hairstyles for men are somewhat more limiting for them than for women.

Nevertheless, there are ways to help men by emphasizing or deemphasizing the lower part of the face, even though it may be more challenging. The hair design that is chosen can improve or take away from the overall appearance. A man also has a different hair feature that can either enhance or take away his best look: facial hair. If used to enhance the smile, facial hair should be groomed and still work with creating the shape and look of the face (Figure 35.6). The oval shape is versatile, and any hairstyle will enhance it, but the patient needs to be aware of the thickness or thinness of his hair texture on his head. Men with a square face may choose short hair for the conservative look with a little natural height on top or they can wear a longer look that takes away from their strong jaw line. Men with long faces should have hairstyles that show width or fullness on the side. A heart shape face or diamond, as in women, features a more pronounced chin that may also be covered with facial hair. The shape can be changed by slimming the forehead with full bangs, while widening the chin area with a tapered look. Also, a very short cut could also work well.

There are some instances when the dentist is not able to create an "ideal" smile for the patient. Often, the patient has financial considerations and a budget that may limit cosmetic dentistry. In these cases, the hairstylist may want to create illusions with the hair that will draw attention away from the smile. For example, a patient with a high lip line who has chosen to not have gum surgery to raise the gum line may have a "horsey" smile. The hairstylist needs to work with his face to draw the attention to other features, and using hair as a directional guide can work wonders.

Ultimately, both the cosmetic dentist and the hairstylist must consider the shape of the face, bone structure, skin color, eye color, hair texture, and smile before they make changes. A cosmetic dentist who takes a digital photo of a completed patient's face and sends it to the hairstylist with notations would be doing the patient a great service in highlighting areas of the face or mouth that the stylist may have overlooked.

Figure 35.6 **(A, B)** This young man had allowed his hair to grow while traveling, giving him a "rugged" look. After he shaved and got a much shorter haircut, his look was more updated. (Makeup by Rhonda Barrymore; hair by Richard Davis.) *Source:* Goldstein 2009, from *Change Your Smile*, 4th edition. Reproduced with permission of Quintessence Publishing Co. Inc., Chicago.[1]

Makeup

The quest for an improved appearance has directed the thoughts and actions of mankind since the beginning of time. Today especially, the general public is extremely aware of physical appearance. Society places high value on youth and health and has set up stringent standards for what is attractive, as dictated by trends in fashion, hairstyles, and makeup. Beauty or strength of character is generally mirrored in facial features and hair. The degree to which these features are accented or emphasized will often determine whether one is merely accepted by his or her peers or admired by them. The term "reflective/self-image" is two inseparably connected images. The "outer image" is how others view a person, and the "self-image" is how the individual perceives themselves. Reflective self-image also determines, to a great extent, the level of one's self esteem, and how one thinks others view one. Self-image is a strong determinant of how a person acts and interacts in society. It determines whether one will be confident and aggressive or shy and passive. A positive self-image enables the individual to compete rather than follow the crowd. As a result, concern for one's appearance, seeking realistic self-improvement, is important to improving reflective self-image.

Plastic surgery and cosmetic dentistry have given patients the option of improving their appearance in more permanent ways. These two fields of medical science have tremendously brightened the lives of people they have touched by helping to create self-confidence.

Cosmetics or makeup, used as an adjunct to esthetic dentistry, as well as corrective/esthetic surgery are further aids for the person seeking maximum results in the pursuit of an improved reflective/self-image. The proper use of makeup can be of tremendous help in enhancing facial features and in diminishing or disguising unsightly facial disfigurements. The use of makeup is an art of illusion that uses color and design to help create a balance and style to enhance or define one's appearance. Makeup is temporary; it must be applied daily, but it is extremely effective when properly used to enhance a woman's attractiveness.

Skin care

Proper cleansing, rinsing, and moisturizing are basic to the total facial appearance. Neglect or improper care in and around the mouth can lead to blackheads, scaling skin, chapped lips, and excessively dry skin. It is as important to maintain proper cleansing and moisturizing around this area as it is on the rest of the face.

Makeup… an illusion

It is important to first understand that the purpose of makeup is to balance and enhance one's appearance or to create the illusion of beauty. The face and its features cannot be changed by makeup, but it can help how others look or perceive a sense of attractiveness. However, improper or excessive use of makeup can make an individual look out of step, hard, theatrical, or out of fashion. The proper use of makeup is an art that can be learned.

There are many types and shapes of faces, and each has its own charm. We live in a world of multiple ethnicities, where there is no longer one set of standard face shapes as a guide. Each ethnicity has its own charm. The trick lies in making the most of an individual's nonverbal communication features. We need to forget the shape of the face and concentrate on creating balance and symmetry while defining and decorating the nonverbal communication features, the eyebrows, eyes, and lips/mouth. These three areas carry the weight of the facial reflective/self-image and nonverbal communication.

Makeup and color

Makeup colors should be selected by a professional makeup artist or esthetician that has an in-depth background and knowledge of makeup products and colors that will suit all ethnicities. These makeup color products generally consist of

- foundations, to even the facial skin tones;
- concealers, to diminish or conceal facial skin discolorations;
- powders, to set the foundation and concealer for maximum wearability;
- blushers, to restore the natural flush to the skin or for a fashion statement;
- eyebrow makeup, to color or shape the eyebrows;
- eyeliner, to define the eyelids;
- eye shadow, creates a fashion statement; and
- lip color, to define and shape the lips.

Each ethnicity from light to dark skins has makeup colors that suit their specific skin color, culture, and lifestyle/fashion.

Corrective makeup and contouring

It is common in the field of consumer makeup for cosmetic sales people, makeup artists, and estheticians to recommend a corrective makeup/contouring approach to designing a woman's face. This entails highlighting features to bring them out or shadowing features to diminish them. A common concern among women is the challenge of reducing the appearance of a double chin. Makeup solutions can help correct this problem. When applying makeup to downplay a double chin, start with shadowing below the jawbone and use a darker concealer to blend down as needed. Then, highlight other features, such as the eyes. Start by applying a neutral shade of eye shadow to the lids. Next, use an eyeliner for definition. For a nighttime look, dark liners like brown/black, charcoal/black, or black can add drama. For a fresh awake look, line the lower inner lashes with white or any light color. Curl the lashes and coat them with mascara. In addition, add some glow and color with blush or bronzer on the apples of the cheeks. The final component is adding lipstick. The lips are close to the chin, so choose a color that helps make them look more attractive. The classic red lipstick is usually a good option—especially with bright white teeth—but not all women can pull it off.

Another tip to minimizing the double chin is to show off the neckline. Keeping the neck free of hair will accentuate the neckline and jawline. A tip for long hair is to wear it in a bun, hair clip, braid, or pony tail. A tip for short hair is to have the hair cut above the jawline to draw attention to the cheekbones instead.

- *Foundation*: Foundations are applied to even the facial skin tones. The foundation color should accurately match the client's real skin tone. It should be matched at the jaw line, which is the medium tone of the face.
- *Concealers*: A facial cosmetic concealer can be compared to the opaque layer used to mask a dark tooth or metal. But in cosmetology, it is used to mask blemishes and discolorations on the face. Concealers should match the skin tone to conceal skin discolorations. It should be applied before the foundation, as the foundation will minimize some minor skin discolorations.
- *Powder*: The powder is applied over the foundation and concealer; this will set the makeup, so it will wear longer and not rub off easily. The powder should not be a tinted powder; it should be colorless or color free, so as to not change the color of the foundation that is matched to the skin tone.
- *Blushers*: Even the sheerest foundation will diminish or conceal the natural flesh or blush of the skin. Blusher is used to restore the appearance of the natural flesh or blush. Blusher can also be used as a fashion statement. The enhanced natural blush of the skin gives a more youthful, healthy look to the face.
- *Eye makeup*: The eyes can be the most expressive feature of the face and, as such, attract attention. Made up properly, the eyes can add attractiveness and charm to the face and create the illusion of beauty. Eye makeup can draw attention away from the less attractive facial features and draw attention away from the lower third of the face if the dentist is unable to achieve the desired esthetic dental effect.
- *Eyebrows*: The eyebrows frame the eyes and help create facial expressions, such as happiness, fear, surprise, anger, and friendliness. Proper shaping and application of eyebrow makeup help to frame and focus attention on the eyes.

Lip coloring

Lip coloring brings the face to life. It is the final balancing feature of the face. The mouth/lips are one third of our nonverbal communications/facial expression. The lip color should be selected in harmony with the color of the clothes being worn. The "no mouth" look, extremely light or white lip color, is most unflattering and detracts from the individual's facial features. Lighter lip colors can be used to deemphasize unattractive mouth contours. Too dark a lip color looks hard unless it is color coordinated with wardrobe colors.

Figure 35.7 Different lips can alter the smile line, so doing a trial smile can help both the patient and yourself see how different tooth shapes and lengths can affect the smile.

Simple yet effective lip contour changes will create a more symmetrically balanced and desirable lip shape. They are outlined in Figure 35.7.

- *Narrow, thin mouth*: Build up the lips by letting the color extend ever so slightly beyond the natural lip line.
- *Large, full mouth*: Add a film of foundation over lips, powder thoroughly to set the lipstick and apply lip color only to area shown. This results in the mouth appearing smaller.

- *Small mouth*: To make fuller, apply a lip liner first to create the shape and then fill in with color.
- *Wide mouth*: Apply color as normal, but stop short at the corners of the lips.
- *Cupids bow*: To minimize the extreme cupids bow, apply lip color slightly outside the lip line and across the top lip, except on the two points where it should be held right to the lip line. To create or emphasize the cupid's bow, carry the color just barely outside the lip line on the two points, but stay on the natural line across the remainder of the upper lip.
- *Restoring the natural lip line*: If the natural lip is incomplete or interrupted (due to an accident or congenital condition), outline the lips with a warm natural colored lip line crayon/pencil. This will create a normal lip shape. Then, fill in with a normal lip color and blend the lip color and lip liner to appear as one.
- *Shape*: Women should never allow the finishing corners of the mouth to droop. To create the illusion of perfect harmony and happiness in the face, always allow these outside corners to finish in a graceful, upward line. Drooping or hanging lines tend to suggest sadness and age. Never make the corners blunt.

Selecting the right lipstick color

SELF Magazine in 2012 featured the article titled "23 lip shades that make your teeth look pearly white."[2] When selecting a color for the lips, *SELF Magazine* offered tips in selecting the right lipstick color. Keep in mind that lipstick colors change with fashion from season to season.

- Shades with strong yellow or orange tones are colors to avoid—these can bring out those same shades in your teeth, making the smile appear duller.
- Do not use nude colors or go too light for the skin complexion—it can make the teeth appear darker in contrast.
- Be careful of deep hues, like purples, because they can reflect on the teeth and also makes the mouth appear darker than it really is.

Makeup for a disfigured face

The diminishing or concealing of minor scars and skin discolorations around the mouth is accomplished with makeup concealers that accurately match the skin tone in the area of need. Some of the mental depression that normally accompanies a disfiguring injury or a congenital skin discoloration can be eliminated with the appropriate makeup.

Makeup for men with disfigurements

Diminishing, concealing, or disguising scars and congenital disfigurements for men are accomplished the same as for a women, minus the eye makeup, blusher, and lip color.

The primary difference is that the concealer and foundation must accurately match the men's skin tone in the area of need. Another element in concealing men's disfigurements that was not discussed in women's makeup is the many skin nuances in a man's face. These nuances are the beard pattern/texture and the pore texture/coloration. The makeup is applied (beard/pore texture color) with a coarse red rubber or a black synthetic sponge in a stippling (patting) motion. Scars that run through a mustache, eyebrow, or beard pattern area can be penciled in with a sharpened eyebrow pencil using hair-like strokes. It is best to use a stick or grease-based cream foundation that matches the men's skin tone, because it is waterproof and wears better when powdered with a color-free setting powder. Any beard pattern or pore texture makeup colors applied after the concealer/foundation must then be repowdered to set them to keep them from smudging. The skin nuances beard color, beard pattern, and texture are found in theatrical makeup but should not be theatrical looking. For men with a facial disfigurement as well as a flush to their complexion or ruddy skin it is recommended that they try to match the nuance of the regular colors of the skin with a color that matches their normal skin. It is unlikely that a man would be able to do this without some professional instruction.

It should be remembered that cosmetics in all its forms is temporary. It is a daily procedure that, when used properly, can and will improve an individual's appearance. An understanding of the proper use of cosmetics enhances anyone's ability to achieve a natural look and can be an important part of the entire esthetic dental treatment plan. When used together, esthetic dentistry and the art of makeup can give a patient an improved enhanced reflective/self-image.

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Chapter 36 Esthetic Considerations in the Performing Arts

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Professionals in performing arts, such as in film, television, theater, and modeling, need cosmetic dentistry more than the general public. Whether the performer appears on the movie screen, television, stage, or catwalk, constant public scrutiny is a major part of the job description.

Entertainers in the motion picture industry, having realized that an attractive smile is integral to success, created one of the first demands for esthetic dentistry. Gigantic screens and close-up shots compelled actors with unsightly smiles to seek out the benefits of cosmetic dentistry. In the late 1920s and early 1930s, Dr. Charles Pincus pioneered many techniques, both permanent and temporary, for masking some of the cosmetic problems that became painfully obvious in close-ups. For film actors, the advent of high-definition video and the growth of IMAX cinemas make attractive teeth essential for their careers.

Performers who limit the range of facial expressions to avoid exposing unsightly teeth might never attain their full potential. Success in the entertainment field is tied to the level of confidence about body image. An attractive smile and range of spontaneous facial expressions can contribute greatly to that confidence.

Ronald E. Goldstein's Esthetics in Dentistry, Third Edition. Edited by Ronald E. Goldstein, Stephen J. Chu, Ernesto A. Lee, and Christian F.J. Stappert.

Figure 36.1 **(A–D)** These actors show diastema, incisal wear, and other teeth irregularities that were no obstacles to their success.

There are exceptions, of course. For example, certain actors prefer to retain a natural look, even with something as obvious as diastema. The men in Figure 36.1A–D are film and television actors whose diastemas, incisal wear, and teeth irregularities have certainly been no obstacle to their success. In fact, they have probably contributed to it, and many stage and film performances today require creating a character with bad teeth or other unattractive orthodontic features. In the 2010 film *True Grit*, actor Barry Pepper's broken teeth, which were created for the role, are a key characteristic in his portrayal of a convincing villain.

This chapter will address procedures for creating a character through the use of dental prostheses. However, it must be noted that actors depend on their appearance for their livelihood, and most do not want a permanent alternation in their look. The treatments covered in this chapter should ensure that the actor can revert to their original, recognizable appearance.

The public has long expected performers and models to be attractive, and it is a reasonable assumption that only persons who are naturally attractive would choose such a career. However, this assumption does not hold when the smile is the primary consideration. In 1968, Goldstein produced the first published study of its kind and that evaluated the attitude toward esthetic dentistry among a group with strong interest in physical appearance—beauty pageant contestants. Of the 60 beauty contestants who participated in the study, 90% could have used some esthetic treatment, and an additional 7%, although already considered pleasing to the eye, expressed a desire to enhance their smiles. Only 3% believed they would not have benefited from such procedures. When the candidates were asked how they felt about their appearance, only 20% were satisfied with how they looked, and 28% thought that the condition and appearance of their teeth detracted from their smile and, ultimately, their overall attractiveness.

Economic dental procedures

Because such a large percentage of performers and models barely make a living, they need to understand that not all cosmetic dental procedures are expensive. It is important to remember this during treatment planning so that alternatives to the more costly procedures are included as economic options for esthetic correction and improvement. Note, too, that dental procedures performed on actors and other entertainers may qualify as tax-deductible expenses.

When developing a treatment plan, be sure to view the performer/patient from all angles. Several approaches utilizing both video and photographs will give the patient/performer the opportunity to see what the audience sees. (This approach is discussed further in Chapter 7.) The mouth is essential for expression, and while the mouth muscles can be more expressive than the eye muscles, both muscle groups work together and should be included in the diagnostic evaluation.

Various cosmetic dental procedures have been proved successful for performers and are addressed herein. These procedures are:

- cosmetic acrylic stent
- composite resin stent/splint
- composite resin direct bonding
- removable porcelain veneers
- removable partial dentures
- overlay dentures
- acrylic overlay for theatrical makeup
- direct composite resin for theatrical makeup.

Cosmetic acrylic stent

Many performers need esthetic improvement for their teeth, but some are not willing to reduce perfectly sound tooth structure, which may have to be removed to achieve the desired result. One temporary procedure for photographic purposes is a removable cosmetic stent. This can temporarily hide conditions such as diastema during a performance or photo shoot. In 1978, Bob Hope was the entertainer at the annual Thomas P. Hinman Dental Meeting in Atlanta and showed me the removable splint Dr Pincus had made him to hide his diastema when taking certain photographs or in movies.

Here's how to create a stent: use white wax on a stone model or the patient's mouth to "restore" it to esthetic standards or to create the specific look and process the prosthesis in acrylic. For added stability, the overlay may be worn with an adhesive, although friction alone will usually provide sufficient anchorage (Figure 36.2A–C).

Composite resin stent/splint

Constructing the splint directly in the mouth with composite resin allows complete control over both color and surface characteristics. A thin coating of lubricant can be applied to the teeth before bonding them with composite resin. When the polymerization and finishing procedures are completed, the splint is gently forced off by first letting the patient rinse with water, then teasing off the appliance. Pay careful attention to any undercut areas, because the composite may lock into them. Block out known undercuts, except where you may find some necessary for retention/suction grip before placing the composite resin. This technique works best with diastemas, but it can also be effective when build-out of individual or multiple teeth is required (Figure 36.3A–D).

Composite resin direct bonding

In many situations, the most effective temporary means of achieving cosmetic correction is through the use of composite resin. Stains can be masked, tooth sizes can be altered, and arch alignment can be corrected by bonding teeth without etching enamel.

However, you may need to etch if you cannot easily lock it in by connecting it to adjacent teeth. When the performer has completed a role, the bonding can be removed. Frequently, the correction appears so natural that performers eventually opt for the more permanent treatments that utilize direct bonding or even porcelain veneers.

Temporary bonding also works well in closing diastemas. This procedure is fast and easy, and the fee can be much less than the fee for procedures that require laboratory assistance. Before bonding was available, many dentists used soft, molded wax to hide spaces for photographic purposes. However, the advent of direct-light polymerized composite resins made such procedures obsolete.

The technique is relatively simple. Select the appropriate shade of a microfill composite resin. A microfill is usually used because it can produce the best final luster. If occlusion is a problem, a microhybrid composite resin serves as an alternative. However, a microfill can still be used as the outermost layer to obtain a high polish.

Removable porcelain veneers

The cost of porcelain veneers can be considerable. Therefore, the use of this technique is usually limited to those performers or directors who want the most attractive temporary result without regard for cost. In addition to the laboratory expenses, there are professional time and artistic requirements associated with the construction and temporary placement of the veneers.

The first dentist to use such a technique was Pincus. In 1929, he described the use of temporary porcelain "shells" to immediately improve the screen appearance of certain movie stars. The costs were usually absorbed by the film studios and did not factor in the decision process for the patient. It should be noted that porcelain was basically the only material available at the time for cosmetic dentistry. They were held in with denture paste.

Tooth preparation is not required to construct removable veneers. An impression is taken using polyvinyl siloxane. Then, the veneers are constructed in the laboratory and individually fitted to each tooth. They can be inserted with a temporary, non-hard-setting cement to ensure that the color will remain constant. Another, more temporary, means of attaching the veneer is with soft, sticky wax (Moyco). Performers can be taught how to place the temporary veneers on themselves, but they must obviously be secure enough so as not to come off during the performance.

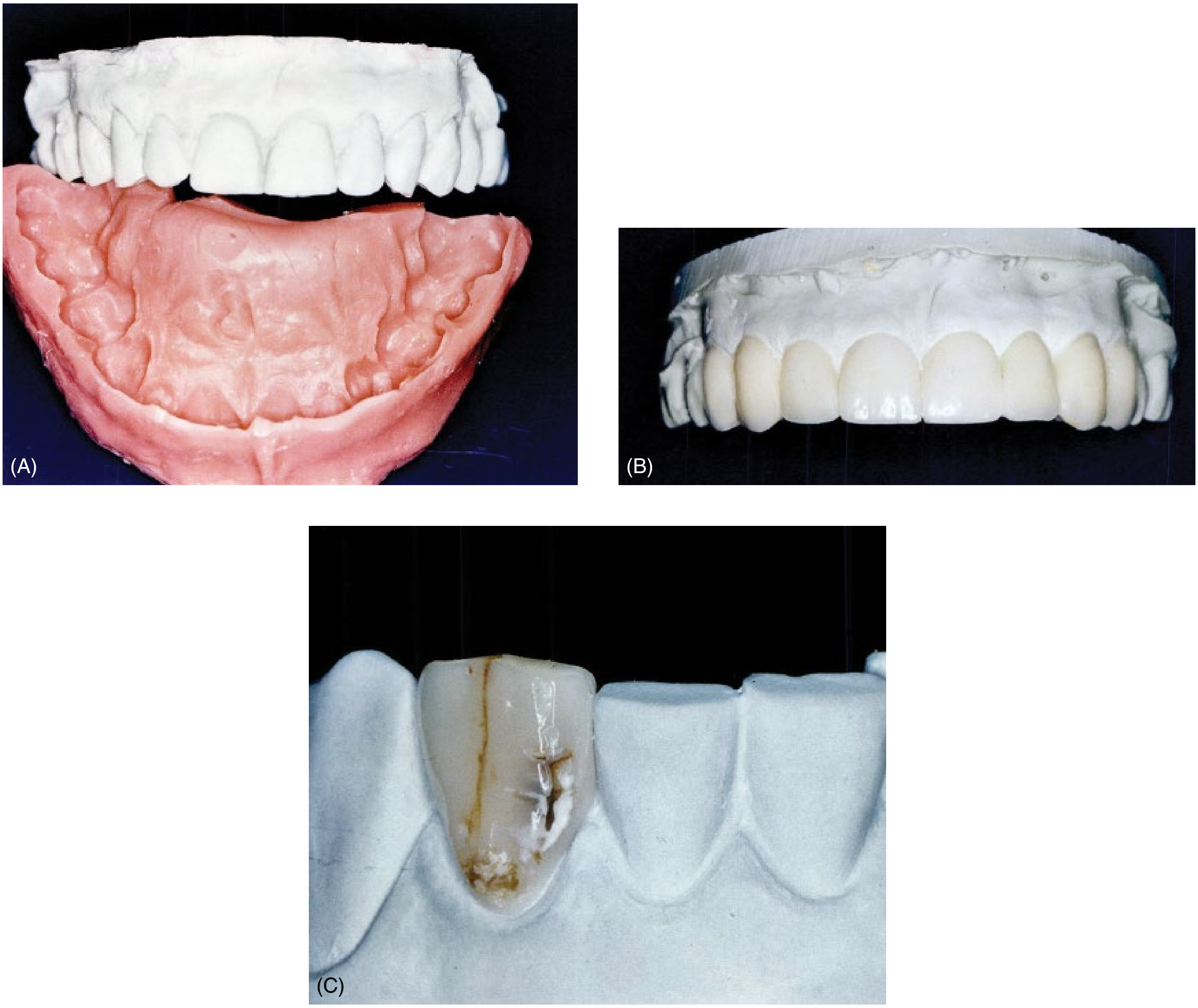

Figure 36.2 **(A–C)** Fred Ward's role in *Miami Blues* required him to "gum" his food. A mouthpiece was made to cover the actor's teeth. After a paper-thin denture fell out of his mouth, veneers were applied over his teeth to make them look like dentures.

Dentures: removable partial or full

It is possible to construct a removable partial denture with the esthetic correction built into the appliance. Spaces can be closed and overlays can even be attached to the partial. Special effects can also be easily built into the acrylic-attached teeth or veneers. The advantage of the removable partial for a performer who wants to alter their appearance is the avoidance of repeat dental office visits and their costs.

Overlay dentures

A full denture is constructed over the existing maxillary natural teeth. The technique involves mounting accurate stone casts on an adjustable articulator and creating a temporary full denture. Because this technique usually requires considerable opening of vertical dimension, there may be restraints on the extent of time this denture can be worn during the day (Figure 36.4).

Creating a character with acrylic overlay

Occasionally, a dentist is called on to create an unattractive, objectionable appearance for theatrical purposes. Character alterations can be achieved with the use of the acrylic overlay. Incorporating stains, various shapes, and arrangements to both teeth and gingiva can contribute to the elaboration of character (Figure 36.5).

Figure 36.3 **(A–C)** These images show the teeth Jim Belushi wore as a mentally challenged dishwasher in *Homer and Eddie*. Notice how a mouth extension was required to show the actor's teeth. **(D)** Note how the splint was attached to the incisolingual surfaces.

Tips for creating an acrylic overlay are as follows:

1. Make a drawing or sketch of the proposed changes as a guide for the lab technician. Use the shade chart in detail to note stains, shade differences, chipped or fractured teeth, and gingival irregularities.
2. If vertical dimension is to be altered, be careful not to obliterate freeway space. All functional mandibular movement must be accommodated.
3. The patient should be encouraged to allow sufficient time to practice speaking while wearing the overlay. If a speech impediment is desired, the appliance can be constructed to create one. The use of even a handheld video camera can be useful for showing your patient just how they sound and look while wearing the appliance.
4. Provide the patient with clear instructions regarding the care, insertion, and removal of the appliance to avoid breakage.

Acrylic overlays are perfect appliances for the vampire look commonly used in film and television today (Figure 36.6).

Checklist for creating a character

1. Ensure that the patient is in good dental health before beginning treatment.
2. Determine the type of look the performer wants for the character being portrayed. For example, will it be a serious character versus someone who's comical?
3. Coordinate with the director or producer on the look of the teeth before designing the prosthesis on a computer and then fabricating it. Photoshop can be used to virtually modify the teeth and create any desired look. The performer should send a photo of their teeth via e-mail to your dental office and the image can be visually enhanced or modified on the computer. Send the enhanced image to the producer or director to see whether the modification is acceptable.
4. All key people involved must sign off on the image. This means the actor, the producer, the director—anybody who has a say in the end result of how the performer is supposed to look. Again, consider routine communication throughout via e-mail. Even photos and/or video of the performer wearing and speaking with the appliance can be sent via zip files using the Internet.
5. Determine whether the look is temporary or permanent. The initial prosthesis will be made of plastic to test the construction, how well it suits the performer's face, and to determine whether the actor can tolerate wearing and speaking with it. This temporary design can be designed on the computer, but it is essential the performer tests the plastic prosthesis in the mouth and be able to speak comfortably while wearing it. Only then will four or five final prostheses be fabricated for use during the performance.

Figure 36.4 **(A)** This 10-year-old actor was chosen to play the part of a boy who gets into two fights and has some of his teeth knocked out (*The War*).

Figure 36.4 **(C)** Working with the laboratory technician, Mark Hamilton, a plan was devised to create several overlay dentures the boy would wear throughout the movie.

Figure 36.4 **(B)** His severe malocclusion was a major problem in planning the appliance to create the illusion of missing teeth.

Figure 36.4 **(D)** Multiple appliances were fabricated to show the progression of the character's teeth problems throughout the movie.

Figure 36.4 **(E)** Note in the mirror view how the tooth sockets were carved out to appear more natural.

Figure 36.4 **(F)** The first overlay dentures were made, so that they could fit securely over his teeth but also allow him to speak sufficiently.

Figure 36.4 **(G)** This was the look after the first tooth was supposedly knocked out. It is very important that the buccal flange be high enough so that when the actor smiles it will look believable.

Figure 36.4 **(H)** The final overdenture constructed showed more teeth knocked out plus a fracture on his left central incisor.

6. Know when to say "no" if you believe the procedure could cause future negative effects on the performer's dental health, such as if the prosthesis will cause teeth to move.
7. Charge an hourly rate for the procedure, because this type of work involves trial and error and it is difficult to quote a specific overall fee for a product. Typical time required is 1 week, but the shortest time frame is 1 or 2 days.
8. The most time-consuming work involves creating a whole new facial appearance for a performer, whereas changing the appearance of just the teeth is relatively simple, such as vampire teeth. Treatments that involve altering the performer's facial configuration, the mouth, and the speaking ability are the most challenging. Marlon Brando's use of prostheses in his lower cheeks for *The Godfather* was a good example of this type of treatment.
9. Determine who qualifies as a candidate for this type of dentistry. Price varies, but the average cost is about \$300–\$750 per hour.
10. Depending on the situation, creating special effects can be time consuming, and amateurish attempts should be avoided. It is important to understand the procedures and the steps taken. You may wish to contact a dentist who has expertise in this area to train and learn how to avoid negative outcomes for the patient and the dentist.

Creating a specific character

In the example shown in Figure 36.7A–H, a major movie producer wanted the actor Richard Kiel's mouth to show abuse and neglect. Compare the actor before (Figure 36.7A) with the final result (Figure 36.7B).

The "heart-of-gold" crown technique was achieved as follows:

1. A stone model was made of the maxillary arch, and a tooth-colored acrylic was applied directly to the prepared model (Figure 36.7C).
2. A controlled-temperature pressure heater hardened the acrylic. A further buildup of acrylic continued until the basic splint was formed in the tooth areas.
3. Tissue-colored acrylic was applied to replicate the gingiva; the acrylic was then hardened in the pressure oven.
4. A heart was carved out of an old piece of shell gold and was added to increase personality to the characterization (Figure 36.7D). It was locked into place on the lateral incisor

Figure 36.5 **(A–C)** Playing Stalin's projectionist in *The Inner Circle*, Tom Hulse required teeth that showed decay, plaque, stains, and misalignment. These images show the actor's teeth in close-up, side, and full facial views.

by bending the edges, then refinished using brown and green polishing wheels.

5. Additional material was added to the labial gingival area to depict periodontal disease.
6. Gingival erosion, fractured teeth, and other defects were carved into the overlay with a straight handpiece No. 701 bur.
7. Quick-cure resin stains were placed to replicate caries, microcracks, stains, defective restorations, and calculus (Figure 36.7E).

An acrylic or composite overlay would have enough flexibility to allow for careful placement over the natural teeth. Figure 36.7 F shows the lingual view of the overlay. Because the actor was to portray an ex-boxer, a removable appliance was constructed for the mandibular arch (Figure 36.7G) that would pouch-out the cheek to simulate facial disfigurement. The characterization created by makeup and dental changes is shown by the comparison of Figure 36.7A and H.

Occasionally, dentists are called on to create dynamic special effects. As mentioned earlier, for example, a removable prosthesis was made to create a strong prognathous jaw for Marlon Brando's character in *The Godfather*, and maxillary and mandibular appliances were fabricated to give actress Linda Blair a demonic look for her role in *The Exorcist*.

Direct composite resin for theatrical makeup

Although the acrylic overlay is the easier method for creating character, an extremely natural appearance can be achieved with direct composite resin bonding. Stained composite resin restorations are created by applying dark composite material to the enamel. If problems of retention occur, a 0.5–1 mm etch can hold the composite to the teeth. However, there are limitations regarding the length of time the performer can wear it. Direct bonding

Figure 36.6 **(A, B)** For the film *Vampires*, a new concept was used. An internal passage was created for sucking blood through the teeth.

Figure 36.6 **(C)** Acrylic overlays are perfect appliances for vampire looks.

has the disadvantage of requiring a dentist to replace the effect each time it is needed, making this technique especially labor intensive. It should be noted that if the actor does not mind wearing the effect for an extended length of time, it is possible to attach the bonding for that required time frame by extending the etching just slightly to 1.5–2 mm.

General tips for direct composite resin

To create noticeable effects, the following guidelines apply:

1. Overemphasize color change. If you want old restorations to really standout, make the stain about two shades darker than you might have initially anticipated.
2. Tooth form requires careful attention. A realistic effect is believable only if the teeth can withstand close scrutiny. This is especially true in the motion picture industry, where an actor's teeth appear on giant screens.
3. The condition of the gingival tissue should reflect the appearance of the teeth. If you are creating an unattractive prosthesis effect, remember that neglected teeth most likely are surrounded by periodontal disease. An acrylic tissue insert that depicts red and swollen gingiva will further enhance the believability of the characterization (Figure 36.8).
4. Do not stop at the cuspids; include as many teeth as necessary to ensure realism, even with maximum smiling. Rather than creating a cuspid-to-cuspid effect, extend to the bicuspids or

Figure 36.6 **(D-I)** Acrylic overlays are perfect appliances for vampire looks. These images show different designs of vampire teeth.

even the first molar for total realism in the lateral views. Remember, the audience must "buy into" the character's total look.

5. Consider the perspective of the audience. If the actor will be revealing occlusal surfaces during the performance, then these surfaces should be altered as well. A typical example is when the character tips their head back for a "sinister" laugh.
6. Do not neglect the mandibular teeth. Even when only the incisal edges are visible while speaking, if they do not match the maxillary corrections, the desired result will elude you. Furthermore, even straight incisal edges can be bonded or

Figure 36.7 **(A)** Actor's smile and teeth prior to procedure.

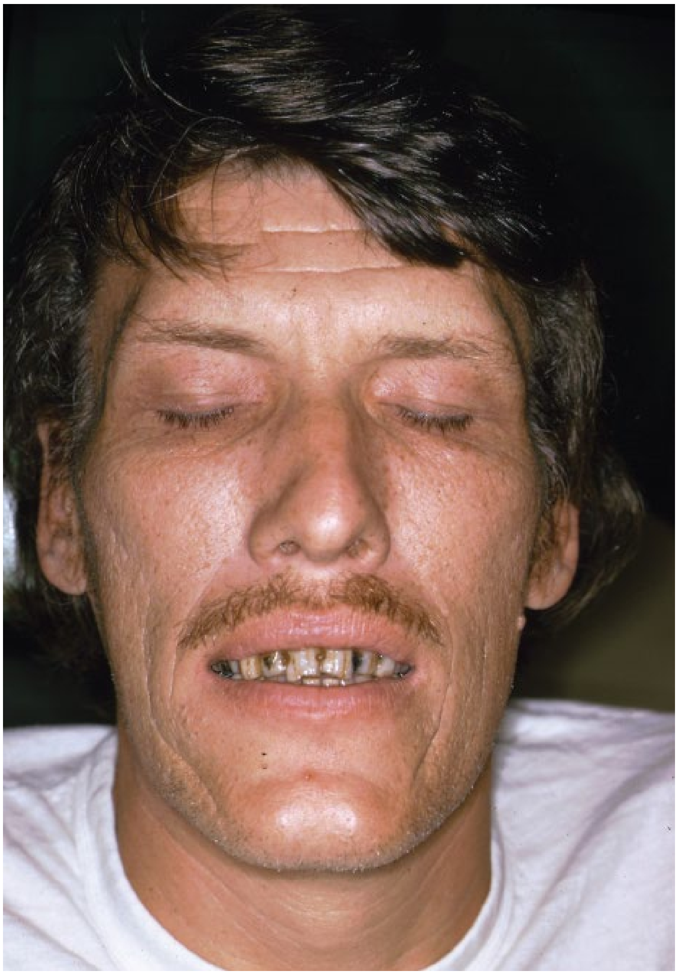

Figure 36.7 **(B)** By looking at the full face, you can see how the characterization in his teeth accomplished what the director wanted for the appearance of this character.

overlapped to look crooked. Again, it is advisable to overemphasize the amount of crowding and good color to ensure believability. If orthodontics is selected as the ideal treatment, remember to include cosmetic contouring to achieve ideal straightening (Figure 36.9).

7. Video the performer in character. If possible, record the actor speaking from their script, smiling, and laughing. Include lateral, top, and bottom views. A video like this can be invaluable, not only for planning the extent and type of treatment or correction, but also for demonstrating clearly to the actor or other interested parties the necessity of creating a more complex correction than may have initially been anticipated.

Figure 36.7 **(C)** A stone model was made of the maxillary arch; tooth-colored acrylic was applied directly to the prepared model.

Figure 36.7 **(D)** A heart was carved out of an old piece of shell gold and added to increase personality to the characterization and locked into place on the lateral incisor by bending the edges.

Figure 36.7 **(E)** Additional material was added to the labial gingival area to depict periodontal disease. Other defects were also incorporated into the overlay, followed by quick-cure resin stains to create caries, microcracks, stains, defective restorations, and calculus.

Figure 36.7 **(F)** Looking at the appliance from the lingual view, you can see how the actor would lock it into place.

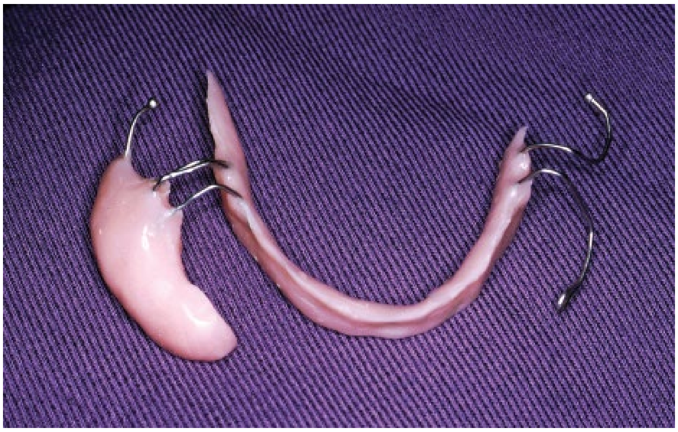

Figure 36.7 **(G)** Because the actor was to portray an ex-boxer, a removable appliance was constructed for the mandibular arch that would pouch out the cheek to simulate facial disfigurement.

Figure 36.7 **(H)** The characterization created by makeup and dental changes is shown in his smile.

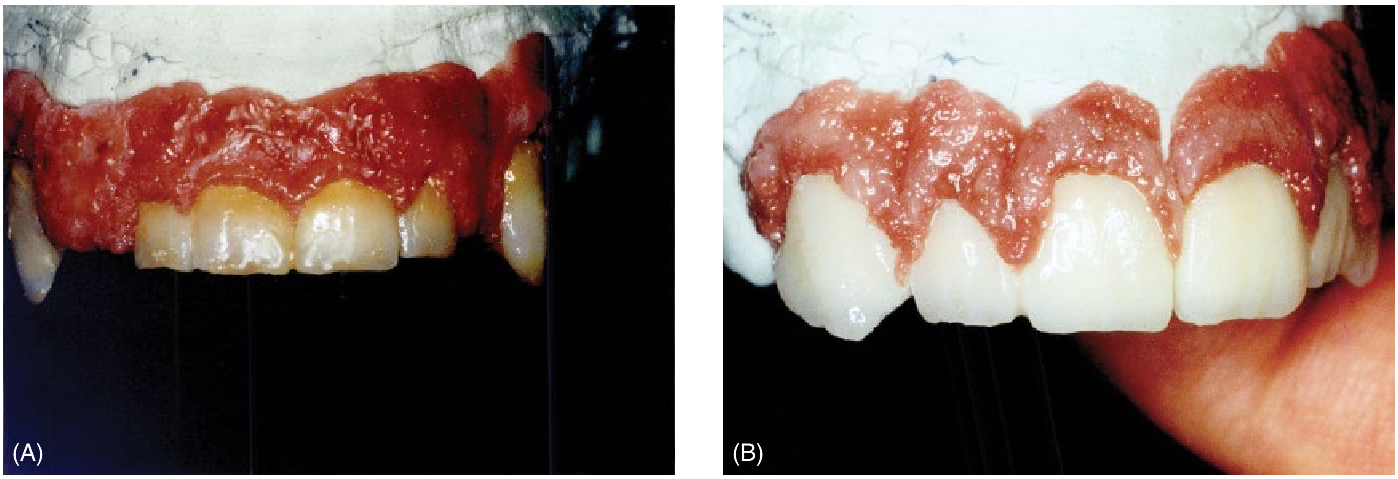

Figure 36.8 For one movie role Nicolas Cage played a half-man and half-ape. **(A)** A prototype of the ape-like teeth and swollen gums that were created for the role. **(B)** Teeth that are more human in appearance.

Figure 36.9 **(A)** As this leading actress's teeth became crowded over time, she wanted to improve her smile. **(B)** Minor orthodontics, bleaching, cosmetic contouring, and bonding helped to produce a more attractive smile. **(C)** The actress now shows straighter looking teeth both close up and from a distance on theatrical performance.

Achieving esthetics in natural teeth

Photographic models and film actors place a high value on their appearance and are especially interested in having healthy teeth and gums (Figure 36.10A–E). However, their natural dentition is often poorly arranged, decayed, or stained. In the following we demonstrate how some of these problems may be managed with minimal time and effort required of the patient.

Suggestions for achieving brighter/whiter teeth

Many performers are extremely concerned about the darkness of their teeth and wish to have them lightened. Here are nine suggestions for achieving brighter teeth:

1. After a thorough prophylaxis, pumice the teeth and polish them with tin oxide. Even using impregnated polishing

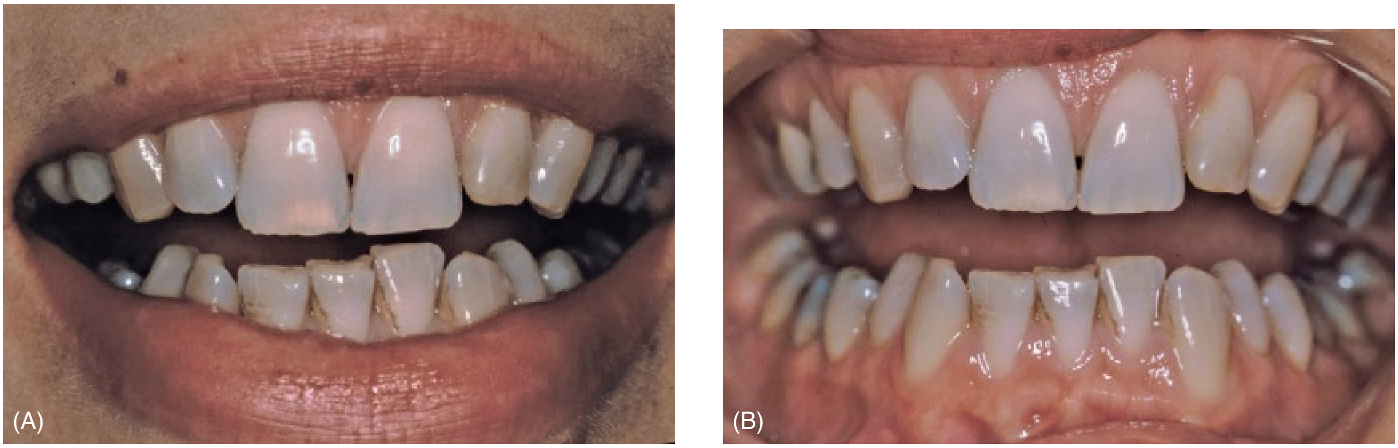

Figure 36.10 **(A, B)** This fashion model, and TV personality, wanted to improve her smile to do photographic modeling as well.

Figure 36.10 **(C, D)** Cosmetic contouring and composite resin bonding instantly improved her smile.

Figure 36.10 **(E)** The final result shows how the improved smile enhanced her total image, as well as her self-confidence.

wheels can create brighter looking teeth because of the increased luster after polishing in this fashion.

2. Use a more abrasive toothpaste than normal to retard further staining.
3. Advise the performer to apply darker shades of makeup so the teeth appear whiter against the darker skin tone.
4. Professionally bleach the natural teeth. However, entertainers vary considerably in their expectations, patience, ability, and willingness to spend time and money for in-office procedures. One alternative is for the patient to bleach themselves, outside of the dental office. Specific techniques can be found in Chapter 12. When bleaching the teeth of entertainers, recommend the "power bleach" as the starting point or even the entire treatment, since busy entertainers may not want the bother with home bleaching.
5. If the patient objects to bleaching, a temporary treatment may be suggested. In these cases, the acrylic cosmetic overlay in a lighter shade than the natural shading of the patient's teeth might be used.
6. Lightening can also be accomplished by bonding a composite resin or porcelain overlay onto the visible teeth. The patient should be informed of the limited life expectancy and of the necessity for periodic replacement.
7. Porcelain veneers offer the most attractive, longest-lasting conservative solution to the problem (Figure 36.11A–E).
8. If the teeth are severely discolored and the patient's demand for esthetics is great, the only satisfactory method of whitening may be the full crown. This should be done when it is the only way to achieve a satisfying esthetic result.
9. If there are maintenance issues associated with any of these procedures, be sure to discuss this before suggesting treatment.

Cosmetic contouring

When the teeth are extremely malposed, and if orthodontia is contraindicated or unacceptable to the patient, cosmetic contouring of the natural teeth may help. Figure 36.10A–E illustrates the effectiveness of cosmetic contouring for a photographic model (see Chapter 11 for technique.)

Because the esthetic result is achieved so quickly, it should always be considered when treating performers. Almost every model or actor should be esthetically evaluated to determine whether cosmetic contouring could enhance their appearance. This noninvasive procedure requires minimal adjustments and minimal time. See Chapter 11.

Composite resin restorations

If the teeth are well aligned, shaped well, and not discolored, the possibility of caries is still present and should be treated esthetically with the use of direct composite resin if trying to save expense and time.

Composite resin can be used to restore most teeth that are seen when speaking, smiling, and laughing. The patient should be informed that these resins must be replaced periodically. Goldstein, in *Change Your Smile*,[1] offers ranges of life expectancy for composite resin restorations and other esthetic treatments for most every cosmetic dental problem. Nevertheless, many patients in the performing arts or modeling consider this treatment as part of their professional expenses. Although composite resin restorations may last longer, the expected life expectancy plus limitations should be explained. Staining is always a possibility, so the patient should be warned of the possibility of early discoloration from cigarettes, tea, coffee, or other causes. However, discolored teeth can be made to look bright again by refinishing them with a 30-blade carbide (ET, Brasseler USA) and air-abrading. Follow this procedure by etching and applying a product such as a low-viscosity, light-cured resin formulation. Only one application of a formulation (BisCover Bisco) is required to create a smooth, polished tooth surface. It may also be necessary to slightly strip the facial surface and re-veneer with a thin layer of brighter polished composite resin.

Composite restorations can be used as both a temporary and a permanent treatment and can be modified to create both good- and bad-looking teeth. Furthermore, composites are an effective method for sculpting different looks, because they can be added directly to the mouth and polymerized.

Figure 36.11 **(A)** This actress and model was displeased with the dark spaces (she called them "caves") that she saw on each side of her mouth when she smiled.

Figure 36.11 **(B)** The solution to this cosmetic problem involved building out both the front and back teeth with light-colored porcelain veneers.

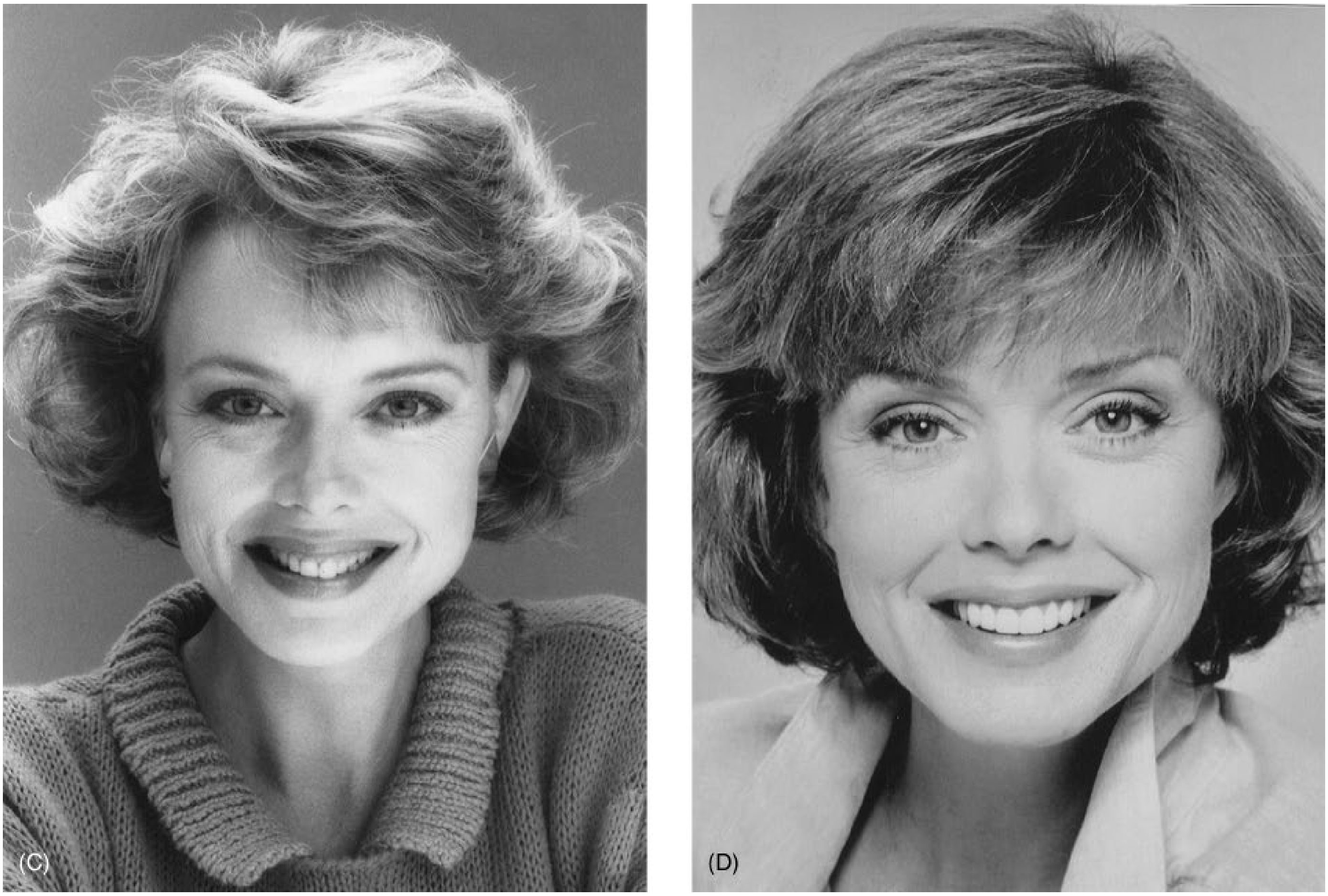

Figure 36.11 **(C, D)** Comparison of the actress's publicity pictures shows the difference in her smile after a brighter color and widening of the arch through porcelain veneers. *Source*: Images (C) and (D) reproduced with permission of Quintessence Publishing.[1]

Figure 36.11 **(E)** It is important to have sufficient thickness of porcelain to be able to mask the underlying tooth color. *Source*: Reproduced with permission of Quintessence Publishing.[1]

Selecting a shade

Choosing the color is probably the most important element in creating a look for a performer's teeth. Color is the most distinctive visual feature for creating a dramatic difference in appearance. Changing the shape of the teeth is not as effective as changing the color because tooth shape is less visible than having one tooth darker than another. For instance, darkened teeth can be seen in the last row of a theater.

Selecting an appropriate shade for an entertainer is one of the most important aspects of the procedure. Generally, there are two treatment options:

1. Select a shade that is perhaps brighter than is normal for nonperforming patients, but which would still appear natural.
2. Defer to the performer's choice of the brightest shade available, regardless of how unnatural it may appear in an off-camera setting.

A possible third choice for performers is a shade just slightly less bright than the second option.

The first choice requires no explanation. The second, however, has roots in cosmetic dentistry lore with an ultrabright shade that bears the initials of the legendary entertainer Phyllis Diller. She had requested the lightest tooth shade available, which at the time was an extra-light hybrid composite. However, after seeing a polymerized direct test shading, Ms Diller said she wanted an even lighter shade. Even though the color already seemed too light, the entertainer insisted that it was not white enough, despite the fact that it was the lightest prepackaged shade then available. The treating dentist (Goldstein) decided to mix white opacifier with the prepackaged shade to create an even brighter shade of white. Containing approximately 75% opacifier, the resulting shade has been called "PD White" ever since. Even now, with bright "bleach shades" of composite resin available, there may be times when you need to use more of the white opacifier to obtain the desired shade.

A color that had previously been considered an embarrassingly bright tooth shade under theater lighting actually looked appropriate on Ms Diller. The heavily textured surfaces of the composite resin used in the procedure also soften the harshness of bright stage lights, a feature that makes for additional appealing results (Figure 36.12).

Metal restorations

Polished amalgams, inlays, onlays, or gold crowns may cause a reflection problem. When these restorations are appropriate or already present, use air abrasion (or micro etcher) to create a dull finish. This procedure can be repeated as necessary.

There is a variation of the aforementioned procedure that can be used to mask an existing gold inlay. The inlay is prepared with about half the occlusal gold removed and covered with tooth-colored composite material. The margins of the cavity preparation are actually covered by a thin edge of gold that bevels back into the body of the inlay. More of the mesial marginal ridge is covered than the distal. The effect of gold inlays that are too visible can be minimized by abrading the surface with air abrasion or microetcher, which puts a satin-like or antique finish to dull the polished metal.

Orthodontic treatment

Problems of malocclusion may present special difficulties to performers because most entertainers travel a great deal and the frequent and necessary adjustments are difficult to arrange. Because appearance is a primary concern, several considerations should be included in the treatment plan.

Whenever possible, try to use "invisible" orthodontic appliances, such as Invisalign, Hawley, or Crozat, because the patient can remove them when performing (Figure 36.13). Ideally, the patient should wear the removable appliance for 24 h a day, although 18–20 h may be acceptable and will ultimately create proper movement. The following photographs illustrate this transformation. The treatment can be completed in five working days using porcelain veneers.

- Always consider Invisalign first, since few people, if any, will be able to tell it is being used. Invisalign is the premier choice of treatment, unless the patient has the time for conventional orthodontics, which would include tooth-colored ceramic brackets.

Figure 36.12 **(A)** The actress and well-known comedian Phyllis Diller needed a brighter and younger looking smile, especially for her stage performances.

Figure 36.12 **(B)** The finished appearance consisting of composite resin direct-bonded veneers.

Figure 36.12 **(C)** Even the lightest color composite was not bright enough for the patient, so Dr Goldstein decided to mix opacifier with the brightest color composite.

Figure 36.12 **(D)** A white opacifier was applied directly to the etched and polymerized resin before applying the special shade composite resin, termed "PD White" in honor of the patient.

Figure 36.12 **(E)** The final smile was accomplished by bright-colored direct composite veneers, which included lengthening her central incisors to produce a younger-looking smile line.

- If full banding techniques are necessary, recommend that the orthodontist utilizes ceramic brackets on the anterior teeth at a minimum, so that the patient will be able to perform without showing unsightly metal appliances (Figure 36.14).
- If possible, consider the use of lingual, or invisible, braces. It is important to note, however, that there are five problems associated with the use of lingual bands on entertainers:
  - Speech may be affected or impeded.
  - The extraction of one or more anterior teeth may sometimes be required.
  - Frequent adjustments are usually necessary.
  - Lingual bands may be more expensive.
  - Dental visits can possibly interfere with a performer's travel schedule.

With the increasing demand for interdisciplinary therapy, more and more performers have taken advantage of the benefit that orthodontics can bring. This also means there is much less need for a compromise treatment when there are easy orthodontic treatment options available.

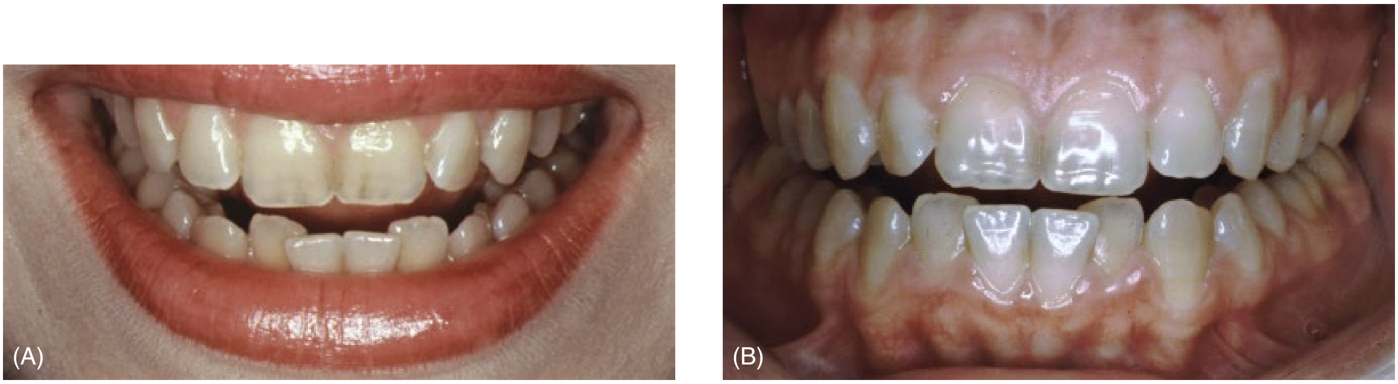

Figure 36.13 **(A, B)** This performer was concerned about her discolored and crowded teeth.

Figure 36.13 **(C)** A removable Hawley retainer was constructed to reposition her mandibular anterior teeth.

Figure 36.13 **(D)** The teeth were then bleached in the office with 36% hydrogen peroxide while the lowers were being straightened.

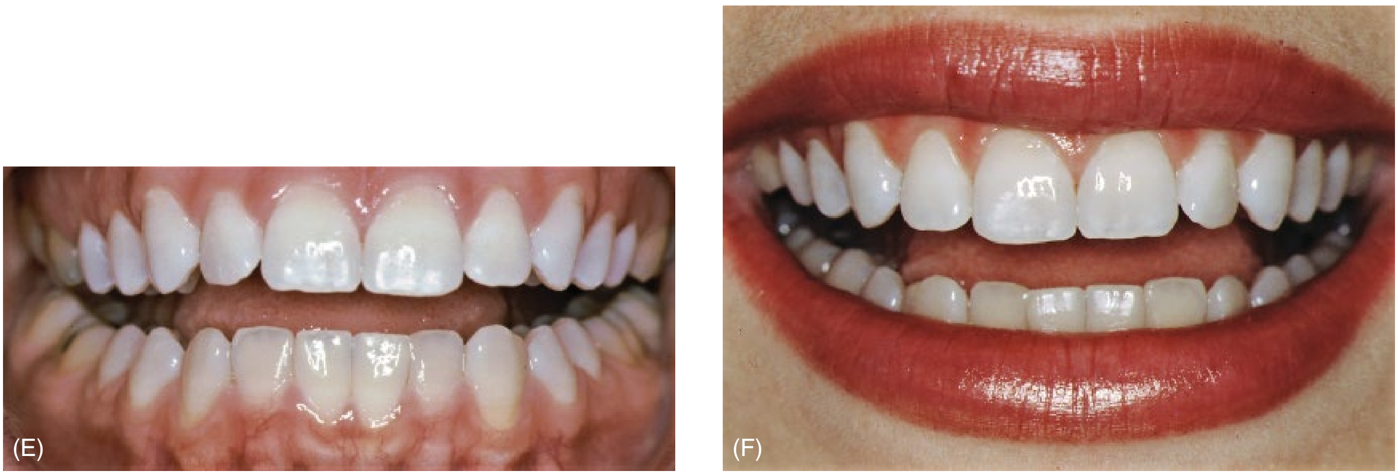

Figure 36.13 **(E, F)** The final result shows straighter and brighter teeth, producing a more attractive smile.

Periodontal treatment

Given the nature of their profession, entertainers need to look as attractive as possible. Appearance problems, such as a high lip line, can many times be corrected through esthetic periodontal surgery. Teeth should be proportionate to the face; when the gingiva covers too much of the tooth surface, disharmony occurs between teeth and gums. A good example can be seen in Figure 36.15. The actress depicted was unaware of the reason for her unattractive smile. Describing it as “too gummy,” she was determined to improve her smile. Computer imaging enabled her to see that lightening her teeth and exposing more of the

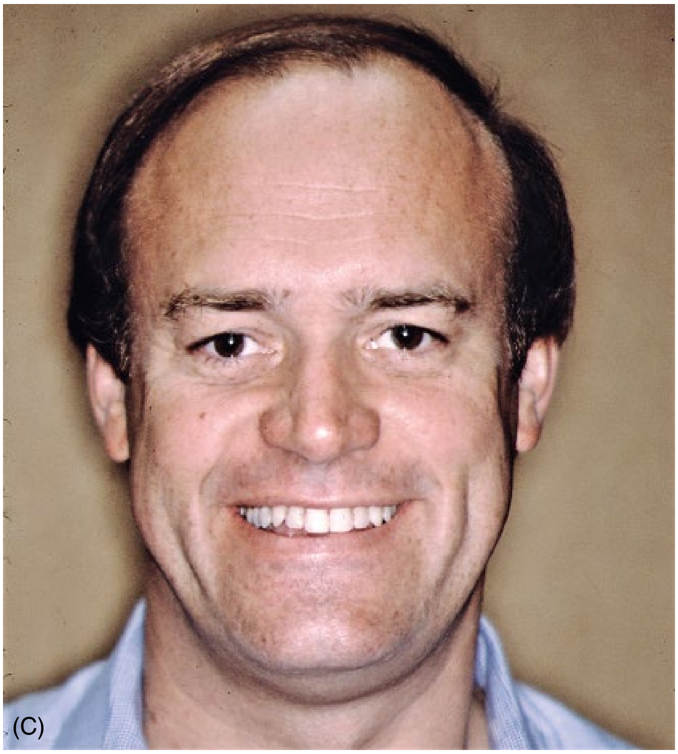

Figure 36.14 **(A)** This well-known broadcast journalist was concerned about the diastema between his front teeth. **(B)** Because of his constant appearance on television, ceramic brackets were chosen to help improve his smile and close the space. **(C)** The final result shows a better looking smile and also helped for more close-up television appearances.

natural tooth structure would accomplish that aim. Therefore, procedures to raise tissue were used, and the teeth were bleached as the finishing touch.

It is important to note that a patient must be in good periodontal health before any type of dental restorative treatment is started. Occasionally, if periodontal surgery is required where restorations are present, unattractive interdental spaces may result. Therefore, consider using laser-assisted new attachment procedure and refer to a periodontist or general dentist who uses this technique. However, if interdental spaces already exist, consider using an acrylic gingival insert or composite resin bonding that will mask the unwanted spaces. Figure 36.16A–E illustrates a combined periodontal, orthodontic, and restorative therapy that transformed the appearance of a young photographic model.

Prosthetic treatment

Temporary measures

A common problem that can detract from an attractive appearance is spacing of the teeth. Because the spaces cannot reflect light, intense lighting reveals spaces as black voids. Irregular spacing can even be more of a problem. Some models have a habit of placing the tongue behind the anterior teeth to mask a

Figure 36.15 **(A)** This part-time actress and model wanted to improve her gummy smile. **(B)** After crown lengthening, bleaching, and composite resin bonding, her smile was improved.

diastema (see Figure 25.5B). The constant pressure from this habit can cause even more space between the teeth. The obvious and ideal treatment includes either orthodontics or restoring with composite resin bonding porcelain veneers or even full crowns if needed. However, two temporary measures can be used when time is a factor. White mortician's wax has been used by some performers to close the gaps during performances or photographic sessions. Composite resin bonding, done with or without etching, can also temporarily close diastemas and should provide the most esthetic result. Clinical case 36.1 illustrates one approach. Other methods of resolving the problem are discussed in Chapter 26.

Fixed restorations

Many performers will require prosthetic restorations to give them a sense of confidence and the best appearance possible. There are special considerations for constructing crowns and fixed partial dentures for performers that may not be discussed elsewhere.

First, most performers work under very strong lighting, and for this reason there are many significant esthetic factors to consider when constructing their prosthetic restorations. Special attention to crown contours, embrasure form, and overall shaping are crucial to creating natural-looking teeth, light reflection, and silhouette form. Variation in incisal lengths is extremely important for performers who want to look younger. Because most performers do prefer a younger look, a youthful smile line

Figure 36.16 **(A)** This runway fashion model was displeased from the poor esthetic treatment received from another dentist and wanted a better smile to do more photographic modeling.

Figure 36.16 **(B)** An immediate six-unit acrylic bridge plus lower ceramic orthodontic brackets were placed to help improve her smile.

Figure 36.16 **(C)** Final prosthetic restorations, consisting of fixed bridge and crowns, showed absence of symmetrical interdental papilla.

Figure 36.16 **(D, E)** An acrylic gingival tissue appliance was constructed to help provide a more esthetic appearance.

can be created by making the centrals longer than the laterals (Figure 36.18). Shading is also important; teeth that are too light show up just as glaringly as teeth that are too dark.

Specific issues for performers

- *Effects of distance and lighting:* As distance increases, detail is quickly lost in very light or dark teeth. When the teeth are not separated enough, light teeth show up as a solid white band. The appearance of missing teeth can be created when dark shades are used for a patient with heavy lips or when one bicuspid is in linguoversion. Beards and mustaches throw the smile shadow forward, creating an even darker or grayer shadow over the teeth. To balance this effect, use a lighter shade.
- *Treating teeth that are too light or too dark:* There is a tendency for performers to want extremely white teeth. Conversely, if the shade is too dark, it may appear as if teeth are missing. Because entertainers may prefer teeth that are blindingly white, there is little one can do other than use digital photos computer imaging or a very bright trial smile to illustrate to the patient just how unnatural the look can be.
- *Use heavier texture:* This should be done on the labial surface for patients who will be under bright spotlights. This will help break up the reflection of the spotlights.
- *Be careful using yellow in shading:* Too much yellow in shading may give a yellowish-orange cast to restorations that—under some lighting—can make teeth appear unnatural, and much darker.
- *Vary incisal lengths:* Most entertainers want to look more youthful. Therefore, make central incisors longer than the laterals. Creating a greater interincisal distance in anterior teeth, especially veneers or crowns, from 0.5 to 1.5 mm is the range for a younger-looking smile line (Figure 36.18).
- *Open incisal and gingival embrasures:* Anterior restorations will appear as one solid band unless incisal embrasures are opened (Figure 36.18).
- *Do not overbuild porcelain:* Unless you are purposely building out the restorations, avoid making your restorations too bulky. Labial bulk only creates a false appearance to restorations. Be sure to reduce enough tooth structure during the preparation.
- *Add characterization:* Characterization not only increases the "naturalness" of the facial appearance but also prevents light-colored teeth from looking like one continuous unit on

Clinical case 36.1: Immediate closure of diastema with composite resin bonding

Problem

Figure 36.17A–D shows a movie and television actress who wanted a diastema between her upper anteriors closed. She had been using mortician's wax to cover the gap during filming but said that doing so gave her a "spooky" feeling. Also, the patient did not want orthodontics or sound teeth reduced.

Treatment

It was decided to close the space with composite resin. The patient was cautioned that the bond would have to be repaired or replaced periodically. She decided that this was her best solution because this procedure resulted in immediate improvement and did not require tooth reduction.

The first step is to decide which tooth or teeth and surfaces should be included in the treatment. Generally speaking, the distal surface of the tooth closest to the midline is best. Whenever possible, the resin is added mainly to the distolingual surface so as not to make the tooth too wide.

Result

Figure 36.17D shows that the space closure did not make the tooth appear overbuilt because its contact area was carved to the lingual. The biggest problem with this type of restoration is that staining can occur. Patients whose teeth stain easily will usually need to have their restorations refinished more frequently or choose porcelain veneers. Alert the patient that bonding tends to discolor over time. Therefore, polishing or resurfacing will be required.

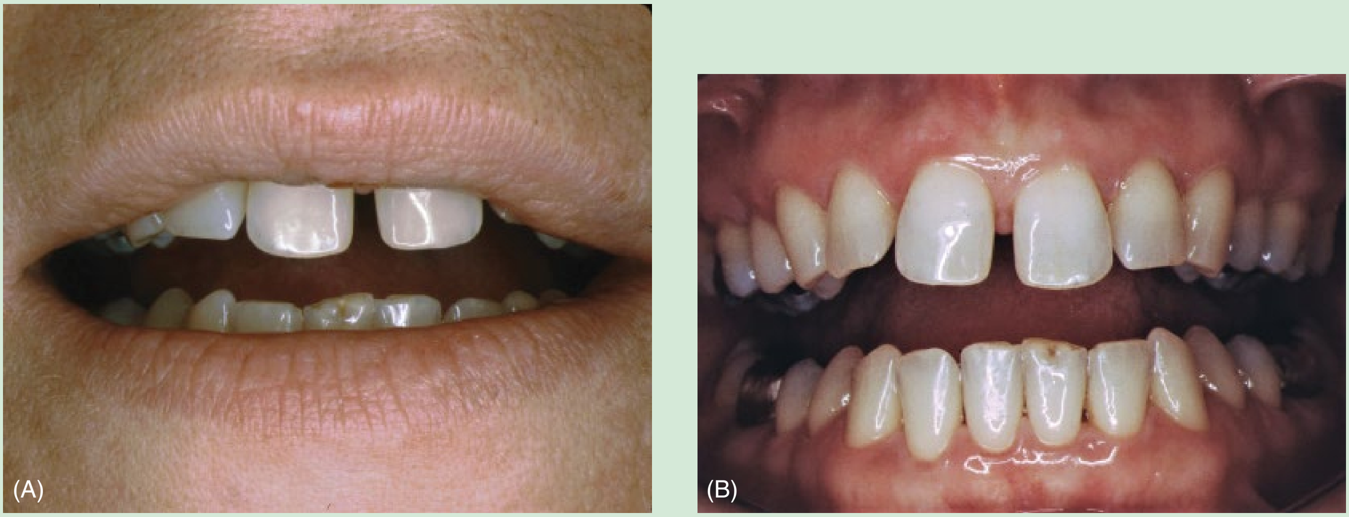

Figure 36.17 **(A, B)** This actress played the part of a stripper in a movie thriller with her natural teeth, but another movie option came up that required a better looking smile so she wanted her teeth instantly changed.

Figure 36.17 **(C, D)** Direct composite resin bonding was chosen to accomplish diastema closure. Later, if she wanted to return to her diastema, the space could be reopened as necessary.

Figure 36.18 **(A–C)** These frontal smile images from the Loren Library Interactive Smile Style Guide depict three attractive variations for performers looking to improve their smiles. Note the differences in incisal length.

photographic interpretation (see Chapter 8). Incisal translucence can go a long way toward making your restorations look more natural, but make certain your patient will allow you to include it.

Emergency treatment

Entertainers have special requirements when it comes to emergency treatment. A dentist who treats performers must be willing to extend special office time to them because, as the adage says, the show must go on. Performers may require priority attention when they have an emergency. Note, however, that the nature of a performer's dental emergency may not be the same as an emergency for a patient who does not work in the entertainment industry. Given their esthetic needs, entertainers have much more at stake, because their livelihoods depend much more on their appearance than those of a nonperformer do.

Long-distance consultation

Long-distance consultation offers another option for treating traveling performers who need modifications to their appearance. This option taps into dentistry's growing use of computer-assisted design and computer-assisted manufacturing. The use of computer imaging and e-mail can be an effective method for treating an actor on a film shoot, for instance. Once it is approved, the prosthesis can be sent to the location by the following day.

Although many entertainers have high travel expenses and low income, they should not be penalized by inferior treatment. This means extraction is not necessarily the best answer for a tooth that could be preserved and useful for a long time. It may take several years before an entertainer can afford more extensive or expensive treatment. Nevertheless, there is no reason that they should lose a tooth because of cost or time constraints. A more economic treatment plan, perhaps consisting of composite resin bonding or even acrylic or composite resin treatment crowns, could be an excellent interim esthetic compromise. In cases where extraction of an anterior tooth is mandatory, it may be possible to salvage the patient's natural tooth crown for quite a long time. Although ideal treatment might well consist of extraction and an immediate implant, it may be out of the performers budget or even not possible during filming.

Occasionally, entertainers may require removable dentures for a special effect. The patient in Figure 36.19, a comedian, wanted a "comic arrangement." The denture was constructed in the

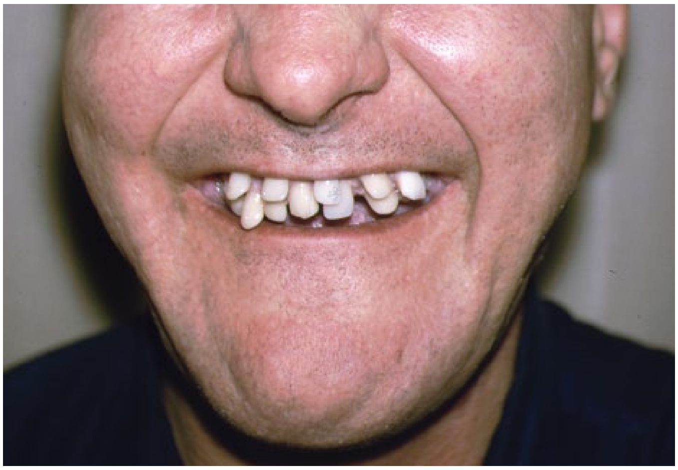

Figure 36.19 This comedian wanted a comic arrangement for his act, so a denture was constructed in the conventional manner but the teeth were widely spaced, in multiple rows placed at random and oversized to create the abnormal effect.

conventional manner, but the teeth were widely spaced in multiple rows at random and made oversized to create the abnormal, comedic effect.

Summary of important principles for treating performers

The trial smile: demonstrating using imaging and video and informed consent

Although the use of esthetic imaging and video can help the performer understand the proposed treatment and the expected result, there is no substitution for a trial smile to make certain the look you propose is also the same as the performer expects (see Chapter 3). If an extremely light shade is desired, be sure to show your patient how the effect of the too-white restorations may look. As seen in the case of Phyllis Diller, some patients will want or need to have a smile with unnaturally light-colored teeth, but

Figure 36.20 **(A)** The Rite-Lite 2 (AdDent) has three sources of light: incandescent, fluorescent, and a combination of both. This way, patients can be tested to make sure the restoration will look good in different environments.

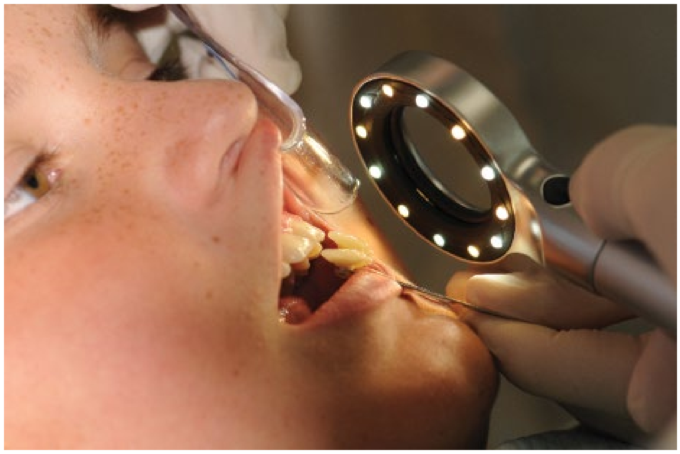

Figure 36.20 **(B)** The light source shown here is a combination of both fluorescent and incandescent light.

Figure 36.20 **(C)** Note the precise difference the Rite-Lite 2 (AdDent) makes in determining a proposed light shade.

these patients should be urged to at least consider their off-stage appearance. As long as the patient is aware of the expected results and approves it in writing before treatment begins, there should be no surprises. Just make sure you have a well-written, understandable informed consent form (see Chapter 6).

Lighting considerations and effects on appearance of the teeth

Careful consideration of light reflection from studio lighting

The effect of light reflection on the appearance of teeth is an important phenomenon to consider, and anything that modifies the reflection, such as lips, beard, or tongue, must be studied appropriately. Under studio lighting, little difference can be seen in similar shades of the all-ceramic crowns, porcelain-fused-to-metal, porcelain veneers, and composite resin restorations. An acceptable difference may be detectable in acrylic resin splints and sometimes in all-ceramic crowns. Such restorations may appear darker than shades used with the other materials. The goal is to have all these materials blend favorably with natural teeth on screen or in still photographs when the shades are matched under different lighting. Incandescent light is generally used in theatrical plays, video productions, or movie productions. One shade detection light that can be quite helpful is the Rite-Lite 2 (AdDent). This has three light sources that can be seen just by pressing a button on the device (Figure 36.20A–C); the three sources have fluorescent, incandescent, and a combination of both.

Restorations that lack deep depressions in the interproximal contact and shoulder areas lose the appearance of separation between the teeth and will appear as broad bands of white. This problem is sometimes encountered in metal-based veneered restorations, when the opaque metal close to the interproximal surfaces reflects light excessively. Staining can be used to resolve this situation when the embrasures cannot be deepened.

Effects of black lighting

If the performer's porcelain restorations will be seen frequently under black light, porcelain that has a luminous effect should be considered. Although the built-in reflecting quality does not completely mimic the qualities of the natural tooth, it is better than ceramic restorations that do not possess this characteristic.

The goal: attractive, natural-looking teeth

Quality functional and esthetic dental treatment always means maintaining the patient's natural teeth, even if crowning becomes necessary. Extractions and removable or fixed partial dentures should be avoided. An attractive, natural appearance is essential for persons in the performing arts. A dentist with a performer for a patient should have a thorough knowledge of the skills covered in this chapter as well as an awareness of the special needs involved in treating patients who appear in films, television, theater, magazines, and on catwalks.

Reference

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Chapter 37 Periodontal Plastic Surgery

W. Peter Nordland, DMD, MS and Laura M. Souza, DDS

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Esthetics and function

Periodontal plastic surgical procedures have the ability to assist the restorative dentist and patient to achieve beautiful results. Esthetic excellence in restorative dentistry mimics the natural shape and color of the teeth. The final restorative outcome will only be optimal when soft tissue and bone also mimic the natural anatomy. The role of periodontal plastic surgery is to give patients back the natural framing when normal anatomy is deficient or missing. Periodontal plastic surgery should restore color, texture, symmetry, size, and proportion while bringing tissues to an anatomically correct position.[1,2] Surgical results should be predictable and long-lasting with health.

This subspecialty is also meticulously focused on preserving the soft tissue and bone during oral surgical procedures to allow for an optimal esthetic result. This is extremely important, especially when working in the esthetic zone. An aggressive approach during the surgical procedure can disfigure a patient's smile by creating scar tissue, bony defects, papilla loss, and gum recession. Focusing on this goal, it is important that the surgeon minimizes or totally avoids releasing incisions. This is mostly evident in the maxillary anterior region with delicate biotype patients.

The papillary microvasculature has been identified as an end-artery organ with delicate blood supply.[3] Loss of the interdental papilla caused by trauma or periodontitis remains a significant esthetic challenge to dentistry.[4] Once the defect has been created, it can be very challenging to correct. Many clinicians have tried over the years to reconstruct lost interdental papillae around natural teeth; however, a high level of success and predictability have not been achieved.[5–14] Examples showing incision defects

Ronald E. Goldstein's Esthetics in Dentistry, Third Edition. Edited by Ronald E. Goldstein, Stephen J. Chu, Ernesto A. Lee, and Christian F.J. Stappert.

are presented in Figure 37.1. A simple surgical tooth extraction can also lead to bone loss and a soft-tissue defect.[15] An anterior collapsed ridge can make it impossible to place an implant in the area and always increases the challenge for the restorative dentist (Figure 37.2). A conservative and delicate approach during a surgical extraction does not always guarantee a good foundation, but will allow for faster healing and less discomfort during the recovery, in addition to a better esthetic result. The likelihood of a severe ridge collapse or soft-tissue defect should be drastically diminished with a delicate microsurgical approach (Figure 37.3).

Microsurgery

When performing microsurgery, small microsurgical instruments can help make the surgical procedure less invasive and less traumatic.[2,16,17] Microsurgical instruments can include microscalpels, microforceps, and miniaturized surgical instruments (Figure 37.4A).[2,17] The use of the surgical dissecting microscope can be helpful to minimize incision size and easily hide incisions.[17] The surgical microscope offers increased illumination and visual acuity to perform procedures with greater precision than with other methods of magnification.[2,17,18]

Microsurgical blades such as the N6900 were developed to allow for atraumatic and undetectable surgical incisions (Figure 37.4B). These scalpels can be modified to provide curves using small bends in the blade and in the shank to allow the

Figure 37.3 All anatomical contours were maintained with a delicate microsurgical approach.

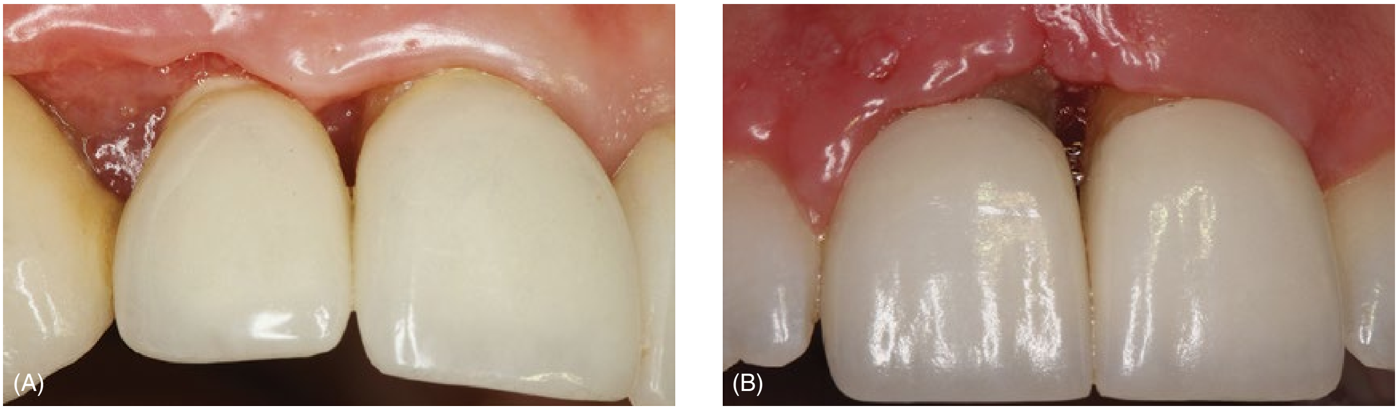


Figure 37.1 **(A, B)** Previous incisions in the esthetic zone disfigured these smiles.

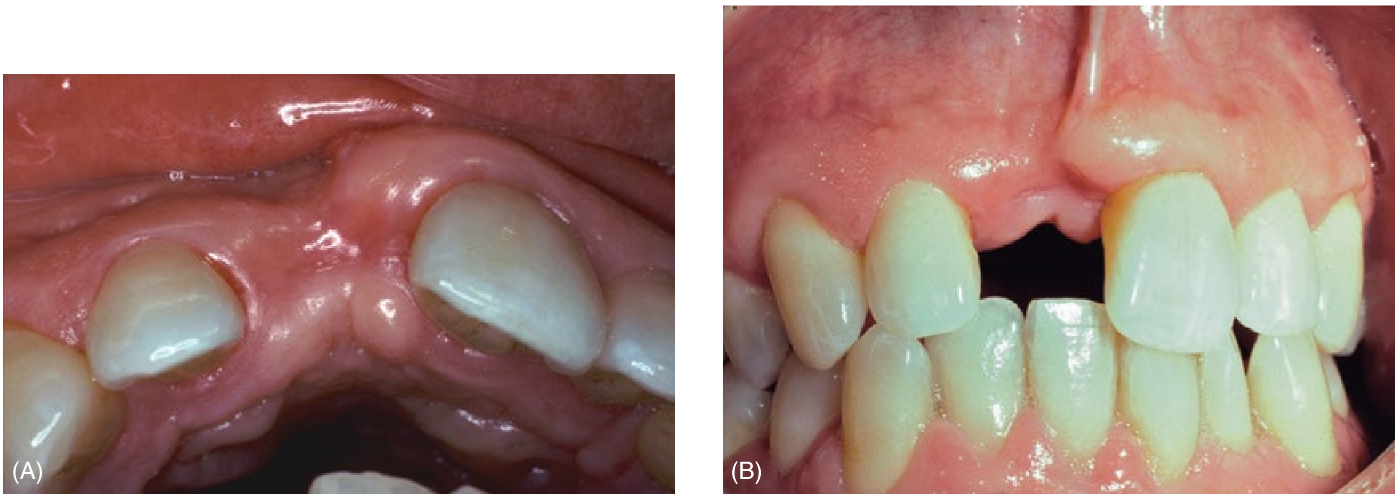


Figure 37.2 **(A, B)** Photos demonstrating anterior ridge collapse.

Figure 37.4 **(A)** Nordland microsurgical kit (Hu-Friedy).

Figure 37.4 **(B)** A comparison between the microsurgical N6900 and the 15-C blades.

dissection under papillae or around tori (Figure 37.4C).[17,19] Making curved incisions around obstacles can avoid additional releasing incisions that otherwise might be used to create access, minimizing soft-tissue traumas and defects.[19] In addition, the surgical dissecting microscope and microsurgical instrumentation have allowed the surgeon the capability of fine-tuning surgical procedures.[2,17,20]

Root coverage

The use of the free gingival graft, as described by Sullivan and Atkins in 1968, detailed the use of a very thin graft harvested from the palate.[21–23] Although the free gingival graft could increase the band of attached keratinized gingiva, it did not provide root coverage. Unfortunately, the tissue color and texture would appear different from the native tissues and remain obvious, creating a permanent unesthetic result (Figure 37.5).

A paper by Cole et al. in 1980 demonstrated, with human histology, that new attachment was possible through acid demineralization of the root surface.[24] This encouraged further studies of soft-tissue grafts with acid demineralization to promote root coverage with possible new attachment. In 1982, Miller published the use of a thicker gingival graft that used butt joint incisions, which enhanced vascularity of the thicker graft by including blood supply to the sides of the graft tissue. This technique incorporated the use of acid demineralization to achieve root coverage and potentially new attachment to the root surface.[25] Later in 1985, Miller demonstrated predictable root coverage using a free soft-tissue autograft following citric acid application.[26] The use of subepithelial connective tissue in a pouch was introduced by Langer and Calagna to correct ridge defects.[27] Raetzke adapted the use of a pouch technique to help surround grafted tissue over exposed roots.[28] This further enhanced vascularity and the surgical outcome for root coverage procedures. In that same year, Langer and Langer[29] also published their paper detailing the use of subepithelial connective tissue to achieve coverage. Nordland, in 1989, published a

Figure 37.4 **(C)** N6900 with blade and shank customization.

Figure 37.5 Example of an unesthetic free gingival graft result.

technique paper to detail the use of connective tissue, acid demineralization, and envelope recipient bed and envelope donor tissue harvesting to achieve consistent root coverage with the potential for new attachment.[30] In 1994, Allen published the use of a tunneling technique to essentially surround the cells totally with blood supply.[31]

Current techniques, as described by Nordland, take advantage of surrounding the graft almost entirely with blood supply, thereby improving the survivability of all the transplanted cells. Esthetic color blending and natural surface textures are maintained in the recipient area because the surface tissues are unchanged, keeping the original native appearance.[19,20] The Miller classification provides guidelines for predictability of root coverage.[32] It has been shown that periodontal root coverage procedures are highly predictable for Class I and II recessions even when root surface defects are present. Success rates for complete root coverage range from 92% to 99% and are stable over time.[33,34]

Etiology of gingival recession

Several etiologic agents have been recognized to cause gingival recession. Often, the etiology of recession can be multifactorial, and the factors may include the following:

- *Inflammation.*[35] The presence of bacterial plaque and its toxins will cause an inflammatory process in the gingival tissue that may lead to bone loss, attachment loss, and recession as a result.
- *Toothbrushing trauma.*[36] Toothbrush abrasion or other cleaning devices can cause mechanical trauma to the gingival tissue, resulting in recession of the gingival margin. A more modern concern could arise from mechanical electric toothbrush devices.
- *Tooth position.*[37–39] If orthodontic treatment is planned, then a thin band of keratinized gingiva can increase the susceptibility for gingival recession.[37] The tooth position plays a key role determining if gingival augmentation is necessary.[38] Teeth that are moved orthodontically to a prominent position have thinner surrounding bone and thin soft tissue that could make them more prone to trauma and gingival recession. If a tooth erupts out of the bony housing, it could emerge through the alveolar mucosa, thereby lacking attached keratinized gingival protection that could result in future susceptibility to recession.[39]
- *Tooth prominence.* Teeth with prominent crowns or roots will be more affected by mechanical trauma from toothbrushing and food than other less prominent teeth and may also experience a thinning of the overlying bone and gingiva.[40]
- *Prominent frenum.* It is thought that a prominent frenum could exert a pull or tug at the gingival margin and thereby contribute to recession, especially if the frenum extends close to the free gingival margin.[41,42]
- *Dental restorations.* Restorations could traumatize delicate tissues with placement of retraction cord. Prominent margins can contribute to plaque retention, and prominent restorations could push the marginal tissue apically.[43–45]
- *Abfractions.* These have not been shown to create gingival recession directly; however, tooth flexure could promote loss of the crystalline enamel structure, resulting in enamel loss and dentinal exposure.[46–48]

Predisposing factors:

- lack or minimal presence of attached keratinized gingiva;
- delicate biotype (Figure 37.6A and B).

Connective tissue versus allogenic tissues

Allogenic tissue has become popular owing to the unnecessary palatal wound and the unlimited supply of donor tissues, allowing the surgeon to treat many areas of gingival recession in one sitting. The supply of autogenous donor tissue is limited and could require sequential surgical procedures when full mouth treatment is anticipated. There is debate whether connective tissue grafts can increase the amount of attached keratinized gingiva, as shown in Figure 37.7A and B. Using autogenous connective tissue, the grafted tissue can create a cell line that will survive and replenish itself over time. The risk of regression is minimized. Allogenic tissues can thicken the tissue surrounding a tooth; however, their efficacy is questionable long term, compared with the use of autogenous connective tissue graft.[49]

Unfortunately, there have been tissue bank recalls of allogenic tissues used for other purposes, which can create a concern by the anxious patient. Allogenic tissues also add an increase in cost for the material. Allogenic material also has the potential to show through in areas of thin native tissue, especially in delicate biotype patients.

In a study evaluating the histologic composition of connective tissue grafts in humans, Harris found that, even though most connective tissue grafts are not uniform in composition, all grafts were successful in producing root coverage with a mean root coverage of 97.7% in Class I or II defects.[50] Long-term stability of root coverage and esthetic results perceived by patients were significantly better 10 years after connective tissue graft surgery, statistically, than after guided tissue regeneration surgery using bioabsorbable barriers.[51] According to Lee et al.,[52] the connective tissue graft is a predictable method for root coverage and the clinical outcomes gained can be well maintained. Chambrone et al.,[53] in a Cochrane systematic review, evaluated the effectiveness of different root coverage procedures including free gingival grafts, laterally positioned flaps, coronally advanced flaps, subepithelial connective tissue grafts alone or in combination with laterally positioned or coronally advanced flaps, acellular dermal matrix grafts, guided tissue regeneration, and the use of enamel matrix protein in the treatment of recession-type defects and concluded that, where root coverage and gain in keratinized tissue are expected, the use of subepithelial connective tissue grafts appears to have superior results.

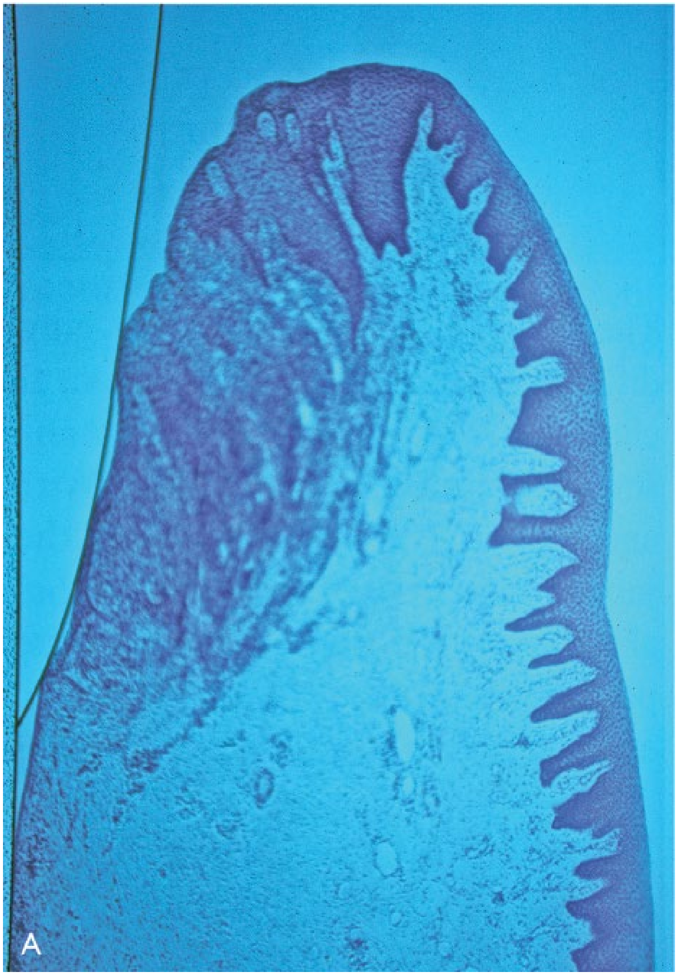


Figure 37.6 **(A)** Histologic image of a thick gingival biotype with inflammation.

Figure 37.6 **(B)** Histologic image of a thin gingival biotype with inflammation.

Indications for gingival augmentation

The following are indications for gingival augmentation:

- gingival recession with root sensitivity, root caries, cervical class v restorations, or overextended crowns;
- insufficient attached keratinized gingiva, which could make the site more vulnerable to recession;
- correction of gingival tissue asymmetry before planned restorative procedures;
- thin tissue with anticipated facial orthodontic tooth movement.

Furcation involvement

Studies by Nordland et al.[54] have shown that furcation sites do not respond as well to nonsurgical therapy as flat surfaces and interproximal areas do. It is unclear whether gingival augmentation over Grade I or II furcation sites can provide better long-term furcation maintenance; however, the possibility for new attachment is biologically plausible and clinically promising (Figure 37.8A and B).

Potential for gingival regeneration

The addition of a connective tissue graft to cover root surfaces could raise the concern for creation of a periodontal pocket. Minimal probing pocket depth is desirable following root coverage procedures. It is expected that a pocket would be created if new attachment of the grafted soft tissue does not occur. To avoid the creation of a pocket, new attachment is necessary. A landmark study by Cole et al.[24] in 1980 showed for the first time that new attachment in humans was possible. This study used demineralization of the root surface to expose collagen fibers of the root with close re-apposition of the flap, and showed that new attachment could occur. Another study, by Steiner et al.,[55] using all the same steps as Cole, showed that new attachment did not occur without the acid demineralization step.

Because acid demineralization increased the potential for new attachment in humans, clinicians have used this rationale to potentiate new attachment with gingival augmentation. Initially, citric acid was used; however, issues with root resorption were

Figure 37.7 **(A)** Pre-op photo shows a minimal amount of attached keratinized gingiva.

Figure 37.7 **(B)** Post-op photo shows a significant increase in the amount of keratinized gingiva.

Figure 37.8 **(A)** Pre-op photo of a molar with significant recession and Class I furcation involvement.

Figure 37.8 **(B)** After connective tissue grafting, root coverage was achieved with an increase in the band of attached keratinized gingiva and minimal probing depth.

reported, and most clinicians now use tetracycline due to its availability and long-term efficacy (e.g., Arestin, Atridox, and Actisite). Block section histology following connective tissue grafting has demonstrated new attachment.[56] Connective tissue root coverage has also been shown to be successful as an alternative to root coverage restorations.[57,58]

Connective tissue graft surgical technique

The patient in Figure 37.9 presents with multiple areas of root exposure, root sensitivity, with minimal or no attached keratinized gingiva.

Figure 37.9 This patient presents with multiple areas of root exposure, root sensitivity, with minimal or no attached keratinized gingiva.

Root preparation

A thorough debridement of the root surfaces needs to be accomplished. Bacterial endotoxins and calculus are removed using ultrasonic scalers, rotary instruments, and hand instruments. Rotary instruments also help reduce areas of prominent root surfaces and reduce undercuts. Finishing burs of varying sizes can be used to clean the root surfaces and modify root prominences (Figures 37.10, 37.11, and 37.12). Undercuts are reduced and flattened. Caries and restorative materials should be removed with the sequential use of finishing burs. Hand instruments are used to smooth and flatten the facial surfaces (Figures 37.13 and 37.14). A 10/11 scaler (G. Hartzell & Son) can

Figure 37.10 Finishing burs of varying sizes can be used to remove old composites, clean the root surfaces, and modify root prominences.

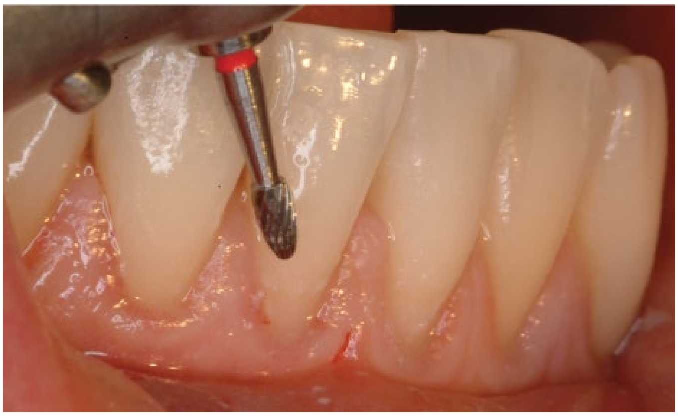


Figure 37.11 A #18 finishing bur is selected to clean the root surfaces and modify root prominences.

Figure 37.12 A #5 finishing bur is used to extend subgingivally.

be used to easily reduce prominent line angle contours (Figure 37.13). Microsurgical instruments are especially helpful when treating small anterior teeth. Special instruments have been developed, such as the SPN1 and SPN2 back action micro-chisels (G. Hartzell & Son) to achieve accessibility for root planing and root smoothing (Figure 37.14). The newer and smaller SPN1 (G. Hartzell & Son, Figure 37.15) is compared with the

Figure 37.13 A 10/11 scaler (G. Hartzell & Son) can be used to easily reduce prominent line angle contours.

Figure 37.14 Microsurgical instruments have been developed, such as the SPN1 and SPN2 back action micro-chisels (G. Hartzell & Son) for small areas needing root planing and root smoothing.

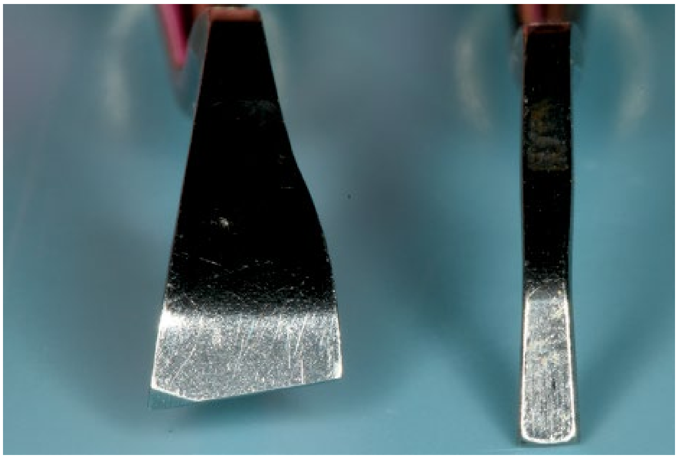


Figure 37.15 The newer and smaller SPN1 (G. Hartzell & Son) is compared to the traditional 13-K.

traditional 13-K that is too large to access small root surfaces. Traditional hand instruments that are too big for the surgical areas are not recommended for this part of the procedure to avoid any unintentional trauma to the surrounding tissues (Figure 37.16). After the roots are thoroughly debrided,

Figure 37.16 Traditional hand instruments that are too big for the surgical areas are not recommended for this part of the procedure to avoid any unintentional trauma to the surrounding tissues.

Figure 37.17 After the roots are thoroughly debrided, a tetracycline paste on cotton pellets is applied.

Figure 37.18 An N6900 microscalpel is selected owing to its small size and ability to be customized.

Figure 37.19 The sulcular split-thickness incision extends around the mesial, facial, and distal, even undermining the papillae.

Figure 37.20 The sulcular incision is extended past the mucogingival junction.

a tetracycline paste on cotton pellets is applied for the purpose of demineralizing the root surface and exposing collagen fibers of the root surfaces, thereby encouraging new attachment (Figure 37.17).

Microincisions and the gingival pouch

The N6900 microsurgical scalpel has been specifically developed to create a sulcular incision that can easily penetrate the sulcus with precision and minimal trauma. The sulcular incision is extended around the facial circumference of the tooth and extended past the mucogingival junction (Figures 37.18, 37.19, and 37.20). As the N6900 microscalpel is inserted into the facial sulcus, obstacles are typically encountered, such as changing contours and bony exostoses, creating unseen obstacles. The microsurgical blade can be modified with custom bending to negotiate these challenging contours to allow separation of a split-thickness flap (Figures 37.21, 37.22, 37.23, and 37.24). Orthodontic bending pliers help to create gentle curves with the scalpel and/or shank to achieve individualized and customized surgical incisions (Figures 37.21 and 37.23). Shank modification is helpful when dealing with the mandibular anterior teeth to help move the scalpel handle into a more ideal working position.

Once the surgical incisions have been accomplished through a sulcular incision, it is important to achieve a patent facial tunnel to allow placement of the connective tissue graft. The interdental papillary area can also be undermined to allow for papillary addition, if desired. Undermining the papilla can also help to reduce any bulkiness of the facial tissue and achieve a gradual

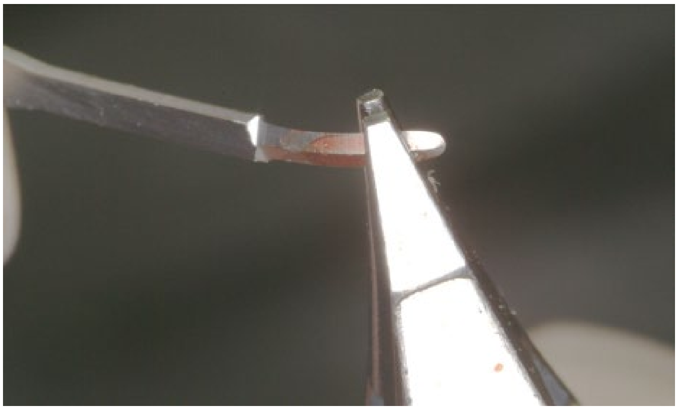


Figure 37.21 The microsurgical blade can be modified with custom bending.

Figure 37.22 The modified microsurgical blade can then negotiate the challenging contours to allow separation of a split-thickness flap.

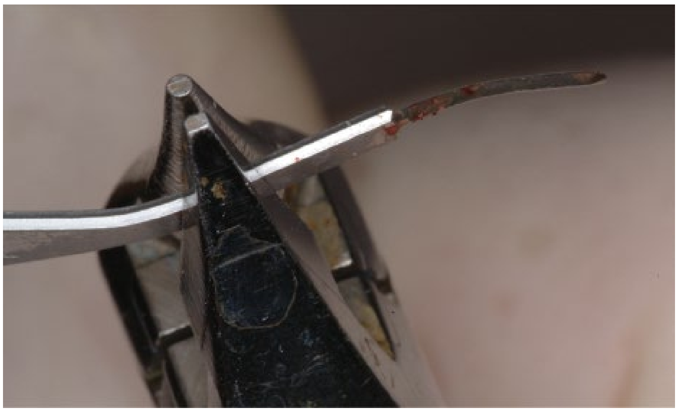


Figure 37.23 The shank of the microsurgical blade can also be bent to conform to surgical needs.

blending at the base of the papilla. A sharpened 10/11 scaler (G. Hartzell & Son) can easily facilitate tunnel patency.

Once it has been determined that the tunnel is patent, tissue mobility assessment should be accomplished to assure that the new tissue position will meet the desired goals (Figures 37.25 and 37.26).

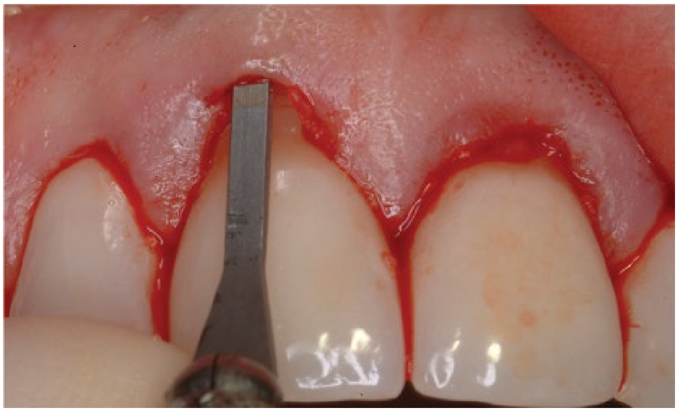


Figure 37.24 Customized scalpel curves allow insertion into the surgical incision to match the individual anatomical contours.

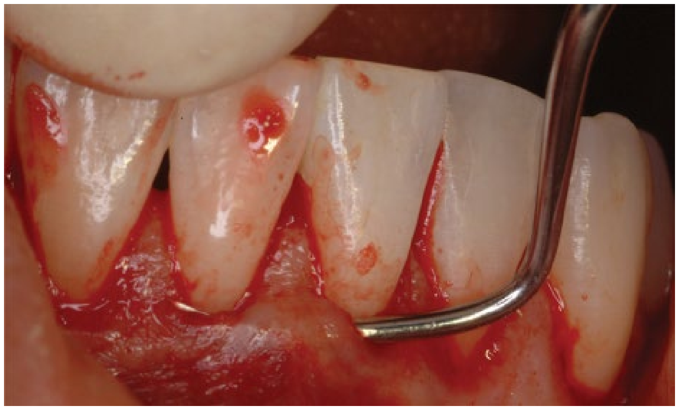


Figure 37.25 A sharpened 10/11 scaler (G. Hartzell & Son) can easily facilitate tunnel patency.

Figure 37.26 Tissue mobility assessment should be accomplished to assure that the new tissue position will meet the desired goals.

Connective tissue harvesting

Specific graft size is determined by measuring the amount of necessary donor tissue with a periodontal probe (Figure 37.27). A connective tissue graft is harvested from the palate using a tunneling approach that allows control of the graft thickness

Figure 37.27 Specific graft size is determined by measuring the amount of necessary donor tissue with a periodontal probe.

Figure 37.28 Parallel incisions are made to define the donor length and thickness.

(Figures 37.28 and 37.29). Palatal connective tissue is lassoed with the suture to allow for delicate manipulation and extraction of the desired tissue dimension (Figures 37.30, 37.31, and 37.32).

Removal of the epithelium is important as the epithelium can survive creating potential epithelial cysts or possible folds in the future healing (Figures 37.33 and 37.34). Once the epithelium is removed, it can be reapplied to the palatal wound to create an ideal surface protection and will typically survive to allow ideal healing of the palatal wound (Figure 37.35). Resorbable or non-resorbable sutures can be applied to maintain wound closure (Figure 37.36). Ideally, a palatal stent is fabricated ahead of time to minimize bleeding, and optimize comfort by protecting the donor site from traumatic stimuli (Figures 37.37 and 37.38).

Modification of the connective tissue graft is accomplished by the removal of the epithelium. Any extraneous tissues, such as adipose tissue or mucous glands, are removed.

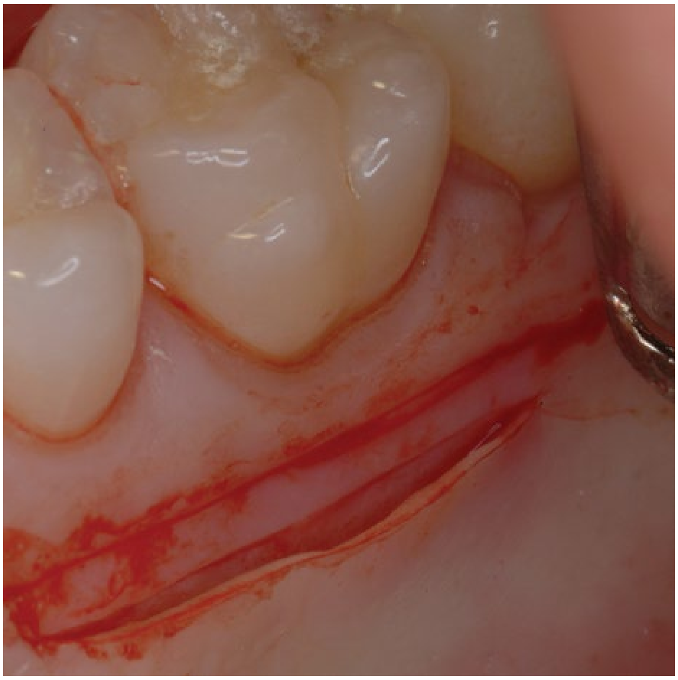


Figure 37.29 A uniform graft thickness is created.

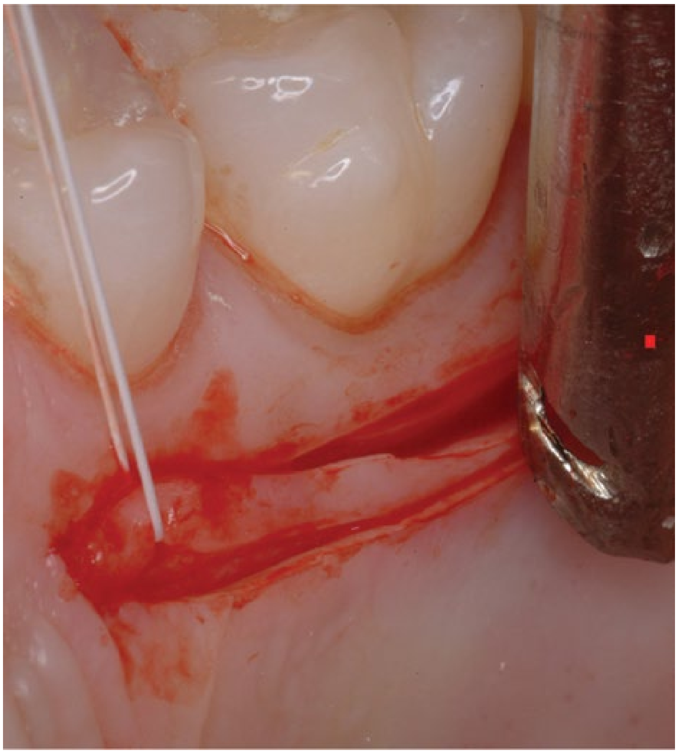


Figure 37.30 A suture is used to secure the donor tissue.

Beveling the mesial and distal segments of the graft helps to create a smoothly blended result (Figure 37.39). Once the tissue is contoured and modified, it is placed over the site to reconfirm the graft dimensions and thickness (Figure 37.40). The graft is worked into the tunnel to extend under the incisions and is guided into place. Working the tissue through a tunnel can be difficult. A variety of instruments can be used to

Figure 37.31 Palatal connective tissue is lassoed with a suture and harvested using a light tugging force while sharp dissection elevates the donor tissue.

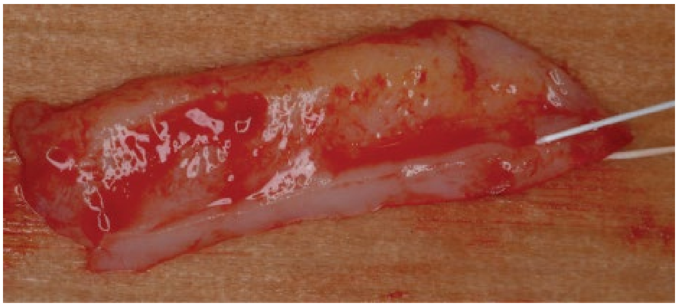


Figure 37.32 Palatal connective tissue is placed on a moistened tongue blade.

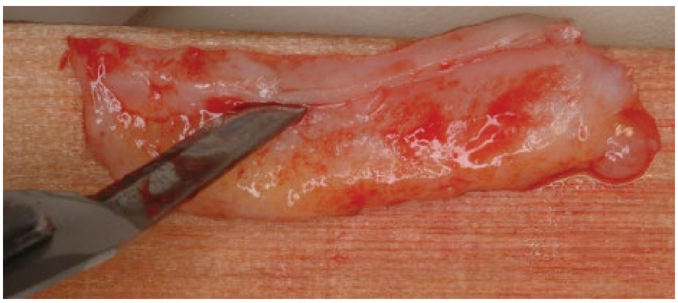


Figure 37.33 The tongue blade provides support for modification of the donor tissue.

accomplish this task. Sometimes it can be helpful to use a suture to pull the tissue through the tunnel. Typically, only hand instruments, such as 10/11 scaler and periodontal probe, are necessary (Figures 37.41, 47.42, and 37.43).

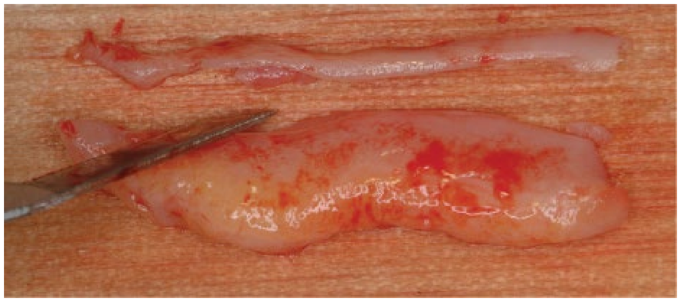


Figure 37.34 The epithelium is removed.

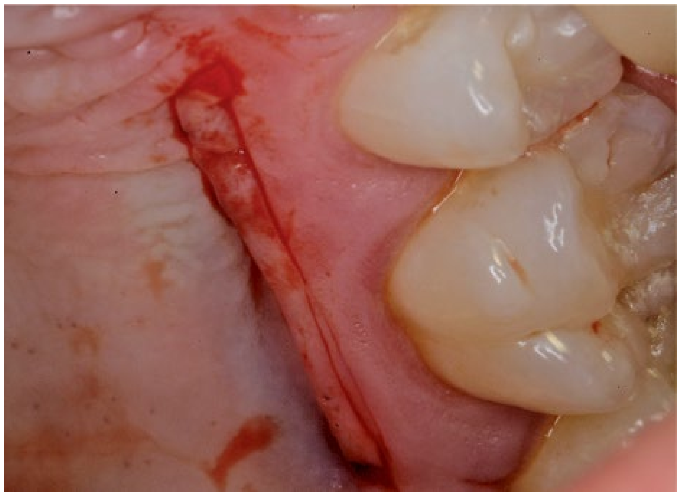


Figure 37.35 The epithelium is reapplied to the palatal wound.

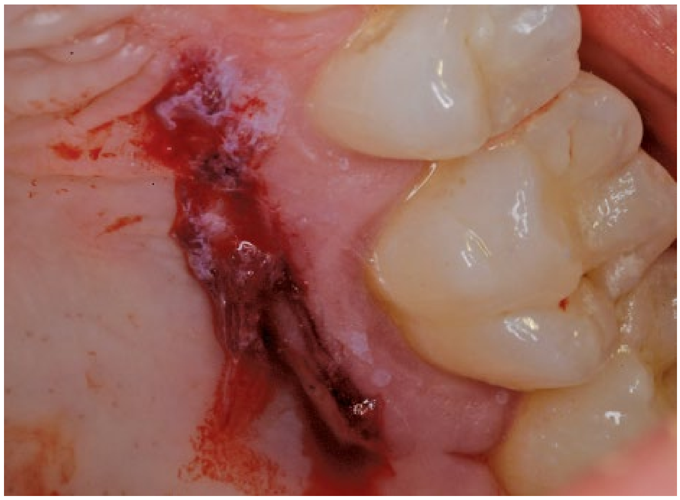


Figure 37.36 Resorbable, nonresorbable, or a liquid suture can be applied to maintain wound closure.

Sutures and dressing

Sling sutures are used to position the overlying existing tissue and stabilize the connective tissue graft under the flap. Once the connective tissue graft is positioned properly, a suture is placed through the flap tissue and through the underlying graft tissue to position it (Figures 37.44, 37.45, 37.46, 37.47, and 37.48). Generally, it is helpful to suture only two teeth at a time as it will

Figure 37.37 A palatal stent.

Figure 37.38 Palatal stent in place.

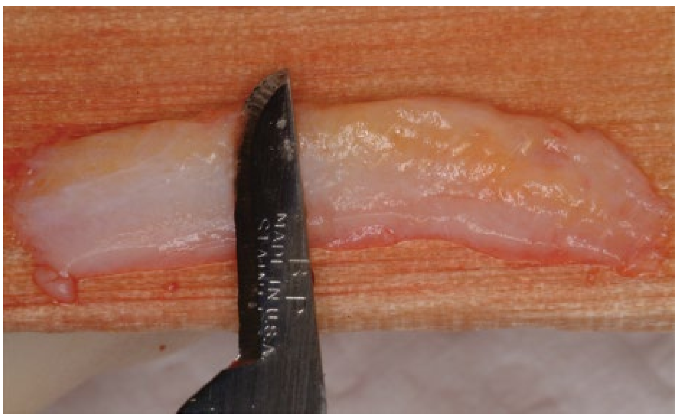


Figure 37.39 Beveling the mesial and distal segments of the graft helps to create a smoothly blended result.

Figure 37.40 Once the tissue is contoured and modified, it is placed over the site to reconfirm the graft dimensions and thickness.

Figure 37.41 The graft is worked into the tunnel to extend under the incisions and is guided into place using 10/11 scaler and periodontal probe.

Figure 37.42 The graft is pulled into position.

allow for better control and positioning of the flap with its underlying connective tissue graft. Ideally, the connective tissue graft should be fully covered by the overlying preexisting soft tissue to insure grafted tissue survival; however, this is not always possible. Previous surgical incisions create scarring and can make the release of the tunnel even more difficult. In these cases, additional time and attention need to be given to achieve a patent movable tunnel and overlying tissue.

Figure 37.43 The graft is worked into the final position in the tunnel.

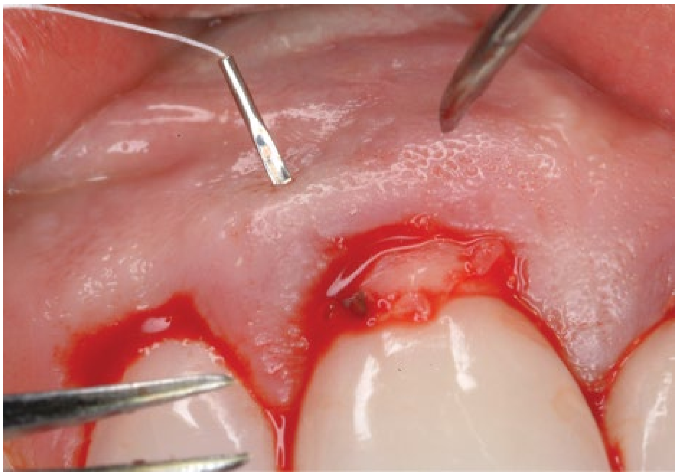


Figure 37.44 A suture is placed through the flap tissue and through the underlying graft tissue to position it.

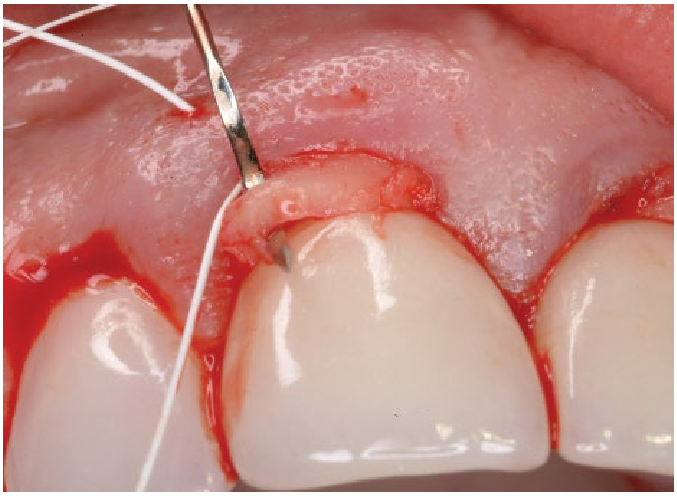


Figure 37.45 The graft was moved out of the tunnel to show how the graft is secured with the suture.

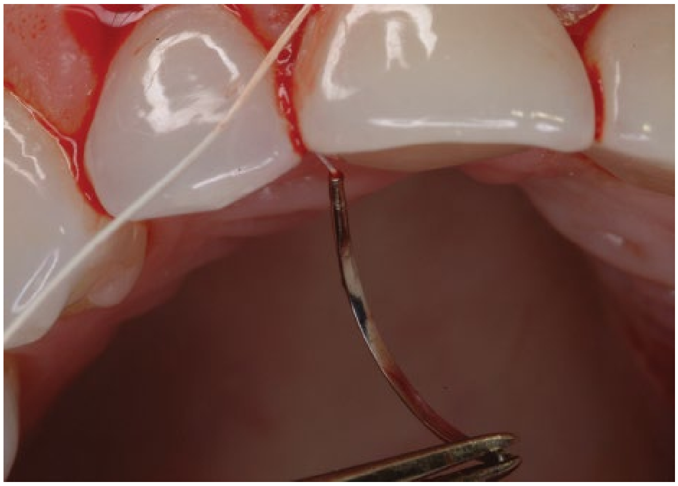


Figure 37.46 The suture passes through the base of the papilla and exits at the base of the palatal portion of the papilla.

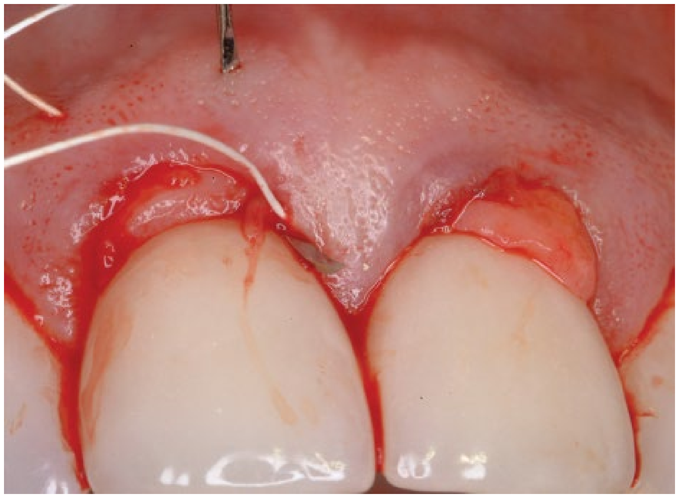


Figure 37.47 The suture is wrapped around the palatal surface of the tooth and re-enters the facial flap at the corresponding line angle.

Figure 37.48 The adjacent tooth is treated in a similar fashion using the continuing uninterrupted suture.

Once the soft tissue has been ideally positioned, stabilization with a liquid suture (isobutyl cyanoacrylate) can be helpful (Figures 37.49 and 37.50). A liquid suture can bring wound edges together without typical needle penetration wounds and has been shown to have a minimal inflammatory result compared with conventional sutures.[59] A dissolving dressing can be placed to help the patient avoid trauma during the first few days of healing (Figure 37.51).

Postoperative instructions and healing

The care of the surgical area is extremely important during the first week. The patient should avoid foods that can cause trauma or hot liquids that can stimulate bleeding and increase swelling. Brushing or flossing the surgical site must be avoided. A 0.12% chlorhexidine gluconate rinse should be used during the first 7 days. An anti-inflammatory prescription is recommended to avoid additional swelling that could otherwise compromise surgical healing. The surgical stent should be kept in place for 1 week.

Figure 37.49 A liquid suture (isobutyl cyanoacrylate) is applied with a micropipette.

Figure 37.50 Stabilization with a liquid suture (isobutyl cyanoacrylate) insures ideal tissue position and minimal bleeding.

Figure 37.51 Dissolving gelatin dressing in place.

Figure 37.52 Postoperative photograph after 6 weeks.

Sutures can be removed in 1 week and oral hygiene instructions are essential to ensure that the patient does not traumatize the area. Many times, the replaced epithelium of the palate heals uneventfully. Reinforcement of oral hygiene techniques is crucial for long-term success. Delicate biotype patients are cautioned against the use of electric toothbrushes that could traumatize the newly grafted tissue. Six to eight weeks of soft-tissue healing is a minimum before restorative procedures can be considered (Figure 37.52).

Other considerations

Old restorations and root caries

Root surfaces with restorative materials and caries can be considered a challenge because they serve as an obstacle for the graft tissue to reattach to the root surface. Even though they can be successfully removed as described earlier, the visualization for such a task can be difficult without magnification. The surgical dissecting microscope is a valuable tool, as it can make visualization of tooth-colored restorative materials more obvious and thereby increase the potential for the success of the final result.[17] It has also been shown that once root caries is removed, connective tissue grafting for root coverage is equally predictable as it is to noncarious roots (Figure 37.53A–C).[57]

Figure 37.53 **(A)** Severe carious lesion on the root surface.

Figure 37.53 **(B)** Connective tissue graft successfully covered the root surface with minimal probing depth.

Figure 37.53 **(C)** Esthetic result well maintained after six years.

Quality and quantity of donor tissue

The quality of the graft tissue to be harvested can vary depending on the patient's biotype and individual tissue thickness. The best quality will be the tissue that is more homogeneous and has a dense fibrous connective tissue composition. It is generally desirable to remove any adipose and glandular tissue from the harvested graft.

When many areas need to be grafted, the amount of available donor tissue can determine how many and which teeth can be treated in the same surgical procedure. The amount of donor tissue available also varies according to the patient's biotype. It has become clear that individuals with thin and delicate gingival tissue, prone to the development of recession, often also present with thin palatal mucosa that might not be suitable for obtaining connective tissue of proper thickness for periodontal plastic surgery.[60] Usually, the quantity and quality of the palatal connective tissue to be harvested can only be assessed precisely during harvesting. If sequential surgical procedures are necessary, harvesting of new tissue should target the healed previous donor site because the healed wound will have a higher percentage of dense fibrous tissue. It is helpful to wait 3 months to assure healing of the palatal wound before reentry.

Grafting over implants

Connective tissue grafting over unesthetic implants can also be accomplished. Ideally, correction of soft-tissue deficiencies should be performed before implant placement. Because the connective tissue graft will not attach to the implant or abutment surfaces, if tissue is added, then the sulcular depth can increase, creating a pocket. The clinician must therefore evaluate exactly how much vertical extension of gingival tissue should be added. The goal is to promote esthetically acceptable tissue contours and gain attached keratinized gingival protection without creating a pocket. The new tissue contours must allow for plaque removal by the patient during daily oral hygiene. Because the soft tissue generally follows the shape of the underlying tooth surface, the final custom abutment and crown should be in place before surgical addition. If coronal tissue positioning is desired, then the prominence of the abutment should be reduced to promote room for the new tissue. After prominences are reduced, the abutment must be thoroughly smoothed and polished to avoid bacterial accumulation in the future (Figure 37.54).

Restoration of the lost interdental papilla

Gingival augmentation of the lost interdental papilla has been very challenging due to the small area in which to work. The vascular supply to this terminal-end organ involves capillary loops, and the dimensions of the area are difficult to negotiate. Conventional surgical techniques are unpredictable due to the small working spaces and limited blood supply to the area.[19]

Many articles have described techniques attempting correction of papillary defects.[5–14] Han and Takei (1996)[5] described the use of a facial approach with a semilunar incision to gain access

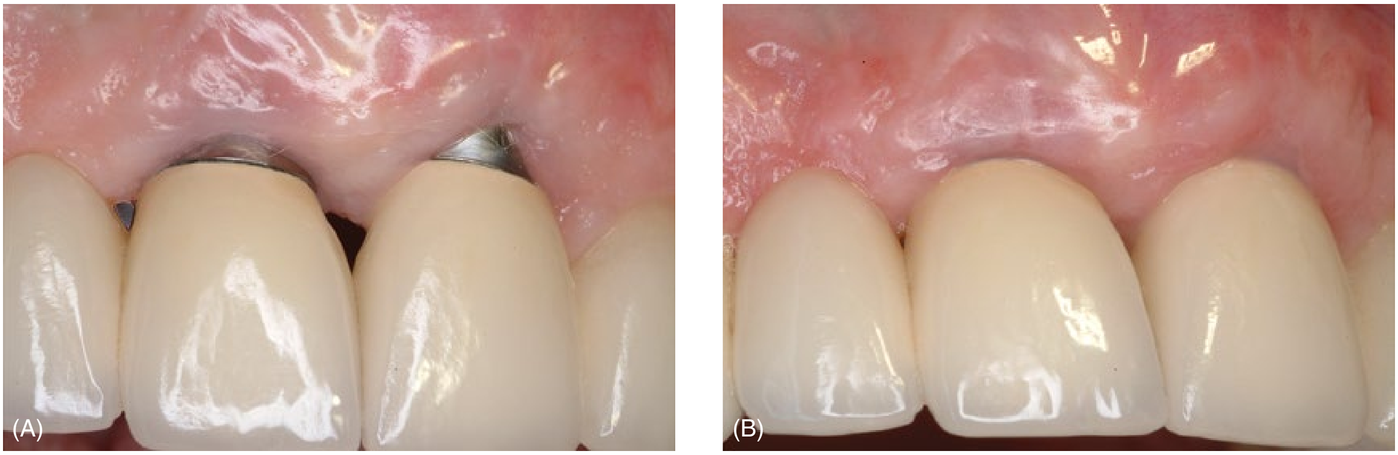


Figure 37.54 **(A, B)** Connective tissue graft surgery accomplished to cover implants in the esthetic zone.

to the papillary area for augmentation of the papilla. Cortellini et al.[6,7] proposed a simplified papilla preservation flap that requires a releasing incision in the papillary area and placement of a barrier membrane under the surgical site. Azzi and coworkers[8–10] developed techniques to gain access to augment the connective tissue and bone under the deficient papilla; however, these techniques may jeopardize the blood supply due to the use of releasing incisions.

The success of microsurgical techniques is dependent on preservation of blood supply and minimal tension on wound closure.[61] Releasing incisions can also cause trauma to the delicate papillary isthmus and risk unesthetic surgical scarring and wound-edge necrosis. It has long been recognized that reduction or elimination of releasing incisions will improve vascularity to the surgical area and enhance the postsurgical outcome.[19] Tunneling surgical approaches can eliminate the need for releasing incisions.[62] Because of the small dimensions of the area being reconstructed, microscopic magnification and use of microsurgical instruments can be of significant value.[4,17]

Multidisciplinary management

Clinical management of the deficient papilla can be multidisciplinary and involve orthodontic root repositioning and restorative contour modification, in addition to surgical correction.[4] Generally, if a papillary defect was caused by a surgical insult, then surgical addition of soft tissue can be the best choice of treatment modalities.[4] Some important variables which may influence the presence of the papilla include interproximal contact position, root angulation, crown form, and embrasure areas.[63]

Interproximal reduction of crowns and orthodontic root alignment can help to close the embrasure spaces when papillary space is opened during orthodontic correction of overlapped teeth. The management of the embrasure space or “missing papilla” due to malalignment of teeth or orthodontic movement of teeth is discussed in an excellent work by Kurth and Kokich.[63]

Long cylindrical teeth can have a narrow cervical area and contact point located near the incisal edge.[40] To increase the chance for embrasure space closure, it may be advisable to move the contact point apically with restorative procedures.[4] The adjustment of the mesiodistal width of teeth can also be accomplished restoratively, creating a wider crown with the addition of restorative materials and allowing some degree of closure of the embrasure space.[64,65]

When all three treatment modalities are anticipated, it is usually recommended to start first with surgical addition because the access will be the greatest before either orthodontic tooth repositioning or restorative space closure (Figure 37.55).

Surgical technique of papilla reconstruction

Nordland and Sandhu[19] published an article in 2008 that described a microsurgical procedure to position the donor tissue under a deficient interdental papilla. The use of the surgical dissecting microscope and microsurgical instrumentation obtain access under the existing interdental papilla without releasing incisions, increasing the likelihood of donor tissue survival and thereby minimizing trauma, excessive bleeding, scarring, and pain (Figure 37.56A and B).[17,19] It must be noted, however, that this procedure is technique sensitive, and it may not be predictable in everyone’s hands.

Defect assessment and root preparation

The classification of the initial preoperative interdental papilla is determined using the Nordland and Tarnow classification scheme (Figure 37.57A–D).[66] The defect is measured preoperatively to establish a baseline to determine just how much tissue gain is achieved. First, the desired gingivoincisal height is measured using a periodontal probe (Figure 37.58). This will determine exactly how much donor tissue volume is needed to be added to the deficient site.

After local anesthesia, root debridement and preparation is accomplished using finishing burs, hand instruments that include the SPN1 and SPN2 chisels, and 10/11 Hartzell scaler (G. Hartzell & Son). Root demineralization and sterilization is performed using tetracycline paste application for 60 s.

Incisions and papillary mobility

A circumferential sulcular incision, using the N6900 microsurgical blade, is made to the crest of bone (Figures 37.59, 37.60, 37.61, and 37.62). This incision also extends circumferentially around the adjacent teeth.

Figure 37.55 Example of a reconstruction of the lost interdental papilla using a multidisciplinary approach. **(A)** Pre-op image showing the defect caused by a surgical mishap. **(B)** Papilla augmentation was performed using connective tissue graft and microsurgical approach. **(C)** Orthodontic treatment assisted the closure of the space. **(D)** Sculpting was also performed to create symmetry and natural contours for the esthetic zone. **(E)** Beautiful porcelain crowns were finally placed, giving the patient a beautiful smile. **(F)** This 13-year follow-up image shows that results were maintained long term.

Figure 37.56 **(A)** Pre-op figure showing iatrogenic trauma following a root planing procedure.

Figure 37.56 **(B)** Three-month post-op following papilla reconstructive surgery and a new crown for tooth #7.

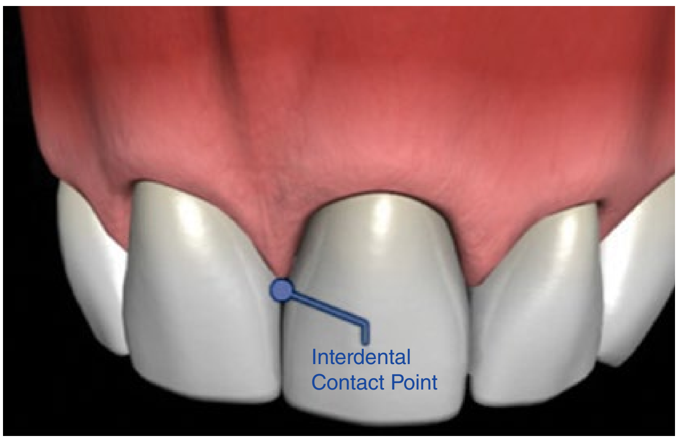


Figure 37.57 **(A)** Papilla within the normal limits.

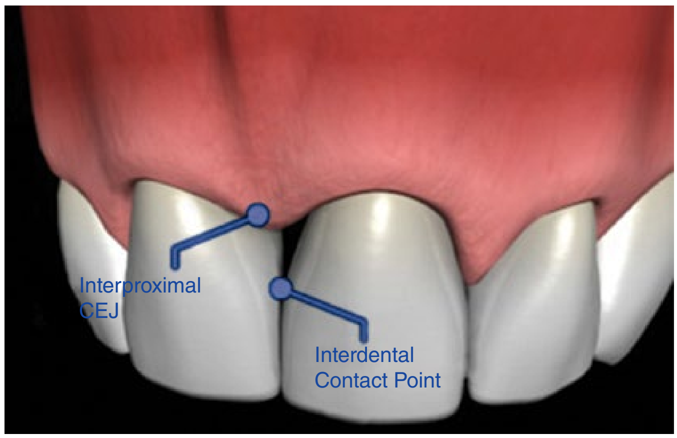


Figure 37.57 **(B)** Class I papilla defect: papilla positioned apically to the contact point but coronal to the interproximal cementoenamel junction (CEJ).

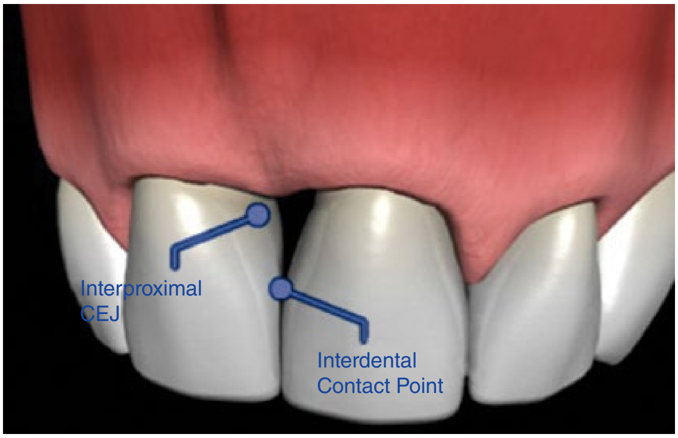


Figure 37.57 **(C)** Class II papilla defect: papilla positioned apically to the interproximal CEJ but coronal to the facial CEJ.

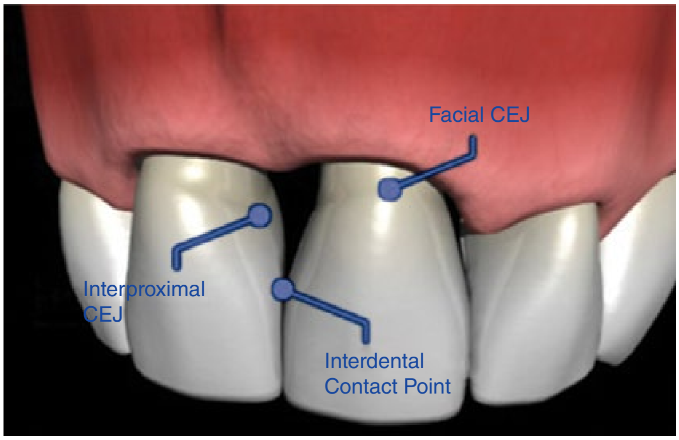


Figure 37.57 **(D)** Class III papilla defect: papilla positioned apically to the facial CEJ.

Figure 37.58 The desired gingivoincisal height is measured using a periodontal probe.

Figure 37.59 An N6900 microsurgical scalpel is used.

Figure 37.60 The scalpel is inserted into the sulcus.

Figure 37.61 A sulcular incision, using the N6900 microsurgical blade, is made to the crest of bone.

Figure 37.62 The circumferential sulcular incision extends to the facial and palatal bony crest.

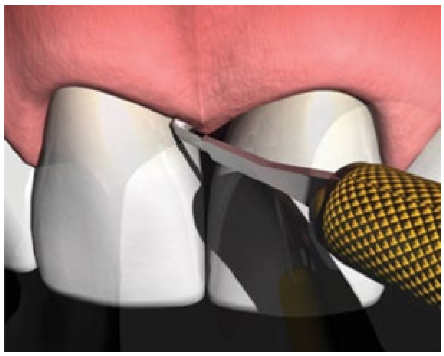


Figure 37.63 Custom modification of the microscalpel allows for complete undermining of the delicate papillary tissue.

The surgical dissecting microscope is used to visualize the morphology of the entire area and will help the surgeon avoid inadvertent severing of the delicate papillary isthmus. Following the minimal circumferential sulcular incision, a split-thickness flap is prepared. Custom modification of the microscalpel allows for complete undermining of the delicate papillary tissue (Figures 37.63 and 37.64). The customization of the microsurgical blade helps to negotiate subtle facial contours of the buccal gingiva and underlying bony contours. This delicate and tedious dissection allows the surgeon to extend the incision past the mucogingival junction. Once the incision extends past the

Figure 37.64 Palatal portion of the papilla is undermined.

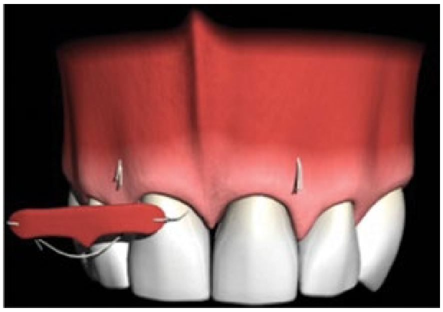


Figure 37.65 Lasso sutures secure the ends of the donor tissue.

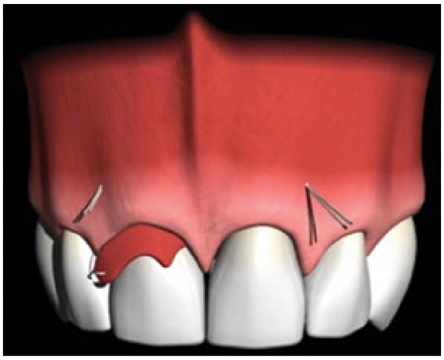


Figure 37.66 Sutures are positioned through the tunnel to gently pull the donor tissue into position.

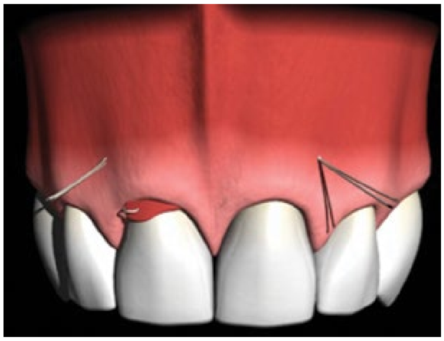


Figure 37.67 After the tissue is positioned the sutures anchor it in place.

mucogingival junction, mobility of the undermined tissue can be achieved. Papillary mobility is essential to allow for the creation of space under the papilla to receive the connective tissue graft.

Harvesting the connective tissue graft

An adequate volume of donor tissue must be procured as determined by the papillary space requirement.[4,19] Bone sounding can be performed to locate donor tissue of adequate dimensions. If a large volume of papillary tissue is required, the maxillary tuberosity will frequently be the donor site of choice because of its fibrous nature and thickness. The graft is shaped to produce the needed papillary dimensions and extends laterally to assist in root coverage, if needed. Often, a papillary shape can be reproduced by harvesting the palatal papillary tissue between the second premolar and first molar as a gingival unit transfer.[67]

Positioning and stabilizing the graft

A "lasso" suture is used to help pull and position the ends of the donor tissue. Sutures are positioned through the tunnel to gently pull the donor tissue into position and anchor it in place. Positioning of the graft under the interdental papilla can be challenging, but it is critical to the success of the procedure (Figures 37.65, 37.66, and 37.67).

Suspensory sutures

Lip musculature and tissue memory can create pressure and tension on the overlying tissue and thereby create a tendency to pull the papillary tissue back to its original position as it heals. To preserve the new papillary tissue position, a "suspensory suture" is used. This suture begins at the base of the papilla and is anchored around the interproximal contact point. The suspensory suture is essential to maintain the new position and height of the papilla. The addition of a composite bonding material at the interproximal contacts of the adjacent teeth can help prevent this suspensory suture from slipping through the interproximal contact. The suspensory suture also maintains the donor tissue under the papilla in its coronal position until the overlying flap has matured at its postsurgery position, thus preventing apical migration or displacement of the graft. If this suture is not used, then retraction of the tissue usually occurs (Figure 37.68).

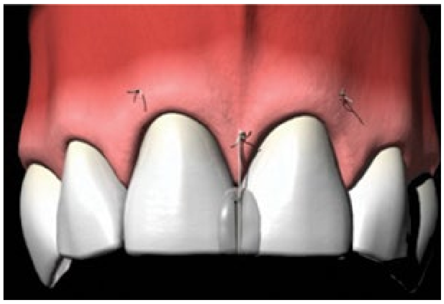


Figure 37.68 A suspensory suture anchors the papillary tissue position.

Postoperative instructions and healing

The care of the surgical area is extremely important especially during the first week. The patient should avoid foods that can cause trauma or hot liquids that can stimulate bleeding and increase swelling. Brushing or flossing the surgical site must be avoided. The mouth should be thoroughly rinsed daily using a 0.12% chlorhexidine gluconate rinse during the first 7 days. An anti-inflammatory prescription is recommended to avoid additional swelling that could otherwise compromise surgical healing.

Most of the sutures can be removed in 1 week. The suspensory sutures should remain in place for at least 2 weeks, and oral hygiene modifications are essential to ensure that the patient does not traumatize the area. Cleaning devices for the interdental area, such as interproximal brushes and triangular toothpicks, should be avoided. Reinforcement of oral hygiene techniques is crucial for long-term success. Six to eight weeks of soft-tissue healing is a minimum before restorative procedures can be considered.

Ridge preservation and ridge augmentation

Ridge defects are a deformity that can occur when the dentoalveolar bone and gingiva collapse after tooth loss.[2,20] Ridge deformities can create esthetic and functional dilemmas for the patient and restorative dentist.[2] Sometimes, patients might not reveal the defect in their smile, and at other times patients psychologically avoid smiling for fear of showing the defect. To provide an acceptable esthetic result, the ridge collapse can be masked, hidden, or corrected. This collapse creates a deformity that can make it challenging for the restorative dentist to develop an esthetic outcome due to the increased space and can also result in less lip support and a prematurely aged appearance.[20]

According to Abrams et al., the loss of an anterior tooth causes a significant deformity 91% of the time.[15] Ridge deformities have both soft-tissue (papilla and attached gingiva) and bony-alveolus components. Soft-tissue deformities can occur when surgical incisions are made in delicate areas (thin gingiva, alveolar mucosa and papillae (as shown in Figure 37.1A and B). Deformities of bone can occur following a simple extraction of a tooth, but deformities are even more common if there has been a predisposing factor present such as a thin dentoalveolus, previous endodontic surgery, endodontic failure, iatrogenic bone removal, intentional bone removal to gain access, root fracture, or periodontal bone loss. Pressure atrophy from a removable prosthetic appliance (such as a flipper) can compress the alveolar ridge and allow the collapse of the adjacent papillae.[2] Until periodontal plastic surgical procedures were developed, a ridge deficiency would necessitate the overbuilding of prosthetic tooth structure, prosthetic gingiva, or acceptance of a space that could appear dark. Phonetics could also be affected where the space could allow for passage of air and saliva.[2]

Modern exodontia techniques focus on an atraumatic and conservative approach during a tooth extraction with the placement of a bone graft and a barrier membrane at the time of extraction to minimize bone collapse while maintaining the soft-tissue surroundings.[2] Delicate biotype patients can present with high, thin bone scalloping, making them even more susceptible to bone collapse. Presence of an acceptable bony foundation following extraction does not always provide ideal soft-tissue contours, and soft-tissue augmentation may need to be considered. Along with maintenance of the bony foundation and soft-tissue contour, the interdental papilla also requires careful consideration. If the papillary tissue is unsupported, then it is reasonable to expect it to collapse as well. Papilla preservation can be initiated prior to tooth extraction with interdisciplinary treatment planning. Ideally, the restorative dentist will fabricate an immediate tooth replacement that duplicates the previous tissue support to provide immediate bracing of the papillary tissue. The immediate tooth replacement should be well anchored and cleansable.

Ridge augmentation

If a ridge defect is present, a bridge pontic will be constructed longer than ideal, or if a tooth of normal length is created, then a dark space can show. With either compromise, the result is unnatural and unesthetic. If an implant is planned, a ridge defect will mandate a longer clinical crown.

Ridge augmentation can minimize or eliminate a ridge defect. Independent of the type of tooth replacement, (bridge or implant-supported crown) or the quality of the bony foundation, a ridge augmentation procedure can restore the natural appearance of the gingival contour in the edentulous area. An ideal ridge will mimic the presence of a root prominence, creating an illusion that the tooth is naturally emerging out of the gingival tissue. Ridge augmentation is a periodontal plastic surgical procedure that also helps function by restoring a band of attached keratinized gingival protection for the pontic or implant. In 1982, Langer and Calagna[27] described the use of a subepithelial connective tissue graft to enhance anterior cosmetics in ridge-deficient areas. The correction of ridge deformities as described by Seibert in 1983, used an onlay graft technique, transplanting a thick epithelialized graft from the palate.[68,69] The thick epithelialized graft created a large tender donor site and a thick free gingival graft patch-like appearance that might not mimic the surrounding area. Periodontal plastic surgical refinements have since been developed to reduce patient morbidity, enhance esthetics, and improve predictability (Figures 37.69A and B and 37.70A and B).

This procedure incorporates a microsurgical technique using a connective tissue graft harvested from the palate, creating minimal discomfort and trauma to the patient; and because grafted

Figure 37.69 **(A)** Patient was unhappy with the ridge collapse in the #7 area.

Figure 37.69 **(B)** Ridge augmentation was performed and a new bridge placed.

Figure 37.70 **(A)** Patient experienced recession and ridge collapse on #10.

Figure 37.70 **(B)** Ridge augmentation and root coverage were accomplished, providing natural contours for a new replacement.

tissue cells are surrounded by a vascular supply, the predictability of cell survival is improved. An ovate pontic is used to allow for cleansability, and its placement during the surgery creates a natural tooth emergence. This procedure is covered in a step-by-step fashion.

Indications for ridge augmentation

- Correction of anterior ridge defects.
- Minimal or lack of attached keratinized gingiva at the edentulous site.
- Can be performed following an extraction that has already healed and before the final replacement (implant surgery or final bridge).

Surgical technique

In this example, the patient presents with a preexisting three-unit bridge with a desire to have a normal ridge contour and appearance. She noticed a dark space around her missing tooth, especially evident in photographs. Psychologically, she was self-conscious and hesitated to smile. Her restorative dentist could remake the three-unit bridge and place a longer tooth or consider surgery to replace the missing contour (Figure 37.71).

Provisional bridge

The restorative dentist removed the preexisting bridge and placed a provisional restoration extending from teeth #7, #8, and #9. Once the bridge was removed, a significant amount of calculus was exposed and removed from the abutment teeth (Figure 37.72). The ridge-lap pontic was converted into an ovate pontic using a flowable composite resin of a matching shade (Figure 37.73). The ovate pontic will help reinforce the illusion of a natural tooth growing out of the gingiva and is easily cleansable with flossing.

Figure 37.71 Patient presents with a preexisting three-unit bridge with a desire to have a normal ridge contour and appearance.

Figure 37.72 Once the bridge was removed, a significant amount of calculus was exposed and removed from the abutment teeth.

Figure 37.73 The ridge-lap pontic was converted into an ovate pontic.

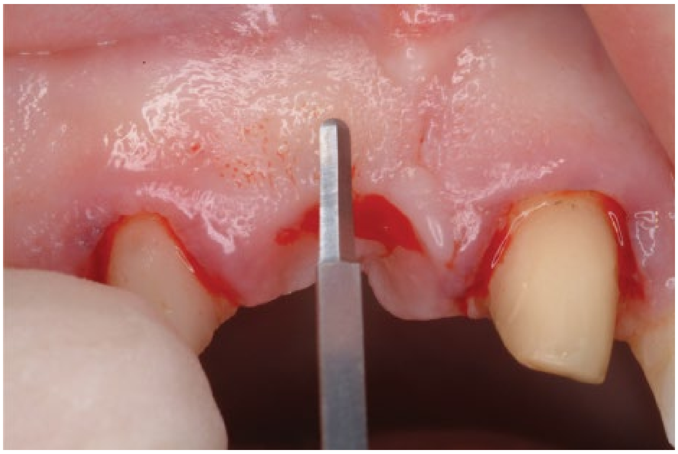


Figure 37.74 The N6900 microsurgical blade is inserted slightly palatal to the future sulcus.

Microincision

The N6900 microsurgical blade is inserted slightly palatal to the future sulcus. The scalpel is unmodified initially (Figure 37.74). As the incision is extended deeper, bony contours are frequently encountered and the scalpel blade can be easily modified with orthodontic bending pliers to follow the underlying bony ridge contour. The shank is modified as needed for ease of angulation (Figures 37.75 and 37.76). While performing the soft-tissue dissection, the surgeon can also evaluate the underlying bony contour if implant placement is to be contemplated in the future.

In this case, the former pontic created a small ridge depression, which acted as guide for the initial incision. The incision was made approximately 1.5 mm palatal to the previous pontic facial location (Figure 37.77). The N6900 scalpel is inserted past the mucogingival junction, creating a tunnel in an attempt to recreate a contour that mimics the former tooth root prominence (Figures 37.78 and 37.79). The previous soft-tissue scarring is relieved with the dissection, and tunnel patency was confirmed with the use of a 10/11 Hartzell curette (Figure 37.80). The palatal portion of the pontic receptor site was prepared with the use of a #6 round bur to create a slight depression for the future pontic emergence (Figure 37.81).

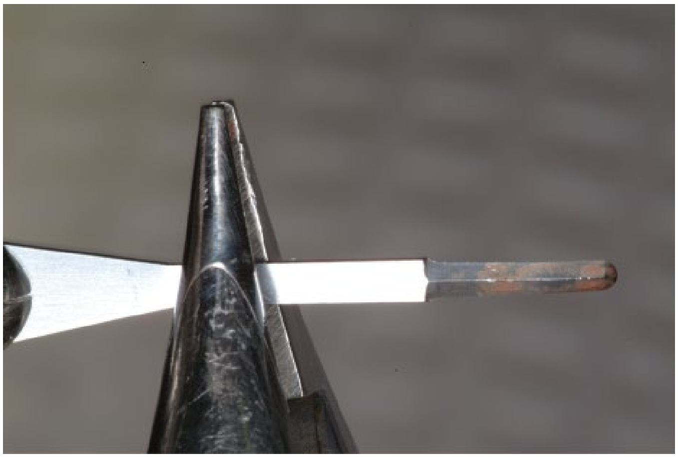


Figure 37.75 The scalpel shank is modified using orthodontic bending pliers.

Figure 37.76 The scalpel blade is modified to follow the underlying bony ridge contour.

Figure 37.77 The incision is made approximately 1.5 mm palatal to the previous pontic facial location.

Harvesting connective tissue

A connective tissue graft was harvested from the palate that mimicked the conical shape of the previously extracted root to create the illusion of a root prominence. The tissue was harvested using a lasso suture and modified using Le Grange scissors (Figures 37.82 and 37.83). The graft was sutured into location. An initial suture needle penetration was made at the apical extent of the tunnel, then the graft was sutured through its apical end and pulled into the tunnel (Figure 37.84). The graft was

Figure 37.78 The N6900 scalpel contour conforms to the anatomical contour.

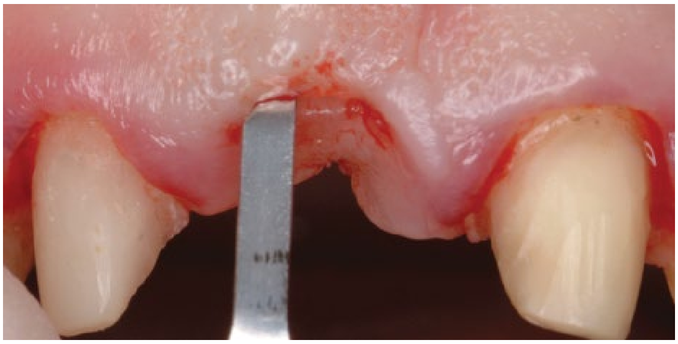


Figure 37.79 The N6900 scalpel is inserted past the mucogingival junction, creating a tunnel in an attempt to recreate a contour mimicking the former tooth root prominence.

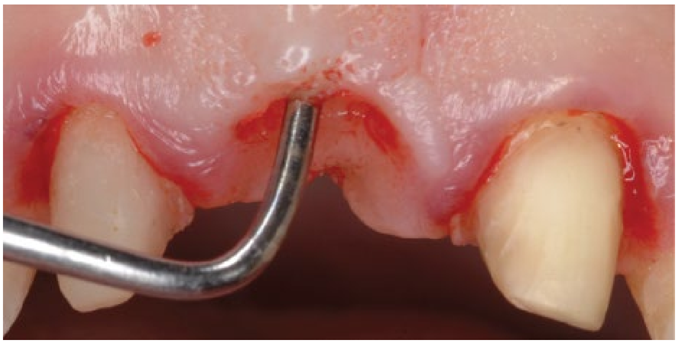


Figure 37.80 The previous soft-tissue scarring is relieved with the dissection, and tunnel patency is confirmed with the use of a 10/11 Hartzell curette.

anchored at both ends to assure its position apically and coronally using a Gore-Tex suture (Figure 37.85).

Provisional bridge placement

The pontic was converted into an ovate pontic and the bridge reinserted into position. The pontic should extend at least 2 mm into the tissue and create a sulcus for the new pontic (Figures 37.86 and 37.87). This will create the illusion that the tooth is emerging out of the tissue. The palatal wound was sutured closed and covered by a surgical protective stent.

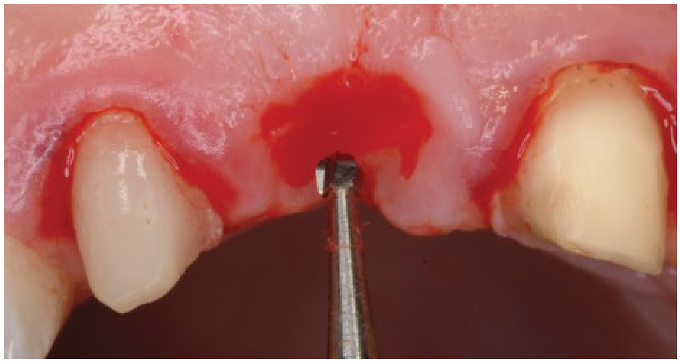


Figure 37.81 The palatal portion of the pontic receptor site is prepared with the use of a large round bur, creating a depression for the future pontic emergence.

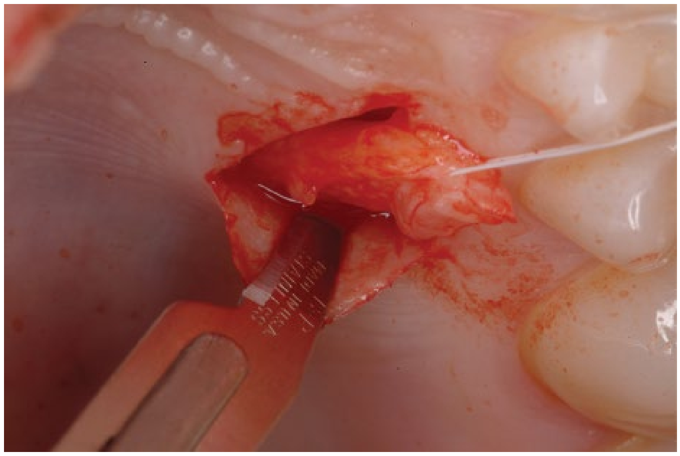


Figure 37.82 A connective tissue graft is harvested from the palate.

Figure 37.83 Donor tissue is modified using Le Grange scissors to mimic the root contour.

Postoperative instruction and healing

Postoperative instructions are similar to those described for previous procedures.

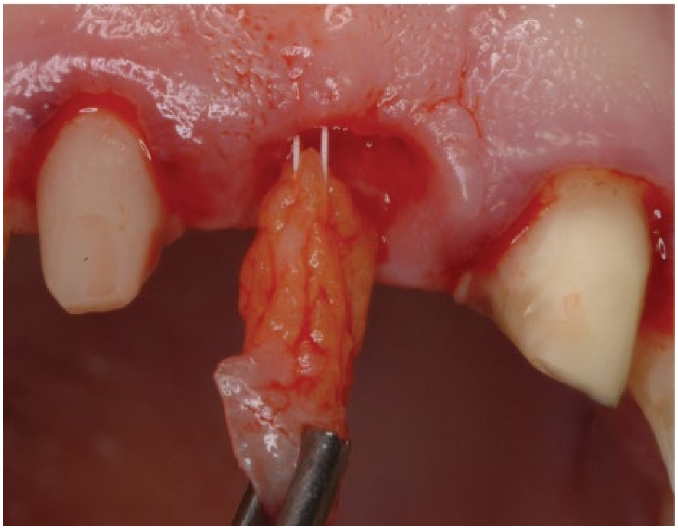


Figure 37.84 The graft is pulled into the tunnel.

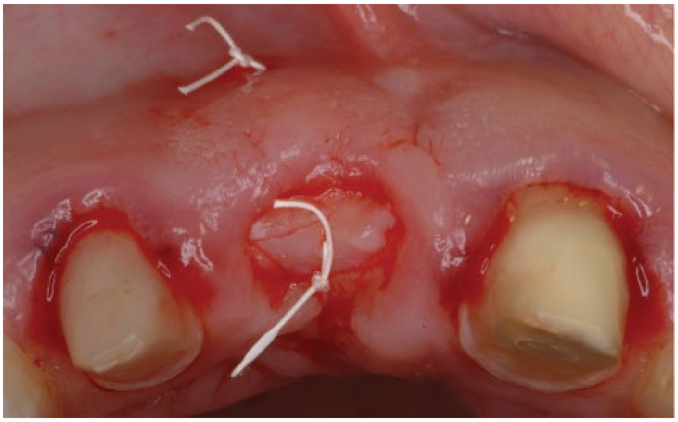


Figure 37.85 The graft was anchored at both ends to assure its position apically and coronally using a Gore-Tex suture.

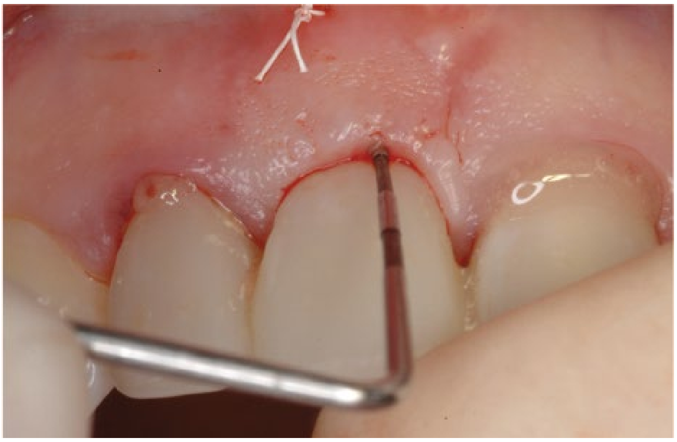


Figure 37.86 The bridge is reinserted into position. The pontic should extend at least 2 mm into the tissue and create a sulcus for the new pontic.

Figure 37.87 The temporary bridge is re-cemented.

Ovate pontic

Ridge-lap pontics have a concavity under the pontic, against the ridge. Unfortunately, the concavity hides bacteria, and inflammatory reactions are found more than 95% of the time.[70] In 1981, Garber and Rosenberg described ovate pontics as esthetically and functionally superior to other pontic designs of the past.[71] The concept of the ovate pontic uses a rounded egg-shaped pontic that allows for a natural-appearing emergence profile and an ease of oral hygiene cleansability.[71] The ovate design is esthetic, cleansable, and promotes a thick healthy periodontium.[72] The pontic should extend 1.5–2 mm below the gingival margin to support the surrounding facial gingiva and the interdental papilla.[2]

Excessive gingival display: esthetic crown lengthening and sculpting

Excessive gingival display, commonly referred to as a "gummy smile," is a description for the situation whereby the patient shows too much gingiva. Commonly in the adult, the gingival margin will be located at or near the CEJ, and normally a patient will show very little if any gingiva over the central incisors when smiling. Three common causes of an excessive gingival display are vertical maxillary excess, excessive alveolar bone, and excessive gingiva.[2] These can occur individually or in combination.[2] Vertical maxillary excess exists if there is an abnormally tall maxilla. In this situation, orthognathic surgery can be considered to move the maxilla to a new level. Orthodontic and oral surgical consultations will determine the ideal position of the maxilla.[2]

When excessive gingiva covers enamel, the sulcus depth will increase, thereby allowing a safe harbor for bacteria and making plaque removal difficult. Osseous resective procedures have been developed to reshape the dentoalveolar architecture to create a more favorable environment for periodontal maintenance and health.[73] Resective periodontal plastic surgery can remove excessive gingiva and bone. If the enamel of the teeth is covered by gingiva and bone, then the smile can be hidden. Microsurgery to remove precise amounts of gingiva

Figure 37.88 **(A)** Pre-op figure showing an excessive gingival display.

Figure 37.88 **(B)** After an esthetic crown-lengthening procedure, smile was enhanced showing the hidden enamel profile.

Figure 37.89 **(A)** Pre-op figure showing excessive gingival tissue with excessive underlying bone.

Figure 37.89 **(B)** Esthetic crown lengthening was performed with reduction of the large bony exostoses and soft-tissue sculpting.

and corresponding alveolar bone can show the full enamel profile of the teeth, which usually creates a bigger, brighter smile (Figure 37.88A and B).[20]

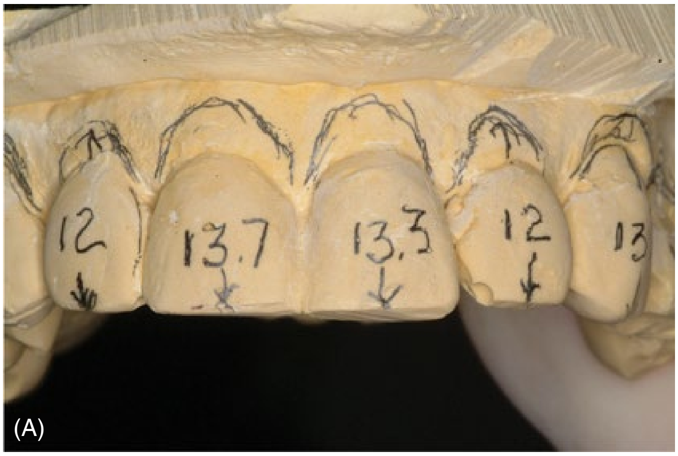
Clinical parameters exist detailing esthetic tissue positions of the maxillary anterior arch and may serve as a guideline for a predictable esthetic outcome.[74,75] In the esthetic crown-lengthening surgery, patient biotypes[76] can play a role in the amount of rebound healing of the newly established gingival margin.[77] Individual variation in gingival thickness will modify final tissue healing levels postoperatively. "Thick" tissue biotypes show the greatest tendency to rebound in a coronal direction.[77]

Excessive alveolar bone can affect the overall tissue contour in both height and thickness. Because the full enamel profile is not visible, the anterior teeth will appear short and square. Both bone height and thickness can also vary considerably. If the alveolar bone is abnormally low, incisally positioned or thick, both bone and gingiva must be treated together during surgery (Figure 37.89A and B). Simple use of a laser can raise bone height but will not taper the contour of the bone to the tooth. Because excessive bony contours can predispose a patient toward gingivitis and periodontitis due to an inability to remove bacterial plaque effectively,[73] the recontouring of excessive tissue can provide a functional as well as cosmetic benefit.[2]

Excessive gingiva (gingival hypertrophy) can occur without an excessive amount of underlying bone. In this case, simple excision of the soft tissue without manipulation of the bone can achieve a normal-appearing result.[2]

Individual's biologic width

In a classic study, Gargiulo et al. measured dentogingival anatomy in humans within Orban's four phases of passive eruption. In the case type where the gingival tissue covers the enamel, the distance from the marginal epithelium to the crest of the alveolar bone demonstrated tremendous individual variation.[78] The clinical consensus as to precisely how much bone resection is necessary when planning an esthetic crown-lengthening case is unclear and somewhat controversial. Several authors have suggested surgically removing the periodontal support to an extent, leaving a distance from the level of a planned restorative margin to the level of newly recontoured osseous crest of 2.5–3.5 mm,[79] 3 mm,[80] and 4 mm[81] of the exposed tooth. Unfortunately, not enough research



#5 – 9.3 mm

#6 –11 mm

#7–9.5 mm

#8–11 mm

#9–11 mm

#10–8 mm

#11–11 mm

#12–8 mm

(B)

Figure 37.90 **(A, B)** Examples of how to communicate precise desired tissue positions.

presently exists to make exacting statements about how much bone should be removed when crown lengthening or sculpting is performed in the esthetic zone.[2] Because there is a great variation in biotypes and biologic widths, a safe guide for bone reduction can consider the patient as having their own "individual biologic width." Clinical observations indicate, for example, that if the soft-tissue reduction is to change 2 mm, then the same 2 mm should be used for bone height modification. This will maintain the "individual's biologic width." Not only should the bone height be modified, but also the bone thickness should be reshaped to create a natural scalloping profile. The thickness and contour are controlled with direct visualization of the bone contour. The use of a laser can reduce height but cannot control bone thickness.

Esthetic crown-lengthening surgical procedure

Before crown lengthening is performed, it is important to have clear communication between the restorative dentist, patient, and surgeon. Precise blueprints of where the future gingival location is desired need to be conveyed. Communication examples could include precise measurements from the incisal edges to the gingival margin, an e-mail, photographs, a mock-up, clear trays, stone models, or whatever communication is necessary to make the request clear to the surgeon (Figure 37.90). Ideally, the restorative dentist will provide a surgical guide based on a mock-up that has been tried in and adjusted on the patient.

Sometimes, sculpting will place the new soft-tissue margin at the CEJ. If the sculpting exposes root dentin, then sensitivity will likely occur if the root is not covered with a restoration. If the restoration is a bonded restoration and extends on to root dentin, the bond will be weakest at that root dentin margin.[82] The restorative dentist must determine if a dentin margin is desired and the patient should be aware of this compromise. Sometimes, root dentin exposure cannot be helped. In this case, precise measurements from the incisal edges are provided by the restorative dentist with considerations for modifications of the tooth shape (e.g., restoration and extension of worn incisal edges) that might be changed with future restorations.

Figure 37.91 Prescribed tissue locations are transferred to the patient, using a periodontal probe and puncture markings at the zenith of the desired soft-tissue location.

Determining the new tissue location

After anesthetizing, prescribed tissue locations are transferred to the patient, using a periodontal probe and puncture markings at the zenith of the desired soft-tissue location (Figure 37.91).

Incisions

After the parabolic peak or zenith has been determined, a scalloped incision is made through the gingiva to the desired level using a 15-C scalpel (Figure 37.92). The incisions should create a papillary design that will meet edge to edge with the future papilla location (Figure 37.93). A sulcular incision is made with the intent to remove the collar of gingival tissue (Figure 37.94). The gingival collar is removed using a sickle scaler (Figure 37.95). Careful attention is paid to the papillary area to create similar incision angles in preparation for future flap replacement without voids or irregularities. The precise replacement of the flap tissue is critical to avoid obvious incision lines, papillary disfiguration, or total papilla loss.

It is important not to thin the papillary epithelium aggressively because it can cause necrosis at the future wound margin.

Figure 37.92 A scalloped incision is made through the gingiva to the desired level using a 15-C scalpel.

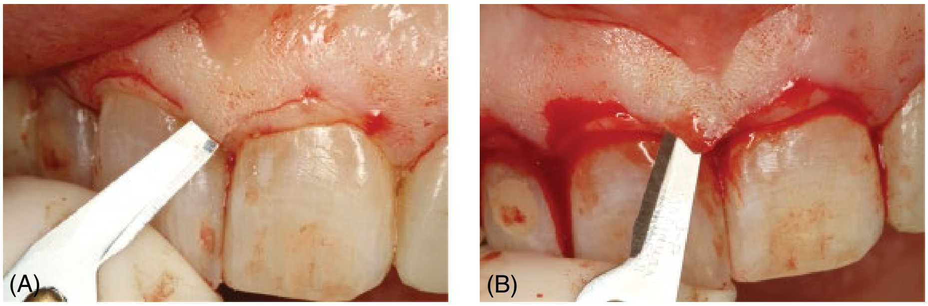


Figure 37.93 **(A, B)** The incisions should create a papillary design that will meet edge to edge with the future papilla.

Figure 37.94 A sulcular incision is made with the intent to remove the collar of gingival tissue.

Figure 37.95 The gingival collar is removed using a sickle scaler.

Figure 37.96 A split-thickness incision is used initially to raise the tissue flap delicately.

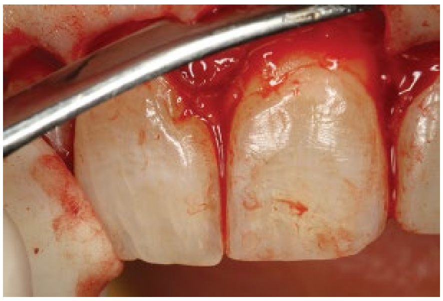


Figure 37.97 The flap is reflected full thickness using a periosteal elevator to visualize the bony contours.

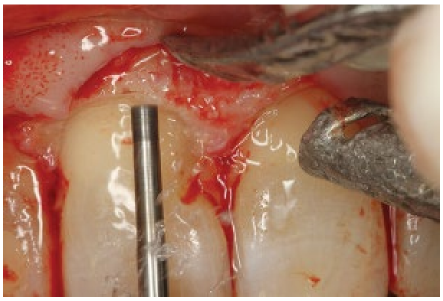


Figure 37.98 End-cutting burs are used for circumferential bone reduction without gouging the root surface.

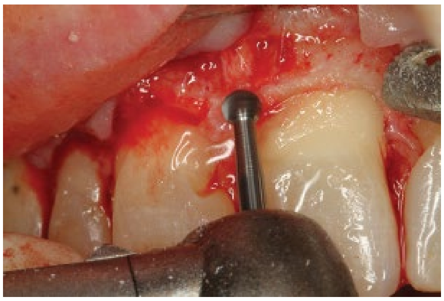


Figure 37.99 A round bur is used to modify any prominence apical and adjacent to the bone reduction areas.

A split-thickness incision is used initially to raise the tissue flap delicately (Figure 37.96). The flap is reflected full thickness using a periosteal elevator to visualize the bony contours (Figure 37.97).

Bone reduction

After achieving adequate visibility of the bony architecture, excessive bony contours are commonly encountered. End-cutting burs allow for circumferential bone reduction without gouging the root surface (Figure 37.98). A round bur can then be used to modify any prominence apical and adjacent to the bone reduction areas (Figure 37.99). Smaller end-cutting burs can reach interproximally to adjust the interproximal bony contours (Figure 37.100). A small round bur is used, ideally with magnification, to blend the osseous contours (Figure 37.101). Varying forms and tooth shapes will affect the tissue position.[40] Sometimes enamel irregularities can be encountered that can also contribute to minor idiosyncrasies in the soft-tissue position. These idiosyncrasies should be taken into consideration with the new desired tissue location. Prominent teeth will require less bony reduction and teeth that are more inset will typically require more aggressive bony contouring. Soft-tissue fiber attachment to the root surface is reduced using small microsurgical hoes SPN1 and SPN2 (G. Hartzell & Son) (Figure 37.102). Fine-tuning of the bone contours is refined using hand instruments (Figure 37.103).

Sutures and final touches

It is extremely critical to realign the wound edges because edge-to-edge incision line apposition will achieve minimal scarring in the delicate and highly esthetic papillary area (Figure 37.104). Delicate individual sutures using a surgeon's knot will help control tissue closure for each individual papilla (Figure 37.105). The soft-tissue position should be reconfirmed once suturing is completed. Minor tissue position modifications can be accomplished using a liquid suture (Figure 37.106). The surgical dissecting microscope can be used to help fine-tune the tissue position. In addition, the use of a laser can perform minor soft-tissue modifications and contour adjustments (Figures 37.107 and 37.108). A surgical dressing is placed to provide protection and stability to the new tissue location during the first week postoperatively. In this case, a surgical dressing, Barricaid (Densply Caulk), has been used (Figure 37.109).

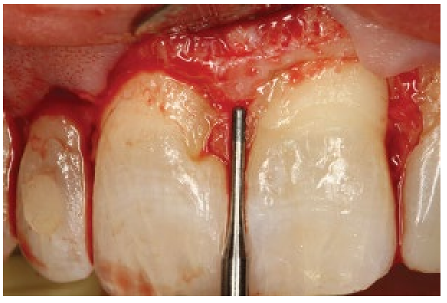


Figure 37.100 Smaller end-cutting burs reach interproximally to adjust the interproximal bony contours.

Postoperative instructions and healing

The care of the surgical area is extremely important, especially during the first week. The patient should avoid foods that can cause trauma or hot liquids that can stimulate bleeding and increase swelling. Brushing or flossing the surgical site must be avoided. The mouth should be thoroughly rinsed daily using a 0.12% chlorhexidine gluconate rinse during the first 7 days. An anti-inflammatory prescription is recommended to avoid additional swelling that could otherwise compromise surgical healing.

The sutures can be removed in 1 week. Reinforcement of oral hygiene techniques is crucial for long-term success. Six to eight weeks of soft-tissue healing is a minimum before restorative procedures can be considered (Figure 37.110A and B).

Figure 37.101 A small round bur is used to blend the osseous contours.

Figure 37.102 Soft-tissue fiber attachment to the root surface is reduced using small microsurgical hoes SPN1 and SPN2.

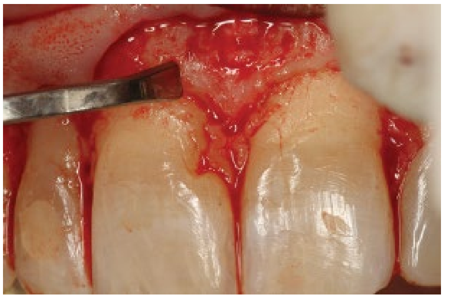


Figure 37.103 Fine-tuning of the bone contours is refined using hand instruments.

Figure 37.104 Realignment of the wound edges.

Figure 37.105 Individual sutures using a surgeon's knot.

Figure 37.106 Minor tissue position modifications can be accomplished using a liquid suture.

Figure 37.107 The use of a diode laser will perform minor soft-tissue modifications and contour adjustments.

Figure 37.108 The final tissue heights are confirmed.

Figure 37.109 Barricaid (Densply Caulk) in place.

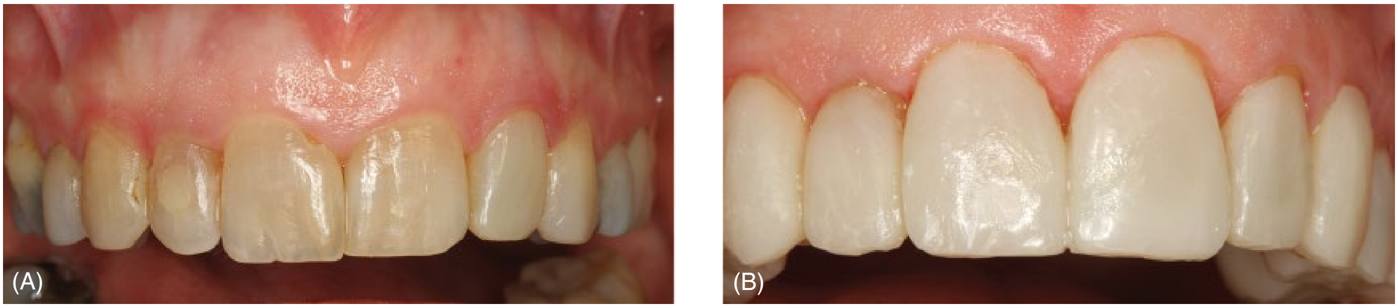


Figure 37.110 **(A)** Pre- and **(B)** post-op figures showing esthetic crown-lengthening procedures. Please note that tooth #10 was bonded to close the space for esthetic purposes.

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PART 7
PROBLEMS OF THE EMERGENCY AND FAILURE

Chapter 38 Esthetic and Traumatic Emergencies

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Chapter Outline

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The patient who believes they have an esthetic emergency indeed has a real emergency. Psychosocial or life-quality effects are critical to patients. Esthetic and comfort-related issues are particularly important. The perception of a diminution in esthetics, or the psychological trauma associated with loss of a visible tooth, has profound effects on self-image and well-being, comparable to major family life events. Some patients may happily live with a fractured angle of a maxillary central incisor all their lives, whereas others may experience a significant esthetic emergency from a similar event. Perception of unattractive appearance is a major factor in causing patients to present with dental emergencies. Generally, the more severe the injury, the less patients are satisfied with their appearance.

The emergencies discussed in this chapter are primarily those caused by sudden trauma to the dentition. In these cases, the patient is generally seen as soon as possible. Conservative palliative measures are taken when it is not possible to provide more than temporary treatment. Prevention is of paramount importance particularly in athletics, where the use of mouth guards substantially reduces incidence and severity of trauma to the mouth. Dentists have a duty to inform their communities of the need for prevention, urgency, and the correct protocols for managing dental trauma.

Long-term preservation is the goal

The responsibility of the dentist is to facilitate the long-term preservation of the natural dentition, the supporting periodontium and bone, and the surrounding soft gingival tissues. Obviously, some circumstances make this impossible, but this obligation must be remembered when a patient is first seen. Unfortunately, many fractured crowns and roots are extracted when they could have been saved. Not only are precious teeth lost, but consequent changes to the alveolus and gingivae complicate restoration and esthetic replacement. Even if a tooth must be lost, measures can be taken to preserve the hard and soft tissues to facilitate esthetic replacement using an implant. Failure

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to recognize the need for appropriate multidisciplinary consultation may result in premature tooth, alveolar bone, and soft-tissue loss.

Accurate evaluation of the injury depends on a thorough history (when, where, and how the injury occurred) to make an accurate diagnosis and an optimal treatment plan.[1,2] The medical history should be reviewed for previous injuries and treatment, the general health of the patient, and the presence or absence of pain. Answers to these questions will indicate the nature of the accident, the potential loss of vitality of the injured teeth, the need of prophylactic medication, and the possibility of damage to the supporting structures of the teeth. The possibility of traumatic brain injury must be recognized and appropriate referral made or transportation sought, if necessary. Likewise, the need for a tetanus shot must be assessed. The World Health Organization Classification of Traumatic Injuries to the Dentition, as modified by Jens Andreasen, describes four broad types: luxation injuries to the periodontal tissues, injuries to hard dental tissues, injuries to the supporting bone, and injuries to gingiva and the oral mucosa.[3,4] Traumatic conditions such as avulsion, bony fracture, extrusive and lateral luxation, and root fracture are considered to be acute and demand immediate treatment. Subacute conditions, including intrusion, subluxation, pulpal concussion, and crown fracture with pulp exposure, necessitate treatment within 24 h. Treatment for crown fractures without pulp exposure may be delayed, unless, of course, it presents an esthetic emergency. Useful guidance can currently be found in the online resource "The Dental Trauma Guide" created by Rigshospitalet Denmark and the International Association of Dental Traumatology (https://dentaltraumaguide.org/).

Once the history is obtained, clinical and radiographic examinations determine the extent of trauma. Clinical examination should assess soft tissues, facial bones, teeth and their fractures, mobility, and pulpal status, as well as the periodontium and alveolus. When soft-tissue lacerations are involved, particularly the lips, it is important to ensure that there are no foreign objects or tooth fragments embedded in the tissue. This can be confirmed radiographically, but glass shards or other radiolucent objects may be difficult to identify. The radiographic evaluation may include dislocations, jaw fractures, root fractures, the stage of tooth development, the periodontal ligament space, and the pulp, including its size, conformation, and any resorptive or calcific changes. Periapical films may be made at different angles to provide three-dimensional information. Cone-beam computed tomography may provide useful three-dimensional information in complex cases. An intraoral camera, or even a camera in a mobile phone, can be a valuable diagnostic aid and can record images of the damage.

Follow-up examinations must be planned. Recalls are generally recommended at 1, 2, and 6 weeks, at 3, 6, and 12 months, and at 5 years.[5] Recall examinations must include very careful endodontic evaluations. Sequelae of traumatic injuries include pulp necrosis, pulp canal obliteration through calcific metamorphosis, internal and external root resorption, and ankylosis. The endodontic evaluation includes cold and electrical pulpal vitality tests, percussion, palpation, mobility, periodontal probing, transillumination, and radiographs. Teeth that become more yellow generally have vital pulps that have laid down secondary dentin, whereas teeth that become blue–grey due to infiltration of necrotic blood products into the dentin typically are necrotic, needing root canal treatment. External or internal bleaching can be used, as appropriate. It is important not to overlook esthetic evaluation when treating the emergency patient.

Crown fractures

The majority of esthetic emergencies involve fracture of the clinical crown. In younger patients, this is often due to falls, sports injuries, or other impacts. Automobile accidents, altercations, and contact-sport accidents are common causes of injury in older patients. The upper central incisors are by far the most common teeth to be traumatized. Fractures of the clinical crown are classified as enamel infractions, uncomplicated fractures, or complicated fractures, depending on the degree of tooth involvement.

Crown infractions

Crown infractions are cracks in the enamel that do not involve loss of tooth structure (Figure 38.1A and B). With coronal infractions, the anatomic shape of the tooth is unchanged, and the tooth appears normal radiographically. Fracture or craze lines are evident in the enamel, and are especially apparent with transillumination and intraoral photography. It is important to document infractions in the patient's chart, using photographs of the crack or craze lines present following an injury, to protect the patient especially in cases of insurance or legal liability. Fortunately, most enamel cracks are arrested at the dentinoenamel junction and do not pass into dentin.

If no other injuries are present, the treatment goal is simply to maintain the tooth structure and monitor pulp vitality.[1,5,6] Even though little other signs of injury are evident, impacts may be so great as to cause hemorrhage into the dentinal tubules of the injured tooth and pulpal death. The extent of damage in any injury is evaluated by carful history, examination, endodontic evaluation, and radiography. If the injury is complicated by pulpal hemorrhage, bleaching will be necessary to restore normal color to the tooth. Bleaching techniques for this situation are discussed in Chapter 12. Even if there is no apparent pulpal trauma at the time of the incident, the tooth should still be monitored at follow-up visits for delayed pulpal necrosis.

Uncomplicated enamel and dentin fractures

Uncomplicated crown fractures can involve enamel or both enamel and dentin without involving the pulp chamber. This type of fracture is usually seen on the incisal angles of maxillary central incisors. The prognosis and considerations for uncomplicated fractures involving only enamel are the same as for crown infractions. Treatment for uncomplicated fractures involving only enamel may range from simply smoothing fractured rough edges

Figure 38.1 **(A)** This patient had a traumatic injury to her front teeth with no loss of enamel. However, it is important to document any craze or fracture lines present in case of any future legal or insurance liability.

Figure 38.1 (B) Transillumination should also be used and photographically documented for the patient. Also, baseline radiographs must be taken to compare against possible future periapical abscess.

and preventing soft-tissue laceration, to placing a conservative-bonded composite restoration[5,6] (Figures 38.2 and 38.3). Parents and patients should be advised that tooth vitality should be monitored.

When injuries involve enamel and dentin, treatment becomes more elaborate.[7–9] Even a minimal amount of traumatically exposed dentin may be quite sensitive to thermal fluctuations, acidic drinks, citrus fruits, and bleaching agents. A great many dentinal tubules connect superficial dentin directly to the pulp. Sometimes, particularly in younger patients, these tubules are patent. Tubules provide a pathway for bacteria, osmotic gradients, and other stimuli to cause pulpal irritation and

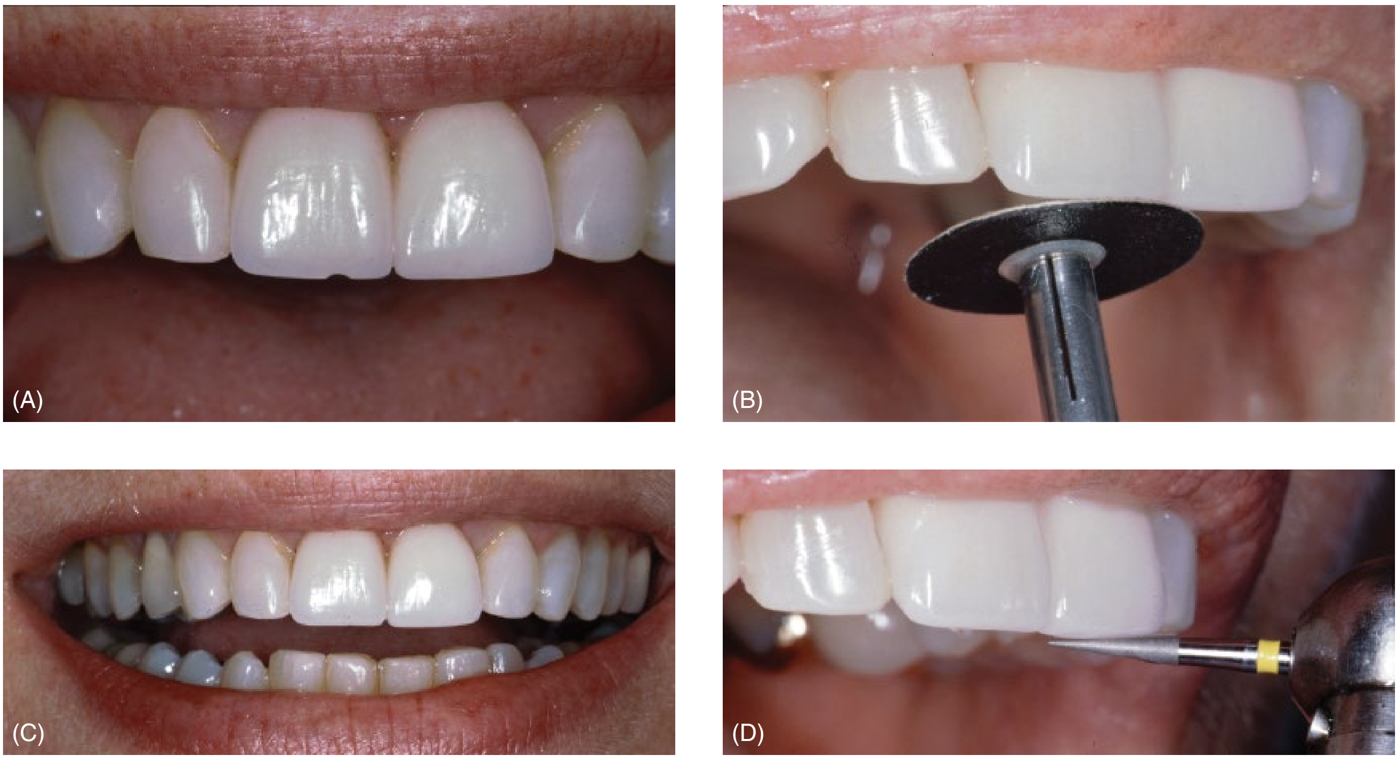

Figure 38.2 (A–D) Accidents involving small chips can many times be contoured depending upon the interincisal distance and its effect on the smile. It is a good idea to let the patient choose between restoring the incisal chip through composite resin bonding versus cosmetic contouring.

Figure 38.3 (A–C) In this patient, if contouring had been elected, the effect of reducing too much incisal enamel would have altered her smile line. As a result, composite resin bonding was the treatment of choice to restore her smile.

inflammation. Therefore, it is recommended that traumatically exposed dentin, which does not need to be restored or is awaiting restoration, be sealed (e.g., Gluma Desensitizer, Kulzer) to minimize the possibility of symptomatic irreversible pulpitis and pulpal necrosis developing. However, dentin that has become exposed due to gingival recession is more likely to have tubules that have become occluded through an external smear layer, cellular degeneration, or the deposition of secondary dentin.

Most fractures involving dentin necessitate restoration. In the past, a hard setting calcium hydroxide liner was often placed over the deeper dentin. It is now understood that providing an excellent seal to protect dentin from bacteria and their toxic byproducts is of paramount importance. Hence, resin-modified glass ionomer bases have become widely used. They seal better than calcium hydroxide liners and have superior physical properties, superior esthetics, and release fluoride. They are also more user friendly than conventional acid–base glass ionomers and may be less likely to cause pulpal irritation. If the dentist chooses, a resin-modified glass ionomer base can be placed over a small calcium hydroxide liner in the area closest to the pulp.

Once the pulp is protected with a desensitizing agent, a hard calcium hydroxide liner, or a resin-modified glass ionomer base, the fractured tooth should receive a bonded composite resin

Figure 38.4 (A) Patient presented with fractured right central incisal immediately after an accident.

Figure 38.4 (B) Accidents where dentin is exposed are best treated conservatively with as little additional trauma to the tooth as possible. The patient's smile was restored using a resin-modified glass ionomer liner, followed by a combination of a hybrid composite to restore the incisal edge, and a microfill composite for better polish.

restoration (Figure 38.4A and B). This protects the pulp while producing an immediate esthetic result. Alternatively, the fractured coronal fragment may be bonded back into place. This technique, known as fragment bonding, has increased in popularity with improved modern dentinal bonding agents. This procedure has psychological and esthetic benefits, because the restoration will most closely resemble the tooth before the trauma occurred.[7,10–12] The goal of the initial visit with uncomplicated crown fracture is pulpal protection, comfort, and esthetics; the necessity for endodontic procedures will be determined at follow-up.

As for all dental traumas, the patient should be examined at regular intervals, as described earlier. A pulp may be concussed for a week or more after trauma, but then return to normality. Therefore, root canal treatment is generally not initiated until after follow-up examinations and after placement of a restoration that facilitates isolation. Pulpal vitality must be checked regularly. In cases where the root formation had not been completed, the goal is to maintain pulpal vitality as long as possible, so that root formation can be completed. Whether the root is mature or immature, it is very important that a dying or dead pulp be identified before apical pathology has developed. The lesser the magnitude and duration of the pathology, the better the prognosis for root canal treatment.

In most cases, the emergency-bonded composite restoration will be the definitive restorative treatment. Even if root canal treatment is needed, no further restorative treatment will likely be needed, other than closure of the access cavity with another bonded composite restoration. The patient is told that it may last for 3–5 years, but can be repaired and polished as needed. Should a bonded composite restoration be esthetically inadequate, then a conservative porcelain veneer could be placed, even if root canal treatment has been performed. Posts do not strengthen teeth; crown preparation weakens anterior teeth. There is no reason to further reduce the tooth if the patient is pleased with esthetic result.

Complicated fractures involving the pulp

In the permanent dentition, complicated fractures are rarer than uncomplicated fractures. For permanent teeth with mature roots, emergency treatments include direct pulp capping, which will generally need to be followed by root canal treatment; pulpectomy, which will need to be followed by root canal treatment; and root canal treatment at the initial visit.[5,6,9] The best prognosis for a direct pulp cap is for a small traumatic exposure, without contamination, without pain, and which is performed immediately after the traumatic accident, but in the long term the prognosis for pulpal survival in mature teeth is guarded. Rubber dam isolation must be used absolutely for any procedures involving the pulp and is strongly recommended whenever traumatically exposed dentin is encountered or when adhesive procedures are being performed (Figure 38.6A–F).

For permanent teeth with immature roots, the goal is to maintain pulpal vitality through vital pulp therapy or apexogenesis, at least until formation of the entire root has been completed.[1] In this situation, a high or shallow pulpotomy, the Cvek technique, is usually used. The tooth is isolated, and pulpal tissue is gently removed to approximately 2 mm below the exposure using a small water-cooled round diamond bur. The pulp is rinsed with sterile saline, hemostasis is achieved, the clot is gently rinsed away, and a hard calcium hydroxide liner is placed, followed by a glass ionomer or resin-modified glass ionomer base, and then by a bonded composite restoration. Alternatively, MTA (Mineral Trioxide Aggregate, Dentsply) can be placed over the pulp instead of a hard setting calcium hydroxide liner. MTA has advantages in that it can be used in a damp field, seals well against dentin, and is bacteriostatic. However, because it sets slowly, its manufacturer recommends checking at a subsequent appointment prior to restoration. It is likely that quicker setting variants of MTA will soon be introduced. Although traumatized teeth with pulpal exposures should be seen within 24 h, the shallow pulpotomy may still be successful even after a week's exposure.

If the pulp in an immature permanent tooth becomes necrotic, or is already necrotic, then nonvital therapy or apexification is performed.[1,5] The tooth is isolated, carefully and thoroughly debrided, a nonsetting calcium hydroxide paste placed, and a durable provisional restoration made. Nonsetting calcium

Clinical case 38.1

Problem

A 17-year-old student fell while skateboarding and suffered an uncomplicated enamel–dentin fracture of his upper left central incisor (Figure 38.5A). He was not otherwise injured. He located the lost tooth fragment and immediately attended the dentist.

Treatment

Rubber dam isolation was immediately provided. The patient described dentin sensitivity to air and contact by his tongue, but not pain, and requested that local anesthesia not be provided. The fragment and tooth were treated with a multipurpose bonding agent and reunited using a dual-cure resinous cement designed for porcelain veneers. Excess cement was gently trimmed using a multi-fluted carbide finishing bur and then polished using copious water spray.

Result

The patient appreciated the fragment reattachment procedure; he explained that he had a similar accident 3 years before, losing 2 mm from his upper right central incisor (Figure 38.5B). Although that composite restoration had undergone noticeable wear, the patient elected to leave it as is. Given his skateboarding history, the use of a mouthguard was advised.

Figure 38.5 (A) This 17-year-old boy fell and fractured his left central incisor while skateboarding. Since it was an uncomplicated enamel–dentin fracture and the patient was able to locate the lost tooth fragment, it was decided to do the most conservative esthetic treatment and reattach the fractured tooth segment.

Figure 38.5 (B) The fragment and tooth were treated with a multipurpose bonding agent and reunited using a dual-cure resin cement.

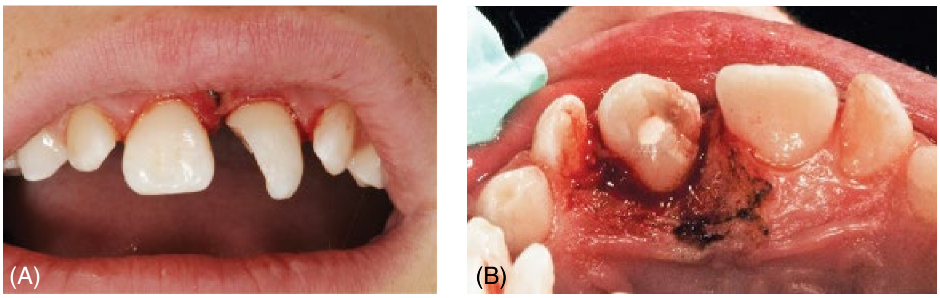

Figure 38.6 (A, B) This 14-year-old boy presented after a fall that fractured the maxillary left central incisor. The patient was referred for endodontics and returned for restoration of the fractured tooth.

Figure 38.6 (C) Tooth was bonded with composite resin and contoured with a 30-µm diamond (DET-6F, Brasseler USA).

hydroxide paste is bactericidal. Typically, after 3–6 months, a delicate calcific barrier is formed across the root apex, but root formation remains incomplete. Then, the calcium hydroxide is carefully removed, a conventional gutta-percha obturation performed, and the access closed and a definitive coronal restoration made. Alternatively, an apical plug of MTA can be placed after brief placement of calcium hydroxide for 1 week to 1 month, and after setting has been checked a conventional gutta-percha obturation is performed.

In the primary dentition, emergency treatment may include pulpotomy, root canal treatment, or extraction.[1,13,14] If the roots are more than half resorbed, extraction is recommended. If root canal treatment is chosen, a resorbable paste should be used for obturation without gutta-percha or other nonresorbable obturating materials.

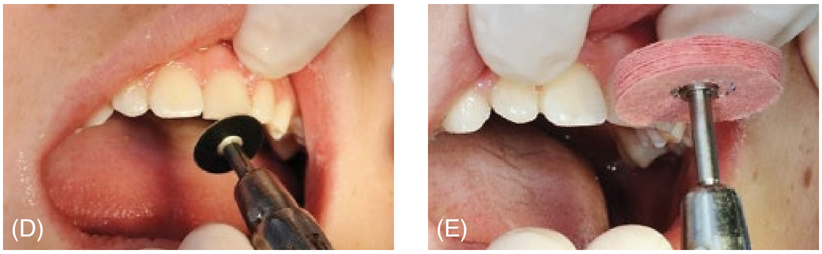

Figure 38.6 (D, E) Final polish was done using abrasive disks (Sof-Lex 3-M) and a polishing wheel (Brasseler USA).

Figure 38.6 (F) Youthful texture surface was incorporated for the most natural look in the final restoration.

As for uncomplicated crown fractures, the conservative-bonded composite is the restoration of choice. Conservative porcelain veneers may be used when extensive destruction has occurred. Posts should be avoided unless there is absolutely no other way to retain the final coronal restoration. Crown preparation should be avoided unless almost all of the coronal tooth structure has been lost.

Crown–root fractures

Crown–root fractures involve enamel, dentin, and cementum.[5,6,9] Careful diagnosis, treatment, and follow-up are necessary even though they only constitute a small proportion of tooth injuries. Anterior teeth are usually injured by direct trauma; posterior teeth are usually injured by indirect trauma. Crown–root fractures may be vertical, horizontal, or oblique; they are often difficult to diagnose visually or radiographically because of their location and orientation. Unless the X-ray beam is almost exactly parallel to the fracture plane, a fracture may not be seen. Fractured tooth and bone fragments may be held in place by the periodontal ligament without any visible displacement and be clinically indiscernible.

Vertical crown–root fractures generally have a very poor prognosis; extraction is often indicated for both primary and permanent teeth (see Chapter 23, Figure 23.14B and C). Some crown–root fractures may be uncomplicated, not exposing the pulp. Uncomplicated crown–root fractures may be managed in the ways described earlier for enamel and dentin fractures. As with other fractures, the pulp should be protected and then the patient should be functionally and esthetically stabilized. Many crown–root fractures are complicated, involving the pulp. Complicated crown–root fractures should receive pulpal management as described earlier for complicated crown fractures involving the pulp. Once the pulp has been treated, the tooth should be temporarily restored until the situation is stable enough to determine a definitive restorative treatment plan. As an interim procedure, loose tooth fragments may be bonded together. Nonrigid splinting to adjacent teeth may be helpful.

Subgingival extension of more than 3 or 4 mm by crown–root fractures requires orthodontic extrusion to expose the fracture surface and allow tooth preparation for full crown or other restorations.[7,15,16] Orthodontic extrusion is preferred to periodontal surgical crown lengthening because the gingival form is preserved. Fractures extending more deeply may require prophylactic root canal treatment, followed by a post and core. Because the restorative prognosis of an endodontically treated tooth is dependent on the bulk of remaining tooth structure, particularly on the height of the remaining dentin stump height, consideration should be given to extraction and replacement using an implant single crown restoration. Likewise, if the crown-to-root ratio is likely to exceed 1 : 1, consideration should be given to extraction and replacement using an implant single crown restoration, which can be seen in Figure 38.7A–H.

Root fractures

Root fractures involve the cementum, dentin, and pulp of injured teeth and represent a small percentage of fractures to permanent teeth.[5,6,9] This type of fracture is rarely seen in deciduous teeth prior to root development. Cementum and dentin are dynamically vital tissues with definite reparative capacities.

Andreasen and Hjortling-Hansen list four types of healing that can occur between the fragments of a root fracture: healing by hard calcified tissue, healing with the interposition of connective tissue, healing with bony interposition, and nonhealing with the interposition of granulation tissue.[17] These are listed in order of most to least favorable prognosis. The first type of healing by hard calcified tissue is the most desirable. In the past, rigid fixation was used for 2–3 months with the aim of healing by bony ankylosis, whereas current approaches use nonrigid splinting for 3–4 weeks for all root fractures with abnormal mobility—except for cervical fractures, when longer periods of up to 3–4 months may be needed—with the aim of preserving the periodontal ligament and avoiding ankylosis.

A wide variety of root fractures occur. If there are no symptoms and no abnormal mobility, then no treatment is indicated. If the coronal segment is mobile, then nonrigid splinting is indicated. If the coronal segment has been displaced, it should be precisely repositioned. If abnormal mobility is present, nonrigid splinting should be used, as already described. It is important to ensure that the tooth is not subjected to occlusal trauma.

A wide variety of pulpal scenarios occur; careful endodontic and radiographic examination and follow-up is critical. Most often, the pulp in both segments remains vital and healthy, and

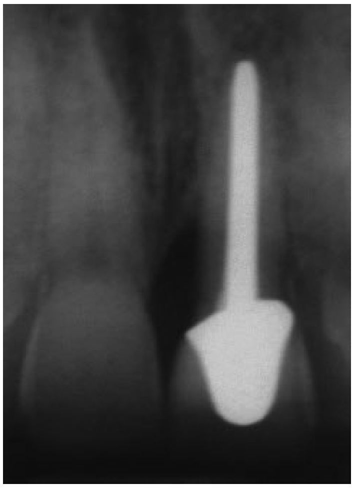

Figure 38.7 (A) This patient fractured his maxillary left central incisor diagonally to the base of the 8 mm mesial defect.

Figure 38.7 (B) The bone defect was corrected through orthodontic extrusion as seen in the above radiograph.

Figure 38.7 (C, D) It is clear to see in these photographs of the patient's anterior incisor how the left central incisor was extruded before extraction.

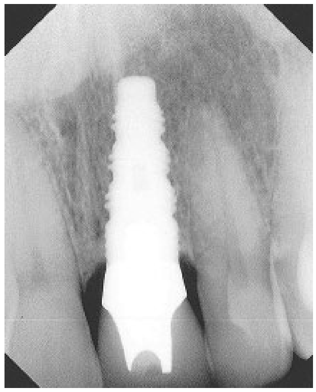

Figure 38.7 (E) This radiograph shows the implant and crown after the crown was seated.

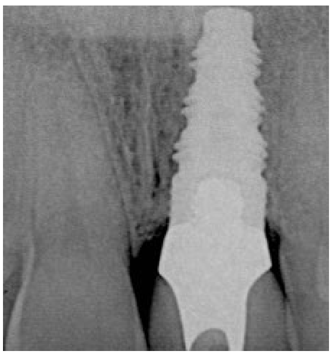

Figure 38.7 (F) Ten years postoperative shows the bone is still stable.

Figure 38.7 (G, H) These before and after photographs show both the functional and esthetic improvement for this young man, who received not only the implant and single crown but also crown lengthening and bleaching.

root canal treatment is not necessary. If both coronal and apical segments become necrotic, both should receive root canal treatment, if possible. If a necrotic apical segment cannot be directly accessed, then the coronal segment should receive root canal treatment and the apical segment should be removed. If the coronal segment becomes necrotic, but the apical segment remains vital, then only the coronal segment needs to receive root canal treatment.

Orthodontic extrusion can be used for root fractures at or near the alveolar crest, but if the crown-to-root ratio is likely to exceed 1 : 1, consideration should be given to extraction and replacement using an implant single crown restoration. In the past, intraradicular splints were sometimes used to unite the coronal and apical segments of fractured roots or to replace the apical fragment and stabilize the tooth.

Primary teeth with root fractures may also be splinted nonrigidly; they can be retained and will usually be shed normally.[13,14] When primary teeth are grossly injured, the coronal fragment should be extracted; but no attempt should be made to retrieve the apical fragment to avoid injuring the succedaneous tooth bud. The apical fragment will eventually be resorbed.[1] Some root-fractured teeth are difficult to diagnose. Others are impossible to save, for which extraction and placement of implant is the treatment of choice.

Luxation injuries

Luxations are injuries to the tooth-supporting structures that result in dislocation or displacement of teeth in the alveolus. They range from concussion to subluxation; extrusive, lateral, and intrusive luxations; and avulsion. The displacement may be vertical or horizontal—a tooth that is displaced by trauma seldom fractures. The patient may complain of a diffuse ache in the affected area or may be free of pain. The injury may cause numbness and accompanying soft-tissue damage. Treatment of luxation injuries depends on the extent of the trauma.[1,5,6] Although many teeth with luxation injuries may need root canal treatment, especially intrusive luxations, others may not; concussions and subluxations rarely need root canal treatment.

Concussion and subluxation involve mild injury to the periodontium; the tooth is tender to touch and biting, but it is not displaced and has normal mobility. The use of a flexible splint for 7–10 days is optional. Follow-up including careful pulpal evaluation is needed. As for all luxation injuries and avulsions, the patient is instructed to have a soft diet, brush with a soft brush after every meal, and to rinse with 0.12% chlorhexidine twice a day for 1 week.

Extrusive luxation is characterized by axial extrusion out of its socket. It is managed by precise repositioning and nonrigid splinting for up to 3 weeks with the same patient instructions outlined directly above. Teeth with mature roots will usually need root canal treatment. Immature teeth will receive periodic recall and careful pulpal evaluation; if they become necrotic, they should receive nonvital therapy or apexification, as described earlier.

Lateral luxation is characterized by lateral displacement, being firmly locked in its new position, and often by an ankylotic metallic tone on percussion. It is managed as for extrusive luxation; but if the marginal bone becomes broken down, the splinting time is increased to 6–8 weeks.

Intrusive luxation is characterized by intrusion into its socket and often by a dull tone on percussion. Mature teeth will almost always need root canal treatment; this is usually delayed until a week or two after the injury. Mature teeth will need orthodontic extrusion or surgical repositioning. Immature teeth generally undergo spontaneous reeruption; they must be closely monitored for pulpal changes or root resorption, which necessitate immediate root canal treatment.

Primary teeth with luxation injuries will generally not need pulpal treatment. Nonrigid splinting is recommended for primary teeth that are mobile after a luxation injury. However, if a primary tooth is significantly displaced, extraction is usually recommended.[13,14]

A splint should be quick to place, not cause any additional trauma, be stable throughout the splinting period, avoid damaging the gingiva or mucosa, facilitate root canal treatment, if needed, and be esthetic. Flexible orthodontic wire, nylon monofilament fishing line (60 lb breaking strain), or other flexible woven polyethylene fibers (e.g., Ribbond) can be used. They are simply point bonded to the facial enamel and must allow physiologic movement. It is important that rigid fixation is avoided so as to reduce the possibility of ankylosis and resorption, and so as to increase the likelihood of periodontal healing.

Two examples of luxation injuries and their treatment follow (Figures 38.8 and 38.9). The patient shown in Figure 38.8A received a luxation injury 24 years ago. He was hit in the mouth when a horse bolted, and the maxillary left central incisor was forced down and lingually into the mouth and the right central incisor was loosened. A tongue depressor was used as the patient bit down, and the teeth were mechanically pushed back into position. No further treatment was performed, and years later the pulps still test vital. (Note the absence of apical pathology in Figure 38.7B.) Clinical case 38.2 was more complex and involved extensive repositioning maneuvers.

Avulsions

A tooth completely avulsed, or exarticulated, from its socket because of injury can be replanted with a relatively good prognosis.[5,18] A clinical examination should be completed to determine if there are crown, root, or alveolar fractures, or obvious contaminants such as soil. The key factors for prognosis are the time outside the socket, the storage conditions, and the stage of root development. Before replantation, the following factors must be checked: presence of gross caries, existing advanced periodontal disease, gross fracture of the alveolar socket, and severe orthodontic crowding.

A good prognosis is achieved when the tooth is replanted within 30 min; the less time out of the socket, just a few minutes, the better. If the tooth was out of the socket for less than an hour,

Figure 38.8 (A) Patient presented 24 years later after a luxation injury in which he was hit in the mouth as a horse bolted and caused the maxillary left central incisor to be forced down and lingually and the right central incisor loosened. The teeth were repositioned back into place using a tongue depressor as the patient bit down and no further treatment was performed.

Figure 38.8 (B) Years later, the tooth still tests vital and there were no signs of apical pathology.

root canal treatment is initiated within 7–10 days to prevent external inflammatory root resorption. If the tooth was out of the socket for more than 1 h, little can be done to prevent replacement root resorption. The best prognosis will be when the tooth has been replanted almost immediately, the preferred course of action. Only if the tooth cannot be immediately replanted should it be stored and transported. The order of preference of storage media, from best to worst is: a commercially available purpose-designed storage solution (e.g., Save-A-Tooth), milk, saline, and saliva. Inappropriate nonphysiologic osmolality or pH damages the periodontal ligament cells, making healing less likely. Mature teeth should have root canal treatment initiated within 7–10 days of replantation, after some stability and comfort have been reached, so as to prevent inflammatory root resorption. Immature roots have the best prognosis. Pulpal revascularization is possible. Endodontic treatment is generally avoided. It may take up to 3 months for the return of a normal pulpal response to cold and electric testing. Only if needed should nonvital therapy, or apexification, be initiated, as described earlier.

When replanting an avulsed tooth, hold the tooth by the crown, not by the root, and simply rinse the tooth in saline or under cold running water, taking care not to drop the tooth down a drain. Do not scrub the root or treat it with disinfectants. Replace the tooth in the socket. Verify the position clinically and radiographically. Place a flexible nonrigid splint for 1 week. Suture any gingival lacerations. Prophylactic antibiotics should be prescribed. Arrangements should be made for a tetanus shot, or a booster shot, if the last one was more than 5 years ago. Follow-up appointments should be scheduled (Figure 38.10 A–G).

Reimplantation can also be performed on primary teeth.[13,14] It is a temporary measure, but an excellent method for maintaining space until a more permanent procedure is indicated. Despite the uncertain prognosis, reimplantation is still advisable in children and young people when the jaws have not yet attained maximum growth and development, when a replacement would be difficult, and when the psychological impact of tooth loss might cause irreparable harm.

Fractured restorations

Patients accumulate direct and indirect restorations, composite and amalgam fillings, veneers, onlays, crowns, tooth and implant-supported fixed dental prostheses, and removable prostheses. No matter how well a restoration is made, it has the potential for degradation and complication. Fracture follows only secondary caries as the most common reason for replacement of all types of restorations. Porcelain fracture, just as a fracture of tooth structure or cusp fracture, adjacent to restorations is a common occurrence.[19] Implant-supported crowns appear to have a particularly high incidence of esthetic and prosthetic complications. Recurrent caries makes restoration and tooth fracture more likely; caries must be fully addressed at the time of repair, if repair is even possible (Figure 38.11A–D). Unfortunately, these fractures most commonly occur in visible areas, creating esthetic emergencies.[20] Most fractured restorations are best and esthetically repaired using highly filled hybrid composite resins along with a multipurpose bonding agent, after surface roughening[21] (Figure 38.12A–N).

Although replacement of the prosthesis may ultimately be recommended, patients may need an immediate interim repair (Figure 38.13). Others may not have the time or financial means to replace a restoration or prosthesis at the time of fracture. It is important to stress to the patient that no repair is as strong as the original prosthesis, and it is at a higher risk of failure. Repair of defects to otherwise sound restorations is now widely taught in dental schools around the world. Many authorities favor repair to replacement. Repair can be more conservative of tooth

Clinical case 38.2: Injury involving luxation

Problem

A 28-year-old female was in an automobile accident that crushed the maxillary anterior segment (Figure 38.9A). The maxillary right central incisor was avulsed, and the right lateral and left lateral were fractured. The central incisor was pushed in so far that the patient could not close her mouth.

Treatment

The crushed maxillary right central incisor was repositioned by hand so that the patient could close in normal occlusion (Figure 38.9B). It is important when repositioning teeth or a segment, by hand or instrument, to esthetically align the luxated part. Teeth that were previously rotated can be made straight and then mechanically bonded with composite resin.

The missing tooth was replaced with an acrylic tooth (Figure 38.9C). Since the luxated segment had to be completely splinted, the six anterior teeth were etched to place a strong splinting action across the front. The area was washed and etched with 37% phosphoric acid. Figure 38.9D shows the area when dried and the amount of etching achieved. The entire area was bonded with composite resin, shaped, finished, and glazed (Figure 38.9E). Endodontic treatment was then performed on the left central incisor and three mandibular incisors.

Result

Teeth that are extrusively or laterally luxated in accidents should be repositioned immediately and be nonrigidly splinted to facilitate healing of the periodontium. This way, the patient can function normally until routine dental rebuilding procedures can be performed.

Figure 38.9 (A) A 28-year-old female presented after an automobile accident that caused the maxillary right central incisor to be avulsed, and the right lateral and left lateral were fractured.

Figure 38.9 (B) The maxillary left central incisor was repositioned by hand, so the patient could close into normal position.

Figure 38.9 (C) The missing tooth was replaced with an acrylic tooth and the luxated segment had to be splinted across the front.

Figure 38.9 (D) The amount of etching achieved is shown when the area is dried.

Figure 38.9 (E) The entire area was bonded with composite resin and polished.

Figure 38.10 (A) A 25-year-old female dental assistant presented for emergency dental treatment after an automobile accident at 1 a.m.

Figure 38.10 (B) The maxillary right lateral incisor plus mandibular right central incisors were avulsed, and the maxillary right central incisor was fractured into the pulp.

Figure 38.10 (C–E) Following local anesthetic, the avulsed teeth were repositioned back into place.

Figure 38.10 (F) After temporary bonding of the maxillary right central incisor, the anterior segments were carefully equilibrated to avoid any occlusal trauma.

Figure 38.10 (G) The maxillary and mandibular incisors were temporary splinted into place until further treatment could be evaluated.

structure, quicker, less costly, less traumatic, and may not require local anesthesia. Repaired restorations can perform surprisingly well.[20,22]

Small porcelain fractures are most predictably repaired by smoothing and polishing the porcelain. Initial adjustment should be done with a smooth diamond bur with copious water spray (red-band ET diamonds, Brasseler). Afterward, the porcelain should be sequentially polished using coarse to fine porcelain polishers, rinsing between each step.

With larger porcelain fractures, it is usually best to completely replace the restoration. As an interim treatment, direct repairs may be completed to restore esthetics and function. Direct intraoral repair by bonding composite resin to the fractured area is the most common clinical repair technique. For most repairs of restorations, retention comes from micromechanical retention. However, macromechanical retentive and resistance form features are desirable, as long as they do not further compromise adjacent tooth structure or an existing restoration.

Figure 38.11 (A) Seven years after the placement of porcelain veneers, this patient showed signs of beginning caries at one of the lingual margins.

Several methods can be used to clean and roughen porcelain and other restorative materials. These include roughening using diamond burs, air abrasion using aluminum oxide abrasives, tribochemical silica coating using air abrasion by silica-coated particles (e.g., Coe-Jet Sand), treatment of glassy materials with hydrofluoric acid, treatment of glassy materials with silane coupling agents, treatment of cast metals using tin plating, and the use of multipurpose bonding agents.[20,21,23] Chairside plasma treatments to enhance bonding to a variety of restorative substrates have been studied, but they have not yet been developed for intraoral repairs.

It is clear that a combination of surface treatments produces the strongest bonds[24,25] It is also clear that no single recipe will be optimal for all restorative materials, or even for single class of materials, such as the porcelains or the composites.[26] Air abrasion will effectively roughen most restorative materials: porcelain, composite, base metal alloys, noble metal alloys, gold, titanium, and amalgam.[27] Air abrasion can be used intraorally, and small units are specifically designed for this purpose (e.g., Microetcher, Danville Engineering) but considerable care must be taken to protect airways and eyes. Air abrasion is generally a good first step for most adhesive repair procedures. Air abrasion can be used to create some micromechanical retention on strong all-ceramic core materials without undue damage. Both air

Figure 38.11 (B) Air abrasion was chosen to make the preparation at the lingual margin to both abrade the adjacent porcelain plus avoid any injury to the veneer that might occur if a handpiece and bur were used.

Figure 38.11 (C) Flowable composite was used to restore the defect.

Figure 38.11 (D) The final result shows the margin sealed for restoration longevity.

Figure 38.12 (A) Patient presents with her fractured maxillary right cuspid and bicuspid porcelain veneers caused by biting on a porcelain object.

Figure 38.12 (B) The porcelain was first roughened using an extra-coarse diamond bur (AC2, Brasseler USA).

Figure 38.12 (C) Next, the area was treated with air abrasion for maximum micromechanical retention.

Figure 38.12 (D) The tissue was retracted using cotton cord (Ultradent) to better isolate the area. Hydrofluoric acid 9 (Ultradent) was applied to the porcelain for 90 seconds.

Figure 38.12 (E) After rinsing with water, a wet cotton pellet was used to wipe off any remaining salt deposits.

Figure 38.12 (F) Next, 36% phosphoric acid was applied to the dentin and then rinsed.

Figure 38.12 (G) Next, bonding resin was applied to both porcelain and tooth structure and polymerized.

Figure 38.12 (H) For maximum polish, a microfilled composite resin was selected for bonding.

Figure 38.12 (I) A bin-angled Teflon-coated composite instrument (Goldstein Flexi-Thin TNCIGFT4, HU-Friedy) was used for placement and contouring the restoration.

Figure 38.12 (J) An eight-bladed carbide finishing bur (ET6, Brasseler USA) was used to contour and finish the restoration.

Figure 38.12 (K) A 16-bladed carbide finishing bur (ET4F, Brasseler USA) was used to finish the gingival margins.

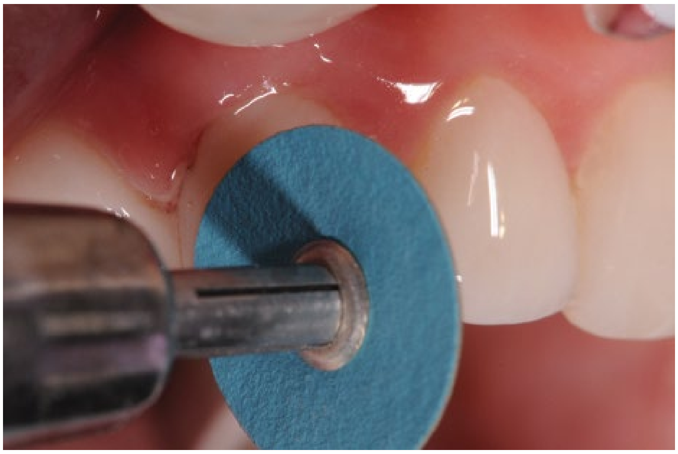

Figure 38.12 (L) A series of four polishing disks (Sof-Lex, 3 M) was used for polishing.

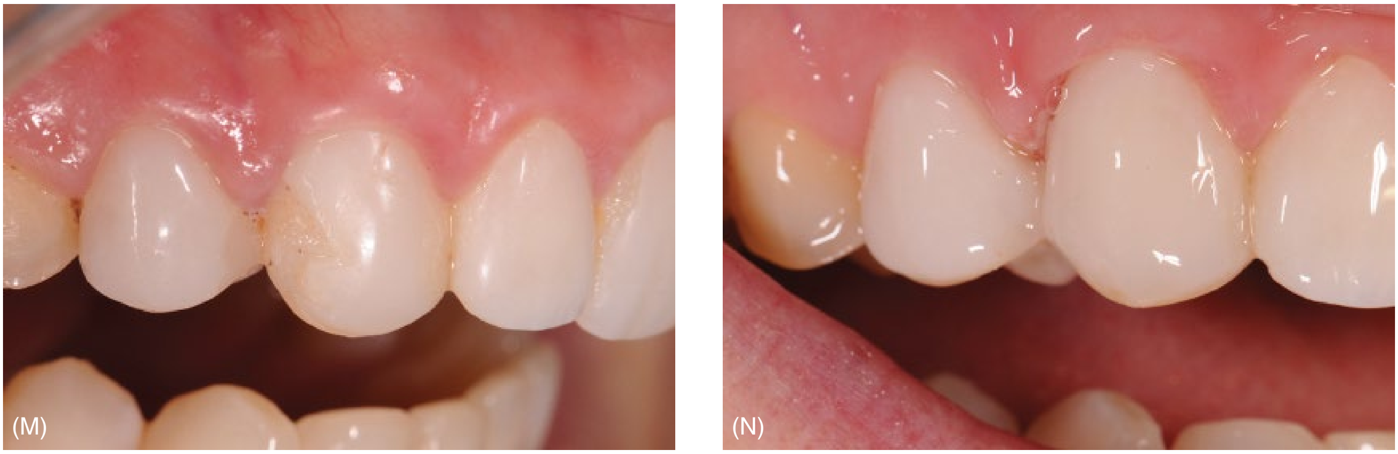

Figure 38.12 (M, N) Note the finish of the microfill composite as it blends in with the porcelain.

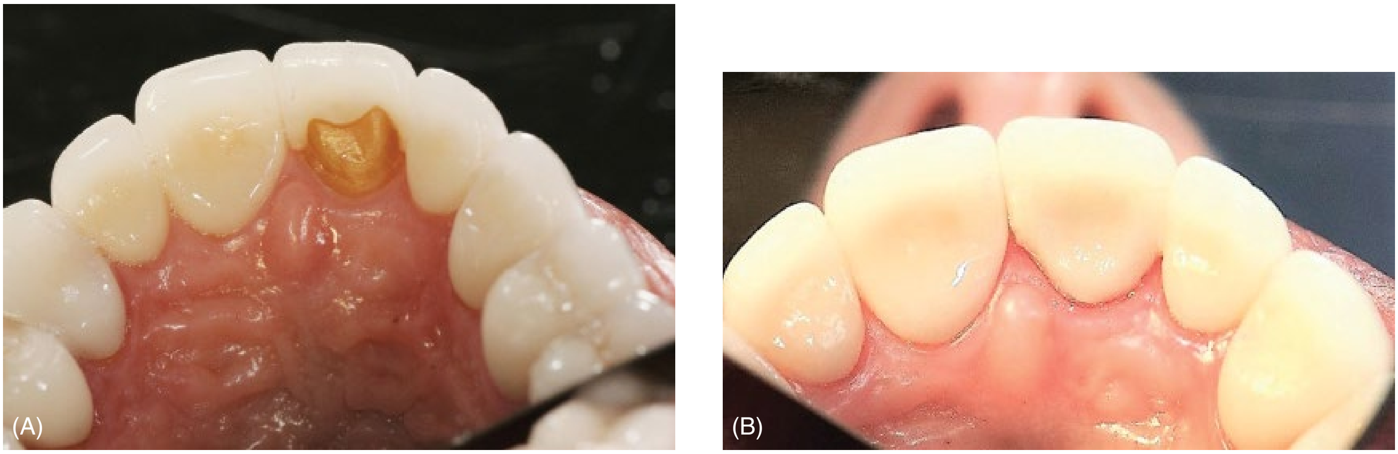

Figure 38.13 (A, B) This lady presented with a lingual fracture on her all-ceramic crown on the left central incisor. Although the crown could be replaced, it was decided to bond the lingual surface with composite resin since there was enough retention of the original crown and facial esthetics would be preserved.

abrasion and tribochemical silica coating have an advantage that they can prepare multiple exposed surfaces at one time.[20]

Hydrofluoric acid gels, at concentrations from 2% to 10%, can be used for 2–5 min to etch and roughen silica-glass porcelains and glass-ceramics, producing strong and durable bonds when multipurpose bonding agents are applied. Hydrofluoric acid is extremely caustic to the soft tissues. Excellent isolation and careful technique are essential if it is to be used intraorally. Gels designed for intraoral use are more amenable to control than the liquids used to prepare indirect porcelain restorations in laboratories. Hydrofluoric acid cannot effectively etch high-strength alumina and zirconia all-ceramic core materials. Hydrofluoric acid should not be used to etch the glassy filler in composite restorative materials because it also damages their resinous matrices, nor should hydrofluoric acid be allowed to contaminate tooth structure. Acidulated phosphate sodium fluoride is ineffective in etching porcelains or composites.

The long-term effectiveness of silane-coupling agents is somewhat controversial. Silane is a dual functional monomer that can react with porcelain and ceramic surfaces as well as with resinous bonding agents. However, silanes tend to lack hydrolytic stability and may be most effective when used in laboratory environments where stability can be attained before they are exposed to the wet oral environments; composites quickly imbibe water in the hours after restorative placement. Nonetheless, the available evidence generally supports the use of silane coupling agents used as adjuncts after air abrasion or etching and before application of a multipurpose bonding.[20,23]

Metals, particularly nonprecious alloys, can be roughened using air abrasion. Tin plating, coating the surface with needle-like crystals, is effective in roughening precious metals. Additional retention can be achieved by roughening and etching adjacent porcelain.

Bonding agents are a key part of the success of any esthetic repair.[28] Opaque masking composites can be applied to exposed metallic surfaces before a layered hybrid composite restoration is placed[29] (Figure 38.14A–D). Fiberglass reinforcement may strengthen large composite repairs. Careful contouring will minimize the amount of finishing needed; thus reducing stresses applied to the new repair.

Figure 38.14 (A) This man fractured his maxillary left lateral ceramo-metal crown.

Figure 38.14 (B) After air abrasion, acid etching, Silane and bonding resin, a small amount of white resin opaquer (Cosmedent) was applied and polymerized to mask the exposed metal, followed by a mircrohybrid composite resin to restore the fractured crown.

Figure 38.14 (C) Final finishing was done using a 30-blade carbide bur(ET4-UF, Brasseler USA).

Figure 38.14 (D) After polishing with Diacomp Feather Lite (Brasseler USA) polishers, the crown repair is complete.

Prosthesis fracture, failure, and repair

Fixed, removable, implant-supported, and provisional prostheses also frequently fracture. Many of the direct reparative strategies using bonded composite, described earlier, can be used to address these esthetic emergencies. Indirect reparative veneers or onlays can also be fabricated to replace fractured porcelain or resin;[30] computer-aided design and manufacturing techniques and in-office laboratory support can expedite this approach. Emergency fixed dental prostheses can be formed from fractured natural tooth crowns, failed artificial crowns, or denture teeth held in place by composite resin using polyethylene ribbon (e.g., Ribbond), fiberglass ribbon (e.g., eFiber, Preat Corp.), and orthodontic wires or surgical bars. Debonded resin-bonded bridges can be cleaned, air abraded, and rebonded, but they may be less successful after multiple rebondings. Prefabricated posts can be temporarily retrofitted to displaced crowns (Figure 38.15A–F). Visible-light-cure denture base

Figure 38.15 (A) This patient fractured his all-ceramic crown and tooth at the gum line. It was decided that the best therapy to try to save his crown would be to retrofit the existing crown to the tooth following endodontic treatment and post placement.

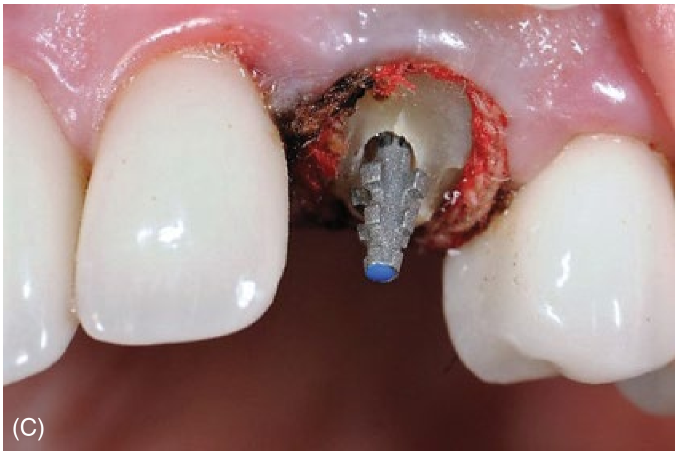

Figure 38.15 (B, C) After tissue retraction, a post canal was prepared and fitted so that the existing crown would fit over the post (Brasseler USA).

materials (e.g., Triad, Dentsply) can be used to make emergency partial dentures or to add to existing prostheses. Lost denture teeth can be replaced using bonded composite. Crowns and pontics from failed fixed prostheses can be added to existing, new emergency, or transitional removable prostheses. Patients should be dissuaded from attempting to repair or recement restorations using superglue. In the case of an esthetic emergency shortly before a social engagement, a dislodged crown or fixed dental prosthesis can be temporarily retained through the application of a little denture adhesive. The patient should be advised to remove the crown after the social engagement, so as to prevent the possibility of its being inhaled or swallowed and to present for care at the dentist's office.

Figure 38.15 (D) After cementation of the post with a resin-modified glass ionomer cement, composite resin was used to build up the tooth for better support and retention of the crown.

Figure 38.15 (E) A series of adjustments to the buildup was done by continuously trying on the crown until obtaining an acceptable fit.

Figure 38.15 (F) The final crown was cemented into place using a resin-modified glass ionomer cement.

Summary

Dentists and patients sometimes incorrectly assume that a tooth fractured beneath the periodontal attachment and within the bone cannot be saved. With proper emergency treatment and surgical and reconstructive techniques, these roots can often be saved for a lifetime. Dentists may assume, again incorrectly, that because of expense or difficulty of treatment, a patient, or their family, would prefer to lose the tooth. As the dentist may not fully appreciate the value placed on a tooth by the individual, the patient should be informed of the options, their advantages and disadvantages, and given the opportunity to decide.

Even though extraordinary measures and a multidisciplinary approach are sometimes required, it may be possible to preserve traumatized teeth and their supporting tissues. A single tooth saved and retained can be far more esthetically pleasing than an artificial replacement. A retained tooth is likely to be less problematic than either a fixed dental prosthesis or an implant. Thus, all possibilities should be considered before a patient is allowed to lose a tooth. Dental care can maintain the integrity, health, and esthetic appearance of the dentition.

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Further resource

Padilla RR, Felsenfeld AL. Treatment and prevention of alveolar fractures and related injuries. *J Craniomaxillofac Trauma* 1997;3:22–27.

Chapter 39 Esthetic Failures

Ronald E. Goldstein, DDS, Azadeh Esfandiari, DMD, and Anna K. Schultz, DMD

Chapter Outline

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Successful dental treatment is one of the primary objectives of every dentist, and is measured not only by the doctor, but also by the patient; however, what the dentist considers "esthetic" may not be agreed upon by the patient. The inability to fulfill both patient and clinician expectations results in esthetic failure, even in light of long-term retention.[1] It is assumed that if the dentist considers a procedure a "failure" that they will try to rectify the situation; however, many esthetic failures discussed in this chapter were eventually noticed by the patients. It is important to note that the values of the patient, as well as the dentist, are subject to change according to social and cultural norms, as well as dental expertise; therefore, what is accepted as "beautiful" today may seem quite unattractive tomorrow.

Obviously, no dentist wants to fail; however, there are three basic reasons why some dentists fall victim to failure: (1) poor or faulty technique; (2) attempting to manage a case that exceeds the dentist's capability or expertise; and (3) overtreatment.[2]

Poor or faulty treatment is easy to understand, and state boards usually deal with many of these problems. The second reason is more difficult to grasp, because many practitioners think they can solve every patient's problems. One motivating factor in trying to avoid treating a patient who requires skills beyond the dentist's expertise is the issue of cost. Failure in esthetic or restorative dentistry is always costly, both for the patient and the dentist. A realistic and objective analysis at the outset, considering the difficulty in pleasing the patient both esthetically and in function, is paramount. Much stress can be avoided just by understanding one's own capabilities, and perhaps referring a patient to a colleague, who may have the training and experience to more expertly manage a difficult case.

We have seen too many esthetic and functional failures due to overtreatment, involving the dentist placing a full arch of veneers and/or crowns, instead of bleaching, contouring, or orthodontics—any or all of which could have saved the patient a good amount of money. In addition, refraining from overtreatment saves the dentist from potential failure due to future occlusal problems that may need to be solved with orthodontics. Obviously, not all of these types of failures are the fault of the dentist, especially when the patient refuses orthodontics or a recommended treatment.

For the purposes of this chapter, esthetic failure will be divided into three specific types: (1) immediate failure, (2) compromised

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treatment plan, and (3) eventual failure. These failures could be the result of problems with esthetics, materials, technique, maintenance, or any combination thereof.

Immediate failure

Some restorations fail, from an esthetic standpoint, upon insertion of the restoration. The dentist may have missed the shade completely (Figure 39.1A and B), or they may not have shaped the restorations to match adjacent natural teeth. Perhaps the gingival margins were left exposed and ill fitting, which would eventually cause discoloration and necessitate replacement (Figure 39.1C–E). Regardless of the cause, the result remains a failure upon insertion, and is most often "treatment-induced." The immediate solution to such a failure usually involves remaking the restoration; however, the best solution is obviously prevention—do not let it happen! *Never insert a restoration that you are not completely satisfied with, because the patient may eventually share your dissatisfaction.*

One of the most immediately noticeable signs of failure is discoloration. Intrinsic, extrinsic, and internalized tooth discoloration boast multifactorial etiologies; however, it is interesting to note the etiology of internalized discoloration as a function of the improper use of dental materials. In a 2009 study conducted by the University of Minnesota, it was observed that ferric ions have a very high affinity for hard tooth surfaces. Ferric ions may be found in gingival retraction fluid, most commonly used in the application of impregnated retraction cord by the clinician. Therefore, the unintended etching of dentin by this acidic fluid, in the most commonly used mechanicochemical method of soft-tissue management, can result in the absorption of iron into dentin. This causes a black, insoluble, ferric compound to form due to the reaction of iron with the hydrogen sulfide produced by bacteria. This kind of contamination can cause microleakage and the perpetuation of dentinal staining seen under porcelain crowns, creating unesthetic discoloration as a result.[3]

A clinical study reported by the faculty practice group at the University of Minnesota described a 45-year-old woman with four lithium disilicate crowns on her maxillary incisors. The patient's crowns were placed approximately 4 years prior, and the patient had since complained of dark marginal areas around the restorations soon after their placement. Upon evaluation, it was noted that all four incisors showed evidence of black internalized dentinal discoloration, particularly at the shoulder region. A clinician removed the staining by refining the crown preparations and then placed knitted retraction cord soaked in aluminum chloride (Hemodent) to make another impression in order to fabricate four new zirconia-based ceramic crowns. It was observed that when the gingival margin of the preparation extends intrasulcularly, gingival retraction fluid will almost indefinitely contaminate the prepared dentinal surfaces, thereby removing the smear layer and causing microleakage and discoloration, as occurred in this particular patient. To address the problem, the clinician's use of aluminum chloride, as opposed to an iron-containing material, prevented the discoloration from occurring a second time, and the patient has been satisfied with the result since the procedure was completed.[3]

Another classic example of esthetic failure at completion of treatment is seen in Figure 39.2. A previous dentist told this patient that if the crowded lower central incisor were extracted, the remaining teeth would fill the space; however, the patient had the tooth extracted many years ago, and the space never closed. The clinician could have used any number of removable appliances to close this space.

Improper crown contours

One of the most frequent esthetic failures results from a lack of both cosmetic and functional skill in contouring restorations. Such an example of immediate esthetic failure can be seen in Figure 39.3A. The patient originally accepted the dentist's result as the best he could accomplish; however, her friends soon let her know that her smile should look better. From that point on, she hated to smile.

Another example of immediate esthetic and functional failure is shown in Figure 39.3B. The recently placed, overbuilt, posterior porcelain-to-metal crowns not only looked bulky, but also lacked occlusal contours. This patient, who may feel that he or she has achieved an ideal result, may soon find quite the opposite.

Figure 39.1 **(A)** This 30-year-old woman was dissatisfied with the color of her two front teeth. Although the patient has tetracycline-stained teeth, the attempt to match the patient's shade was a failure.

Figure 39.1 **(B)** New crowns with improved shading methods helped enhance this patient's smile.

Figure 39.1 **(C)** This patient had 10 porcelain veneers inserted only 7 months before and complained of constant sore gum tissue. Probing of margins showed a poor fit on virtually every veneer. Note exudate around the cervical portion of the right cuspid.

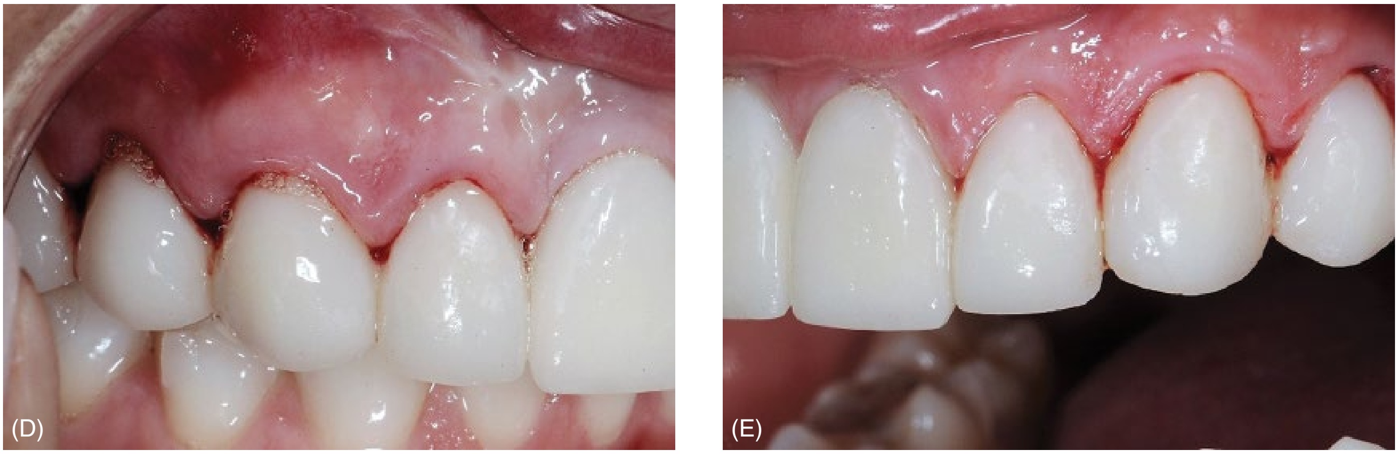

Figure 39.1 **(D, E)** Although the veneers had to be replaced, the first step was to remove as much of the defective margin as possible so that the tissue could begin to heal before veneer replacement.

When basic principles of crown contouring are overlooked, results such as those noted in Figure 39.3C can occur. This ceramometal restoration had only been in the mouth for 2 months, yet it is total failure for the following reasons:

- The porcelain was overbuilt and poorly contoured. Failure to allow for proper embrasures resulted in tissue impingement and gingival hypertrophy (Figure 39.3C and D).
- Unesthetic porcelain contouring, and failure to create adequate incisal embrasures, gave a "straight-across," false appearance.
- There was no variation of depth or shade in the porcelain, resulting in a chalky white and unnatural appearance. Since this patient was a beautiful young model, this unsightly appearance was even more pronounced.
- The dentist failed to create an illusion of separateness. It is important to include both carving and interproximal staining in the fixed restoration in order to create separateness and to avoid a false appearance.
- This young woman was made to look much older when an improper smile line was created. The incisal edge length should have varied to produce a more natural and youthful appearance.
- Lacking feminine crown contours, the result has no personality or appropriate sex characteristics, both of which are so important to an esthetic restoration.

Figure 39.2 In this case, the crowded lower incisor was extracted; however, the remaining teeth never filled the space.

Figure 39.3 **(A)** This woman was embarrassed to smile due to the unesthetic appearance of her restorations placed by her previous dentist. Note the significant widening of the lateral incisors, lack of interincisal distance, and failure to achieve uniform gingival height through cosmetic periodontal surgery.

Figure 39.3 **(B)** The overbuilt posterior porcelain-to-metal crowns are not only bulky, but also lack occlusal contours.

Without taking these factors into consideration, the total effect is dentist-induced failure in the truest sense, because there is no substitute for time and attention to detail. The try-in appointment would have been the appropriate time to discover and correct these faults.

If the occlusion is not perfect when crowns are inserted, the teeth may eventually move. Figure 39.4A demonstrates a case in which crowns were inserted too high in occlusion. The dentist told his patient that he would "get used to them," but unfortunately a space developed. After occlusal adjustment and orthodontic repositioning with a removable appliance (Figure 39.4B), two full porcelain crowns were constructed (Figure 39.4C).

The most advantageous time to ensure proper occlusion is prior to placement of the restorations. In the case of a single anterior crown, the restoration should be harmonious with the patient's existing occlusion. If the restoration fractures after placement, the patient's posterior occlusion should be examined and potentially modified to correct the problem; however, if an older patient presents with gross malocclusion evident from the beginning of treatment, and has become well-adapted to this occlusion, it may be more effective to accept this patient's occlusion rather than initiating an extensive occlusal adjustment.[4]

Unesthetic clasp design

Another type of esthetic failure is shown in the case of a poorly designed removable partial denture. An excessive amount of metal, which is evident when a patient smiles, may mean poor clasp design on the removable partial denture. Such a case is

(C)

(D)

Figure 39.3 **(C, D)** This woman was unhappy with reconstruction done to enhance her smile only 2 months prior. This treatment violated almost all esthetic and functional requirements that the patient assumed would give her a beautiful result.

Figure 39.4 **(A)** When his previous dentist inserted this patient's crowns, there was no space between the crowns. Owing to the occlusion not being adjusted properly, eventually the two central incisors moved labially, which resulted in the space. He was told by his dentist that, "he would get used to them."

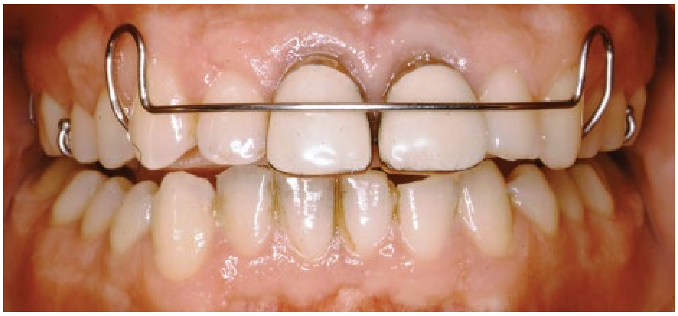

Figure 39.4 **(B)** Orthodontic repositioning by removable appliance. The crowns were replaced.

Figure 39.4 **(C)** The final result showed improvement of both proportion and shading.

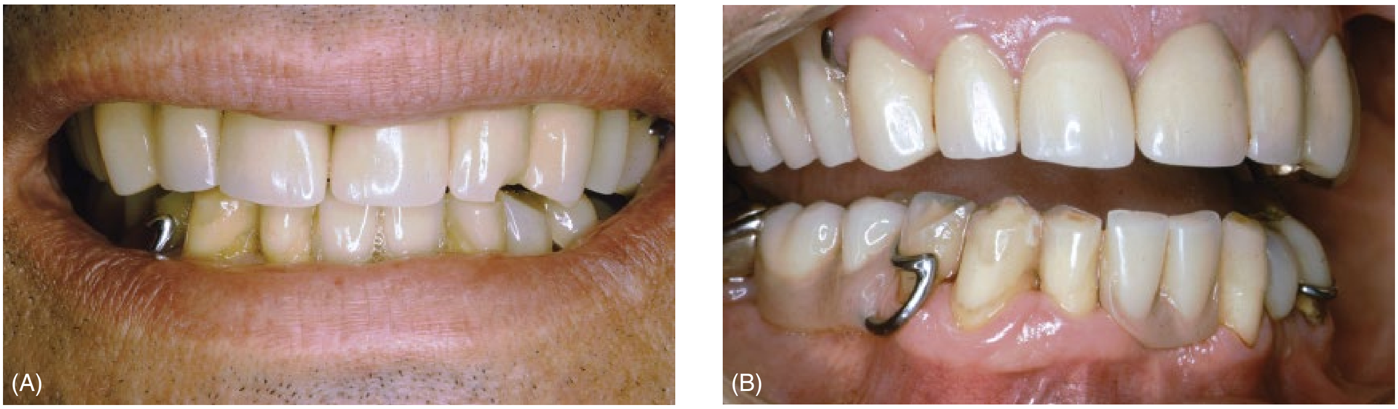

Figure 39.5 **(A, B)** A distally placed I-bar could have been used to prevent the metal from showing.

shown in Figure 39.5A and B. A distally placed I-bar could have been used, or another clasp designed to prevent the metal from showing.

Incorrect pontic height

A basic need in fixed or removable partial denture replacement is symmetrical pontic height. Failure to achieve this symmetry usually results in an unesthetic restoration. Defects of this kind are typically easier to treat if they involve only soft tissue; however, most are usually a combination of both hard- and soft-tissue malformations. The extent of reconstruction depends on the size of the defect and how much of the defect is visible; however, in unesthetic areas, reconstruction may be necessary both to facilitate speech and to prevent excessive salivary outflow.[4] The case in Figure 39.6A–I is an example.

Failure to alter adjacent or opposing teeth

It is important to study adjacent and opposing teeth before planning partial- or full-arch restorations. Cosmetic contouring for extruded or malformed teeth should be completed before fixed restorations are made. If there are esthetic deformities due to tooth position or wear, repositioning or recontouring should be considered. An example of failure to reshape adjacent teeth is seen in Clinical case 39.1 (Figure 39.7A–D).

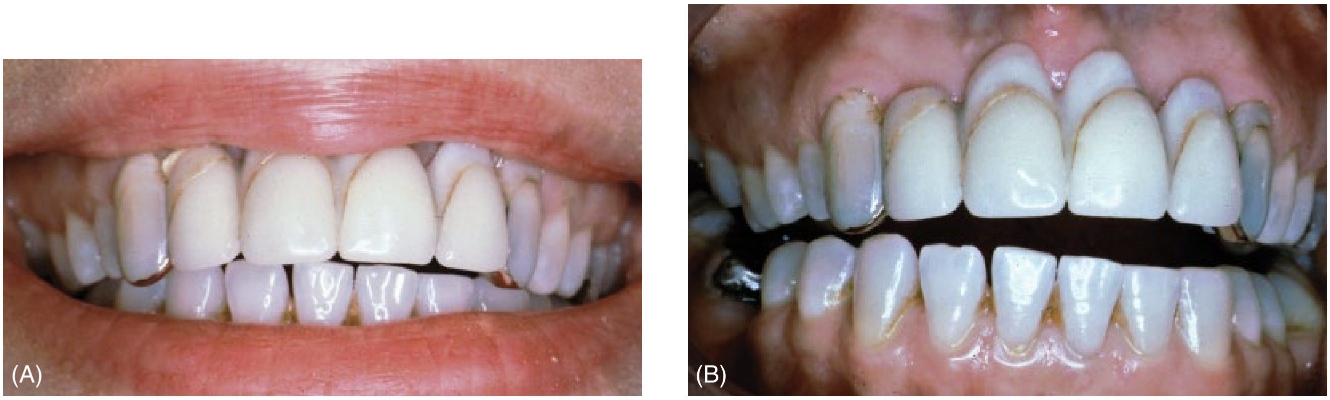

Figure 39.6 **(A, B)** This woman was very concerned about her smile, because she had to hide it for her job as a model.

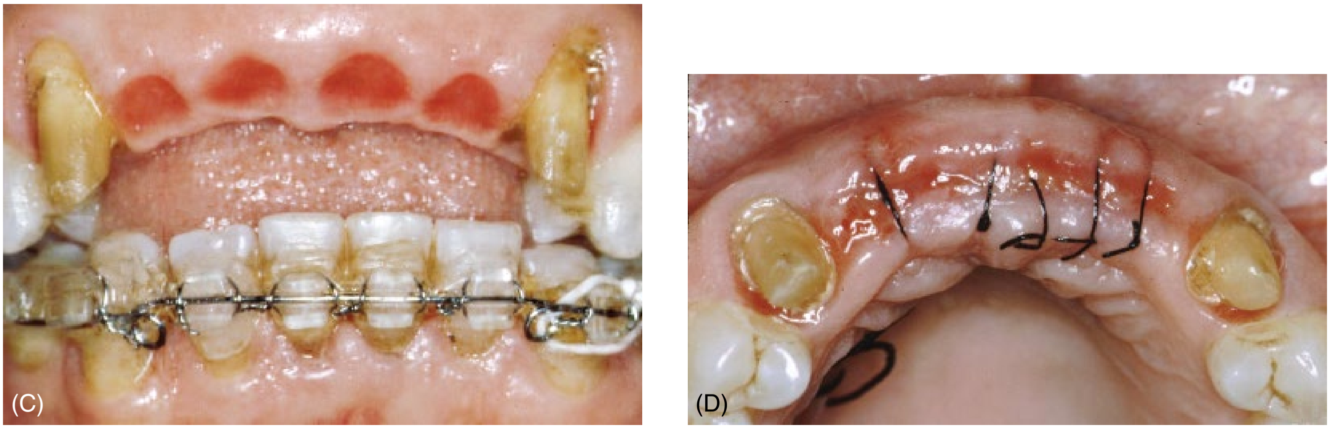

Figure 39.6 **(C, D)** Ridge augmentation was accomplished to improve the pontic area.

Figure 39.6 **(E)** At the try-in stage, although the gingival height was improved, the esthetic proportions needed improvement.

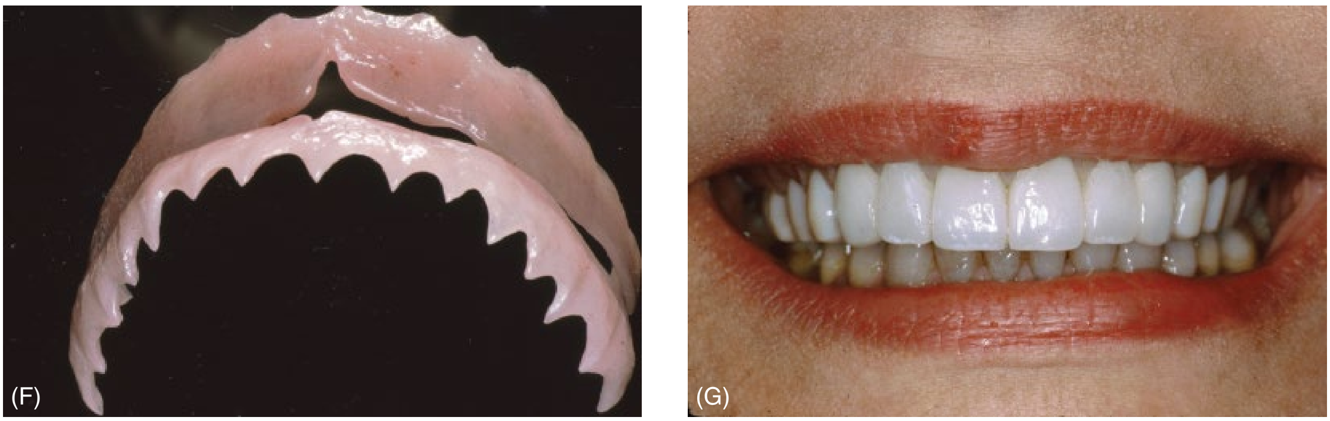

Figure 39.6 **(F, G)** A removable artificial tissue appliance was constructed that could be snapped into place by the patient.

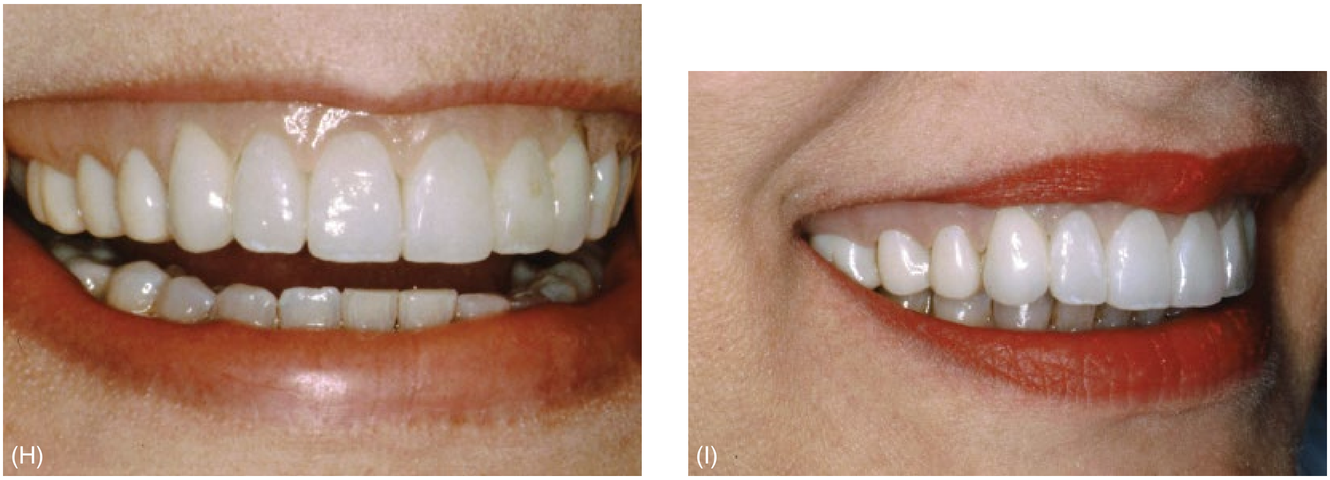

Figure 39.6 **(H, I)** A more esthetic proportion was created with the artificial tissue appliance, creating a normal crown-to-root ratio, as well as gingival papilla.

Clinical case 39.1: Failure to reshape adjacent teeth

Problem

A 24-year-old female presented with an unattractive porcelain-to-metal crown constructed in labioversion on the maxillary right central incisor (Figure 39.7A). This case is actually a space problem with crowded maxillary incisors. A previous dentist treated this problem by placing the right central in labioversion (Figure 39.7B). Instead of reproportioning the teeth, the dentist made the right central the same size as the left central, and since there was not enough space, the tooth was placed labially. This produced a most unattractive result that displeased the patient, and it contributed to eventual mesial caries on the adjacent central. Lack of embrasures prevented proper cleaning, and a periodontal condition developed. When the patient expressed dissatisfaction, she was told that this was the best that could be done.

Treatment

Teeth that are in labioversion usually reflect more light than others (Figure 39.7A), and unfortunately call attention to themselves. Treatment in this case consisted of cosmetically contouring the adjacent teeth and restoring the right central incisor to the correct position. The key to the success of this case is to correct the acrylic treatment crown (Figure 39.7D); therefore, the lateral and adjacent central incisors were reduced proportionally and recontoured to permit the treatment crown to be positioned correctly. This done, the final crown replaced the temporary crown (Figure 39.7C and D), and the mesial surface of the maxillary left central was treated for caries.

Result

It is possible that the previous dentist suggested orthodontic treatment that the patient refused. Nevertheless, this illustrates poor planning and ignorance of the value of recontouring.

The result shown in Figure 39.7D is a satisfactory treatment alternative to the problem of anterior crowding. It demonstrates a respect for proper crown contours, while emphasizing the importance of adequate gingival embrasures.

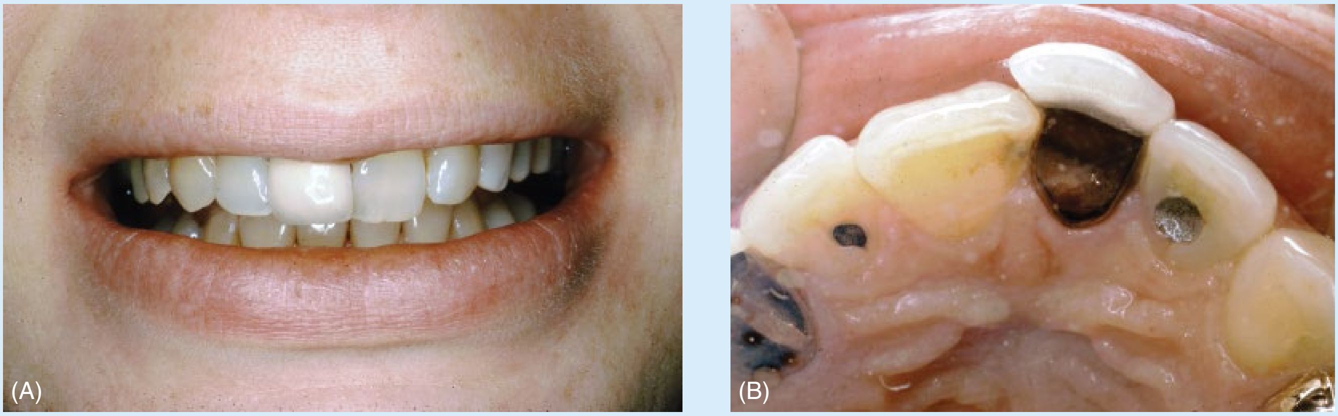

Figure 39.7 **(A, B)** The dentist who completed the restorative therapy for this patient did not suggest orthodontic treatment and failed to study and alter the adjacent teeth before completing a full crown on the maxillary right central incisor.

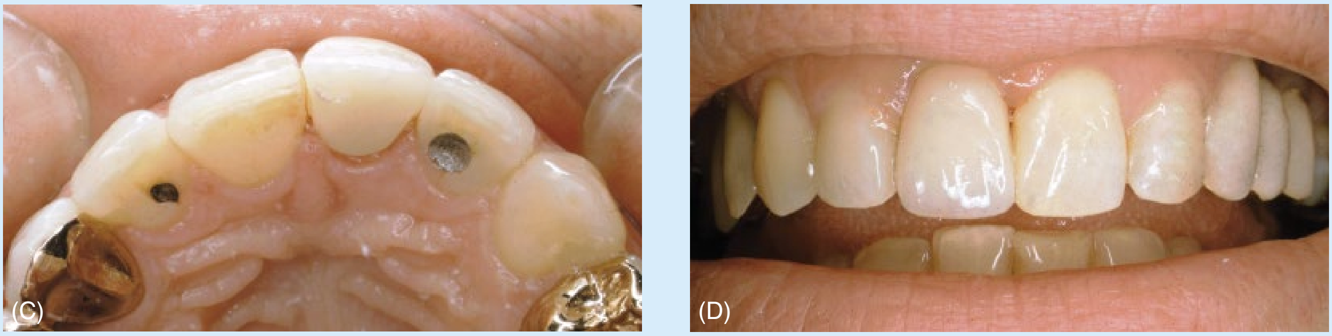

Figure 39.7 **(C, D)** Cosmetic contouring was first done to reproportion the maxillary anterior teeth before replacing the full ceramometal crown with an all-ceramic crown.

A compromised treatment plan

Patients sometimes consider their restorative treatment an esthetic failure, when it is actually the result of a compromised treatment plan. This usually happens when the patient is not fully aware of any treatment limitations. For example, under certain conditions there may not be enough room between abutment teeth to adequately carve and insert teeth of an appropriate size. If the dentist recognizes this problem initially, several alternatives may be possible, including:

- Repreparing the teeth and performing vital extirpation, if necessary, to allow more room.
- Carving overlapping into the restoration to allow for the proper number of teeth.
- Carving one less tooth, but making everything appear symmetrical.
- Contouring adjacent teeth to provide more space.

Regardless of the choice, you must make a compromise and inform the patient, who may view the result as a failure if not forewarned. Sometimes a compromise cannot be avoided in extremely difficult cases, and patients must realize their specific treatment limitations from the outset.

Because of time or financial limitations, patients may impose certain restrictions that make successful esthetic dentistry almost impossible. These limitations, the problems involved, and the reasons for reaching the decision should be documented. Often, all that is necessary is that the limiting conditions be stated in the chart, where the patient signs after approving the treatment plan and estimate.

In cases of financial limitations, oftentimes less expensive treatment may be associated not only with esthetic compromise, but also with longevity. For example, patients who request an inlay in lieu of a crown must understand that, although they may be saving money initially, there may be additional costs associated with their decision in the future. An analysis of indirect restorations performed by Lucarotti and Burke in 2009 demonstrated that crowns outperform other types of indirect restorations, specifically outperforming inlays and veneers. In their study, it was noted that metal crowns, for example, had a reintervention time in excess of 6 years, while inlays involving two or more surfaces displayed reintervention times of less than 3 years. It is of utmost importance that patients fully understand not only the immediate treatment recommendations, but also any potential longevity implications and/or limitations in the future. Patients must be fully informed of all possibilities in the decision-making process.[5]

When an esthetic compromise is necessary, a thorough explanation of the limitations, and the reasons for these limitations, is essential because the patient needs to understand the compromise before treatment begins. Comments on the discussion, and the patient's choice of treatment, should be recorded in the chart, and the patient should also receive a letter documenting this choice. This will serve as a reminder to the patient who may forget the limitations and may consider the treatment of the previous dentist poor. And finally, always have either your dental assistant or treatment coordinator present when these limitations are being discussed.

Choice of restoration

Another issue that is often considered an esthetic failure by the patient is failure of the dentist to discuss the life expectancy of certain restorations. For instance, when patients demand a tooth-colored filling material instead of amalgam or gold, composite resins can be used as a compromise in Class I or II restorations; however, the patient must be informed that these restorations have to be replaced every 3–5 years, lest they consider the restoration an esthetic failure when the time comes. Generally, composite resin failure will be functional rather than esthetic; however, many patients will object to staining that can occur in time with these restorations.

In a study conducted in public dental health clinics in northern Sweden in 2009, the longevity of replaced restorations was evaluated. According to this study, the median ages for replaced restorations of resin composite, glass ionomer cement, and amalgam were 6 years, 11 years, and 16 years respectively, with the most frequently replaced restorations being Class II, followed by Class I and Class IV for resin composite restorations.

This study demonstrates that resin composites, although oftentimes the material of choice for esthetic reasons, are most often replaced for reasons associated with failure. It is also interesting to note that restorations placed in patients with a high caries risk did not last as long as those placed in low-risk patients, regardless of the material used. Additionally, dentists with less experience were more prone to replace restorations than those who had been practicing longer, demonstrating a median longevity of 5 years for replaced restorations completed with more than 5 years professional experience, compared with 4 years for those restorations completed with less experience. Based on this study, it is evident that a portion of these failure statistics could be related to iatrogenic reasons as well.[6]

Many esthetic failures are not easy to remedy. Figure 39.8 shows a case of multiple esthetic problems that are difficult to treat: anterior space limitations and difference in pontic height due to gingival recession of the left central and lateral incisors. Because the patient has a low lip line, treatment can be improved by better proportioning of the anterior teeth. Nevertheless, this case requires complete understanding of patient objectives. A thorough review, including waxed study casts, is needed to find the best esthetic and functional solution.

Compromise when patient rejects repositioning treatment

When the dentist suggests that only repositioning will give an optimal result and the patient rejects such treatment, this must be stated and initialed by the patient in the record. The final esthetic result may not be as pleasing without repositioning. In such cases, the patient often forgets they rejected the dentist's recommended choice of treatment after treatment has been completed. The final restorative treatment plan should thus be considered a "compromised treatment" and the patient made fully aware that they chose the compromise at the outset. Most patients forget that a former dentist ever mentioned any alternatives or warnings of limitations of final esthetic results. An example of this is seen in Figure 39.9. The patient presented with the complaint of two central incisor crowns being too large. When questioned, she at first stated that her previous dentist never suggested orthodontic therapy; however, after extensive discussion, she finally admitted the possibility of this suggestion once being made.

Many esthetic failures may be traced to poor planning. All limiting factors, and the probability of success, must be known

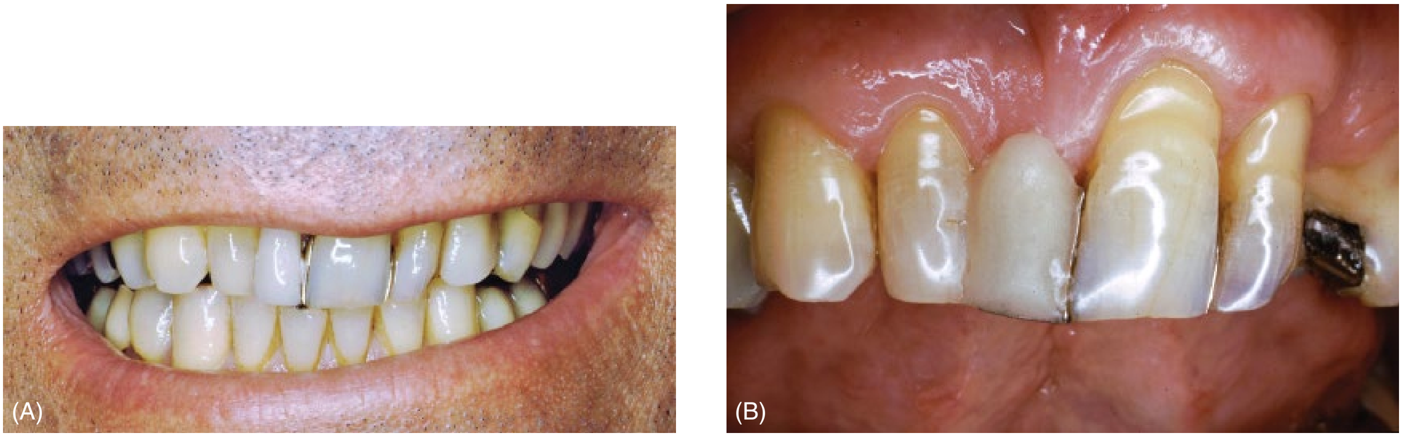

Figure 39.8 **(A, B)** This man presented with multiple esthetic problems that were difficult to treat: anterior space limitations and difference in pontic heights due to gingival recession of left lateral and central incisors. Here, orthodontics would have been the ideal treatment.

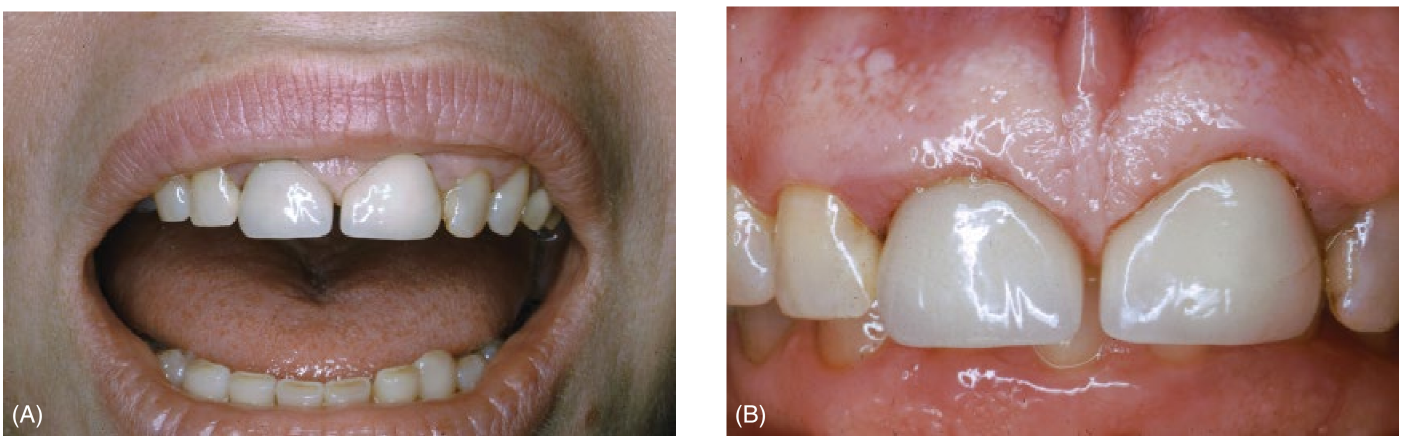

Figure 39.9 **(A, B)** Although this patient rejected orthodontic treatment, the dentist could have suggested including the adjacent laterals and cuspids, in addition to the centrals, to create a more esthetic result.

before treatment is begun. Checklists, written or mental, should always be used to help determine the various problems and considerations that any one case presents.

Eventual failure: restoration longevity

Few dental treatments last indefinitely—almost every dental treatment has a limited life span. In fact, in a 3-year study of 406 patients by Schwartz et al., it was found that the mean life span for all fixed restorations was 10.3 years.[7] However, more than 20% of the restorations surveyed failed in less than 3 years. A total of 3.3% of these failures were considered by the patient to be esthetic in nature, due either to an excess of visible gold or unesthetic acrylic facings. Almost all restorations eventually need to be replaced; repositioned teeth may continue to move, and even endodontically treated teeth can fracture or become problematic. *Use the word* permanent *with patients only to explain to them that nothing is permanent when it comes to discussing the longevity of any proposed restorations.*

Longevity of a restoration, or the reintervention time, is an important topic to be discussed with patients, especially when considering crowns. A study conducted over a number of years in England and Wales assessed varying crown survival rates. A total of 68% of metal crowns survived 10 years without reintervention, whereas 62% of metal–ceramic crowns survived the same amount of time. If these crowns were to be replaced, 36% of the reinterventions would involve recementing, 17% would involve replacement crowns, 13% would involve direct restorations, 12% would involve root canal treatment, and 19% would involve extraction. This study concludes that all-metal crowns are more successful than both metal–ceramic and all-ceramic crowns.[8]

Although all-metal crowns prove the most successful, they are unfortunately not the most esthetic. A study conducted by Galindo et al. examined the long-term survival of alumina crowns over a 10-year period and found that alumina single-unit crowns had comparable survival rates to those of metal–ceramic crowns. Although certain risk factors, such as bruxism and clenching, must be evaluated on an individual basis, this study supports the use of such restorations in clinical practice.[9]

Some differences in survival rates may be related to esthetic expectations from all-ceramic crowns, as many of these failures could be related to patient and/or clinician dissatisfaction with the appearance of the crown. Regardless, all crowns exhibit reasonable success over the course of 10 years, with the incidence of re-intervention decreasing as the age of the crown increases.[8]

When a patient is dissatisfied, it is usually because they did not understand the treatment limitations. When it becomes necessary to replace restorations, such patients may feel that their previous treatment was inferior, when the opposite may well be true. Thus, always inform the patient as to the life expectancy of all treatment. Generally, it is best to underplay the number of years that any treatment will last, since no one can accurately predict what will happen in any given oral environment.

It is most unfortunate to find patients who have had their entire mouth rebuilt with fixed arch splinting, with great investments of time and money, only to have the reconstruction fail sooner than they thought it should. Few patients ever think that treatment may fail, unless they are thoroughly indoctrinated by the dentist before treatment. Therefore, many of these patients tend to switch dentists, and to seek someone who will assure them that a longer restorative life expectancy can be obtained with different treatment.[10] Generally, the more complex the case, or the longer the span of fixed replacement, the less the life expectancy.[7] A patient who has all of their teeth and healthy supporting bone can likely keep them for life, but they will need restorations replaced from time to time. This is a much easier oral environment to maintain than the patient who is missing many teeth and has weak bone. Such patients must be clearly informed of the limitations of their restorations.

Problems that cause failure

Exposure of margins

Intact margins can be exposed by tissue recession. If the gingival portion of a ceramometal crown contains a small gold collar, eventual exposure of the gold may be considered an esthetic failure by the patient. The purpose of the gold collar should be explained at the onset of treatment, because if the patient objects then some other treatment may be necessary. The patient should also be informed of the potential for this compromised result. It is usually possible to hide the gold collar subgingivally; however, in time, tissue may recede, possibly due to brushing habits or pathological changes in the oral environment. The assumption must be made that the restoration was originally properly contoured at the gingival margin; otherwise, it would be considered an esthetic failure at the outset. If the patient has a high lip line that may potentially show the margin, this must be a consideration in the treatment plan (Figure 39.10A and B).

If a ceramometal crown is being contemplated, an alternate solution would be to use an all-porcelain butt joint, instead of a gold collar, on the labial surface. If the patient has a low lip line that will not expose the margin under normal conditions, you must demonstrate this fact to the patient during examination and treatment planning. Photographs of the patient's smile should be taken for records, with the objective to obtain the widest possible smile for treatment planning purposes. Even all-ceramic crowns can be a problem if the root beyond the ceramic margin is exposed through tissue recession. Again, depending on the lip line, it may not be visible; however, perfectionist patients may well complain, regardless of whether or not their smile line shows the problem area. Therefore, it is critical for you to know your patient and predict just how demanding they can potentially be, so that you can thoroughly discuss any potential problems before your treatment plan is finalized.

Periodontal disease

Poor tissue response to restorations is one of the leading causes of esthetic failure. The probability of success is based on basic functional prosthetic principles; however, the opposite is also true. Improper marginal fit, poor crown contour, and the level of gingival embrasure can all cause gingival hypertrophy and poor tissue response.

Figure 39.10 **(A)** This patient's high lip line must be taken into consideration when planning anterior restorations that may expose the margins of her crowns.

Figure 39.10 **(B)** Since the patient requested a complete treatment plan to improve her smile, crown lengthening plus a combination of porcelain veneers and all-ceramic crowns helped give her the smile she desired.

Figure 39.11 **(A)** This woman developed a habit of smiling with the right side of her lip to avoid showing the unesthetic gingival hypertrophy in the upper right posterior quadrant.

Figure 39.11 **(B)** A natural smile with the patient completely relaxed reveals the unattractive right side of the arch.

Gingival hypertrophy frequently results from improper crown contours and lack of marginal adaptation. The gingiva may grow over the crown, hiding part of the crown and producing an asymmetrical smile. In Figure 39.11A, the patient tries to keep the right side of her lip from rising any higher. This is caused by an asymmetrical hypertrophic reaction of the gingiva (Figure 39.11B). The importance of preventive maintenance for crowns or fixed partial dentures cannot be overstressed.

Patients with short clinical crowns, bulky gingival margins, or localized gingival inflammation due to poorly contoured restorations oftentimes require crown-lengthening procedures to improve appearance. In such cases, it is advantageous to begin with a wide zone of attached gingiva, such that lengthening can be successfully completed without apically positioning the gingival tissues, while still maintaining the zone of attached gingiva. It is most ideal to leave an attached gingival zone of at least 2 mm, although the clinician may have no choice but to apically position the gingival tissues in cases where this zone is found to be too narrow.[4]

In addition to excessive gingival contours, patients may alternatively present with gingival insufficiency. Localized recession might necessitate periodontal surgery instead of extending the margins of the crown, the result of which would be ultimately unesthetic. In cases of gingival insufficiency, try reshaping gingival contours, using either a scalpel or electrosurgery. Such techniques may include coronally and/or laterally repositioned flaps, or palatal autografts, otherwise known as free gingival grafts. The result of such procedures is alleviation of recession and, ultimately, esthetic success.

While soft-tissue defects pose potential problems, esthetic restorations will also fail if supporting bone continues to deteriorate in periodontally involved cases. Patients with periodontal disease should be warned about the possibility of replacement, and an estimate of life expectancy should be given. Prosthetic esthetic failures can occur through no fault of the restoration itself; and if this occurs, either crowns or veneers can be repaired or replaced (Figures 39.12A–E and 39.13A and B).

Recurrent caries

In the Schwartz et al. study,[7] caries accounted for the largest number of failures (36.8%) in fixed restorations, the average life span of which was 11.1 years. Secondary decay can be the result of a multitude of factors, and it is important for the clinician to

Figure 39.12 **(A)** This man's previously discolored teeth were masked with porcelain veneers.

Figure 39.12 **(B)** A decade later, veneer margins were exposed due to periodontal disease. Since finances were a concern, the patient elected to have the margins repaired, instead of replaced.

Figure 39.12 **(C)** Air abrasion, porcelain etch, phosphoric acid etch, silane and microfill composite resin (Renamel..Cosmedent) were used to carefully prepare the root surface, as well as the porcelain.

Figure 39.12 **(D)** A 30-blade carbide bur (ET6UF, Brasseler USA) was used to shape the composite resin for the repair.

Figure 39.12 **(E)** The bonded margins now blend in with the ceramic restorations effectively postponing need for replacement.

Figure 39.13 **(A)** This patient was not happy with her exposed margins, even though the crowns lasted for 7 years.

Figure 39.13 **(B)** The defective crowns were replaced with better-proportioned crowns, following minor orthodontics to reduce the amount of space between the centrals.

understand whether or not maintenance may be feasible from the onset of treatment (Figure 39.14). Based on such factors as the extent of caries, access to the lesion, restorative material used, and the possibility of adequate isolation, caries progression may be arrested through appropriate therapy. Removal of decay, in addition to such prophylactic measures as dietary counseling, fluoride rinse, and consistent reassessment, can better ensure a successful prognosis for the expected lifespan of the restoration.[4]

Figure 39.14 Neglect was the main reason why this patient allowed herself to develop recurrent caries under all her restorations.

Figure 39.15 **(A)** This patient presented with recurrent decay around her existing restorations.

Regardless of esthetic considerations, failure to control plaque formation, and subsequent caries, can doom the result from initiation of treatment (Figure 39.15A). In order to ensure success, preventive procedures should be routinely instituted before restorative treatment. For example, before fixed restorations are cemented, fluoride should be applied to the abutment teeth. It is especially helpful to continue this process yearly in patients with exposed margins. After restorative therapy, the clinician must continue to review oral disease control measures to avoid plaque formation and recurrent caries (Figure 39.15B). Studies have shown that secondary carious lesion progression is slow (usually 3–5 years), but those who receive acceptable dental prophylaxis tend to demonstrate a decreased rate of progression and, ultimately, an increased rate of success.[11]

It is also advised that a fluoride-containing cement must be considered when cementing restorations in patients prone to dental caries. This is the reason that resin-modified glass ionomer cements have been so popular and, indeed, useful for many years. In our extensive clinical experience with resin-modified glass ionomer cement, only a handful of crowns became

Figure 39.15 **(B)** Since the patient desired a better-looking smile, full-mouth restorations were fabricated, in addition to replacing the defective restorations.

debonded, and none had caries underneath. As a result, most of our restorations are cemented with resin-modified glass ionomer cement.

Material failure

Porcelain

With material such as porcelain, there is always the possibility of fracture at a later date (Figure 39.16A and B). Although a full porcelain crown is perhaps the most esthetic of fixed restorations, its lifespan is somewhat shorter. Burke and Lucarotti evaluated the long-term success of various kinds of crowns and determined that all-porcelain crowns had the shortest survival rate (48%), compared with 68% survival of full metal crowns over the course of 10 years.[8] Judicious selection of cases where occlusal demands are not too great is necessary.[12] Patients who have habits that put torque on the porcelain, such as bruxism and clenching, will probably have earlier fractures as a result of undue stress on the material. This is especially true if the occlusal

Figure 39.16 **(A)** This patient fractured her porcelain veneer while biting on a foreign object.

surface of the crown is gold and the labial surface is porcelain. Depending on the location of the porcelain-to-metal labial junction, definite problems can exist.

Although the patient's occlusion must be carefully considered when assessing the possibility of porcelain crowns, restorations such as porcelain veneers have been considered to mimic the mechanical behavior of the patient's existing occlusion, so that the biomechanics of the original tooth do not need to be altered. In a study assessing the outcome of porcelain laminate veneers, it was found that 53% of teeth with these restorations survived 10 years without reintervention; however, success rates of 64% and 91% have also been reported in various other studies, a discrepancy that may be attributed to varying operator and patient factors. In this particular study, factors such as patient gender and age were considered most important when assessing the clinical success of these restorations. Findings such as deteriorating periodontal status, reduced posterior support, and/or reduced salivary flow from the use of a variety of medications are all indications for the failure of these restorations due to increasing age[8] (Figure 39.17A–G).

All ceramic

All-ceramic materials with high translucency are preferred in the esthetic zone, and high-strength materials are preferred in the posterior; however, when addressing problems such as discoloration of anterior teeth, higher strength materials may be preferred to mask such problems.[13]

Ceramic crowns and fixed partial dentures also have variable survival rates, depending on the different all-ceramic systems to be used. In a 5-year clinical trial conducted by Larsson and Vult von Steyern, the clinical performances of Denzir® (DZ) and In-Ceram Zirconia® (InZ) two- to five-unit implant-supported all-ceramic restorations were evaluated and compared with one another. The restorations were cemented with zinc phosphate cement onto customized titanium abutments, and were evaluated after 1, 3, and 5 years. At the 5-year follow-up, it was determined that all restorations were in function with both all-ceramic systems; however, 9 of 13 DZ restorations and 2 of 12 InZ restorations exhibited superficial cohesive (or chip-off) fractures. Thus, the results of this study suggest that although the DZ system could not be recommended as a treatment regimen for

Figure 39.16 **(B)** The fractured area was restored using a microfill composite resin. (Durafill VS,Kulzer).

Figure 39.17 **(A)** This man fractured his maxillary ceramometal bridge and asked if it could be repaired instead of replaced.

Figure 39.17 **(B)** The remaining ceramometal pontic was prepared with a taper, so that a new pontic could be constructed.

Figure 39.17 **(C)** An impression was made of the pontic area and a model created, so that a new ceramometal pontic could be constructed.

Figure 39.17 **(D)** This demonstrates the underside of the ceramometal pontic.

this type of restoration, an all-ceramic implant-supported fixed dental prosthesis may be an acceptable treatment alternative.[14]

Fixed-prosthesis frameworks

When evaluating the framework and veneering ceramic possibilities for any case, it is important to note the combinations that produce the best results, so that the longevity of the restoration can be assessed and any errors in material choice avoided. Both ceramometal and all-ceramic fixed prosthetics are susceptible to abnormal or increased occlusal stress, resulting in fracture. Depending on the severity of the stress, it is sometimes possible to repair, instead of replace, the fixed prosthesis (Figure 39.18A–E).

In a clinical study conducted by Christensen and Ploeger, the performance differences between metal, zirconia, and alumina fixed partial denture frameworks were assessed, according to the type of ceramic veneer chosen for each—pressed or layered ceramics.[15] For this study, dentists prepared posterior three-unit fixed partial dentures with 10 different framework/ceramic veneer combinations. The results were as follows: metal frameworks with veneer ceramics had the best clinical performance, followed by zirconia frameworks with veneer ceramics. Of the veneer ceramics, CZR Press veneer ceramic proved to be the best option, mainly because of its leucite-containing and pressed properties. Of all framework possibilities, the alumina frameworks had the most clinically inferior performance.

Composite resin

As in the case of most restorative materials, functional failure usually means esthetic failure. In general, there are five leading causes of failure of in composite resins: (1) marginal leakage, (2) material that is too translucent, (3) esthetic problems in shading, (4) porosity or air pockets, and (5) fracture.

The biggest problem to date with composite resin restorations is marginal leakage, leading to recurrent caries. Depending on such factors as concentration, type, and flexibility of material used, shrinkage stress may preclude restoration contraction, and

Figure 39.17 **(E–G)** Slight grooves were roughened on the inside to aid in retention of the pontic and cemented into place.

eventually bacterial microleakage, staining, inflammation, and/or caries.[11] The most pronounced clinical symptom is generally discoloration of the resin restoration, with predominance in one particular area of stain, indicating possible caries (Figure 39.19A–C).

In a study by van Dijken and Lindberg, published in 2009, the durability of Class II restorations was assessed over the course of 5 years using two different materials: a low-shrinkage composite and an optimized particle resin composite. It was hypothesized that Class II preparations restored with low-shrinkage composite would be more durable than those restored with the optimized particle resin composite; however, it was concluded that no significant differences existed between the materials, although the low-shrinkage material did prove to last slightly longer, with an annual failure rate of 1.7% compared with 2.4% for optimized particle resin composite. It is notable, however, that shrinkage stress over the course of time manifested itself in the presence of secondary decay, found in both materials. Thus, it may be concluded that secondary decay, regardless of the product used, was the primary reason for failure due to marginal leakage.[11]

While only a small difference between materials was observed, the authors emphasized that the success of these restorations may have been somewhat dependent on technique as well. When conducting their study, an oblique layering technique was employed when possible, intended to reduce the shrinkage effect and configuration factor of the restorations. If such a technique is used, it may be concluded that operator ability, in addition to other factors dependent on the individual patient, may be more important variables to assess when considering durability due to shrinkage, than considerations based on the type of material used.[11]

Another type of esthetic failure with composite is seen in restorations that are too translucent, especially in Class IV restorations. Figure 39.20A and B shows a Class IV restoration that is functionally well done; however, because of a difference in light reflection and translucency between the enamel and the restorative material, the shade variance is apparent.

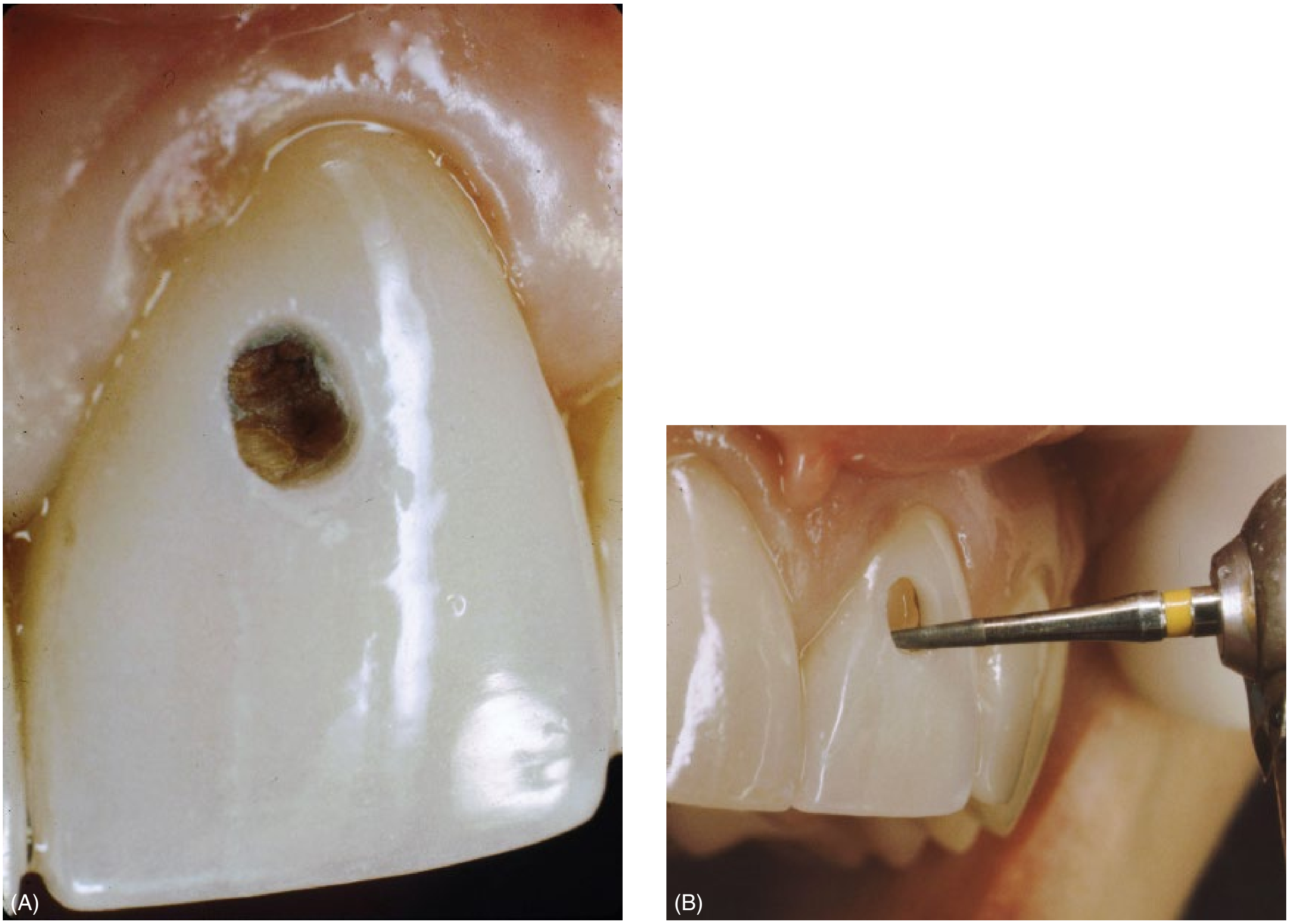

Figure 39.18 **(A, B)** This patient had a dark shadow in the middle of her porcelain veneer. The porcelain was carefully removed in that area to reveal the cause of the discoloration.

Some brands of resin composite are more translucent than others and lack sufficient filler material or opacity to block light. Therefore, use a material that has more opacity, or an opaquing tint, in the restoration for these cases.

A third type of esthetic problem is stain caused by microleakage that occurs at the junction between the restorative material and the margin of the tooth. It can usually be avoided by using a long bevel that involves overlapping of the margin. An example of this type of esthetic problem is seen in Figure 39.21A, which demonstrates a patient with cervical erosion and microleakage on a canine. Figure 39.21B shows the restoration being replaced by using a long bevel. The final result shows how extending the actual margin beyond the bevel allows for easy repair later, if needed (Figure 39.21C).

Another form of composite failure is due to the presence of air pockets or bubbles that attract food, stain, turn dark, and can be due to percolation. In most composites, the catalyst is built into the material, and when it is mixed, a certain amount of evaporation takes place. This sometimes causes the appearance of small air pockets, which could be avoided by careful operative techniques.

A fifth cause of composite resin failure is fracture. The first step in any composite fracture is discovering the reason for the fracture. If the fracture was caused by a patient biting down on a foreign object, such as a fork, then obviously the patient's abusive habit is the cause of fracture, and replacement of the restoration is in order; however, if the patient has another habit (such as clenching or grinding) that causes the fracture, then steps must be taken to control the habit and possibly to adjust the opposing occlusion, demonstrated in Figure 39.22A–F. Even if the patient states that they do not clench or grind their teeth, it has been our experience that, in times of stress, most people unconsciously do so.

Technical failures

Dentists usually assume that laboratory procedures are completed correctly; however, failure occasionally occurs through no fault of the dentist, who must still assume the responsibility and undertake the repair. Unfortunately, patients are not interested in what the laboratory did or did not do. If dentists want to maintain rapport with the public, and specifically with their patients, they must continue to assume such responsibility.

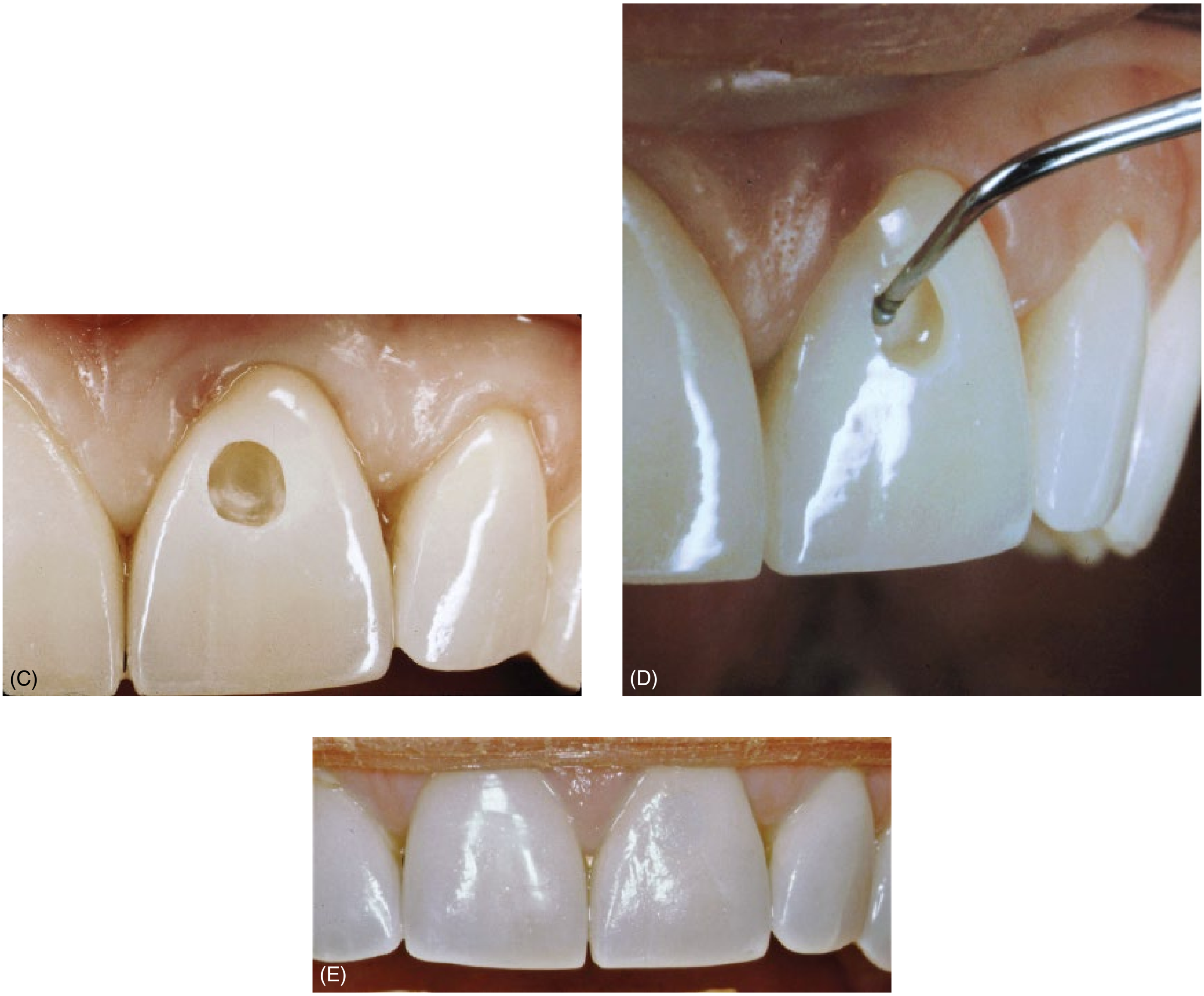

Figure 39.18 **(C–E)** After the final removal of the discolored area, the defect was repaired with microfill composite resin to match the polished surface of the porcelain.

For example, when comparing the probability of failure of three systems of machined zirconia ceramics (Lava, DC-Zirkon, and Cercon) with a zirconia-reinforced aluminum ceramic (In-Ceram Zirconia), it was found that the strength of DC-Zirkon, a postsintered machined yttria-stabilized zirconia (Y-TZP), was higher than that of the other two presintered machined Y-TZPs. The authors found that presintered machined ceramics seem as if they are the better material, because surface flaws that may be created during the milling process are often eliminated after sintering; however, surface grinding of these materials tends to compromise their strength—creating surface cracks, and increasing the size of any remaining defects. In comparison, sintering conducted after machining allows the repair of small cracks and defects, and can allow for maintenance of the inherent properties of the ceramic.[16]

Figure 39.23A illustrates that a void in the metal substructure of a ceramometal crown may result in serious internal stress, producing a fracture when the crown is cemented. The cement is normally displaced in the direction of the arrows; however, the cement applies great pressure on the opaque layer and usually results in the primary fracture area. If the restoration had been a veneer, there would be a chance that the entire facing would pop off without fracturing. A second reason for internal stress to cause fracture is if the dentist removes some of the intaglio metal surface of the crown in attempting to fit the restoration. The dentist should instead use a disclosing material (such as Occlude or other pressure indicator) to indicate areas that need to be adjusted, and adjust the tooth accordingly (instead of the metal) to ensure a proper fit without excessive thinning of the metal. An area of secondary stress may occur if the porcelain coverage is too thin near the bucco-occlusal line, and fracture may occur in this area as well. In any case, the metal should be of consistent thickness, and any voids must be properly repaired, or the crown remade. Stresses may still occur if the metal is thinned beyond its

Figure 39.19 **(A)** These composite resin restorations show early signs of microleakage. Note the darker brown stains around the margins.

Figure 39.19 **(B)** Although many times it is possible to use air-abrasion and re-seal the margins, if the stained areas are too deep, it is best to replace the entire composite restoration as above.

Figure 39.19 **(C)** The final restorations were restored with a microhybrid nano composite.

limits, even though no hole may be present. The clinician must check the thickness with a gauge, and if it is below the specifications it must be refabricated. The main problem is that dentists rarely have the opportunity to examine the metal, unless a metal try-in is arranged (Figure 39.23A).

If porcelain is too thin in the posterior region, owing to improper or inadequate tooth reduction, fracture can occur under occlusal loading. If using a porcelain occlusal surface, a minimum of 2 mm of clearance is required for a ceramometal posterior restoration, to avoid such failure as that shown in Figure 39.23B and C.

As zirconia-based crowns and fixed partial dentures gain popularity, it is important not only to understand clinical errors that might result in fracture, but also to recognize the inherent properties of zirconia that may differ due to the position of teeth, single versus multiple units, and opposing teeth. In a study conducted by Nathanson et al. at Boston University, failure statistics were obtained for zirconia-supported porcelain restorations. Over a period of 2–3 years, the combined total failure rate for porcelain and zirconia restorative systems was 2.8%. Of those failures, 2% were porcelain chips, 0.5% were porcelain fractures, and 0.2% were core fractures; 60% of the failed restorations required replacement.[17] In an additional study conducted by Blatz et al. the clinical survival of posterior zirconia crowns, in particular, was evaluated. When compared to traditional porcelain-fused-to-metal crowns, zirconia crowns did not differ statistically.[18]

According to these studies, zirconia has proven to be a reliable substructure for porcelain veneers; however, it is of utmost importance that clinical and laboratory work be completed satisfactorily to ensure their success. The clinician must ensure adequate reduction, and the lab must ensure that there is a minimal difference in the coefficient of thermal expansion between veneering porcelains and zirconia. Clinicians at the University of Pennsylvania found that, although the bond of veneering porcelain to a zirconia substructure is similar to that of a veneering porcelain bonded to a metal substructure, it is important to ensure that the coefficients of thermal expansion are similar to ensure success.[18]

Four of the leading principles for a successful zirconia restoration include: core integrity, appropriate preparation, marginal ridge support, and anatomical cores. Proper firing temperatures

Figure 39.20 **(A)** This patient presented with an incisal fracture on a lower right anterior tooth.

Figure 39.20 **(B)** Because of the difference in light reflection and translucency between the enamel and the restorative material, the difference in shade is apparent. A more opaque composite is recommended for a more esthetic result.

and appropriate fabrication of the zirconia core are essential to a strong restoration. The teeth to be restored must be adequately reduced to allow room for both the core and the veneering porcelain. There must also be enough core zirconia on the connectors to support occlusal forces, thereby preventing fracture (Figure 39.24A–C). In Figure 39.24D, note the bulk of zirconia also placed over the marginal ridge of the premolar, which would not have been possible without adequate reduction by the clinician. It is also important to remember that however thick the zirconia core may be, it must follow the anatomical contours of the tooth to be restored. Any unsupported zirconia will likely fracture.

If an all-ceramic crown is fractured from occlusal stress and the underlying core material is exposed, it is also important that the wear of enamel opposing a core material be evaluated. If the fracture occurs almost immediately, it is most likely an error of the dentist or laboratory; however, if the exposure of substructure occurs over a longer period of time, the patient's occlusion may have had a more significant impact on the prognosis of the restoration, and it becomes important to evaluate potential solutions for the patient.

In a study published by the *Journal of Dental Research*, the wear of enamel opposing yttrium-oxide-partially-stabilized zirconia core material was evaluated. Researchers found that if the restorations fractured, that zirconia polished with abrasive wheels and diamond polishing paste caused less wear on opposing enamel than did zirconia left as produced. Therefore, if the patient does not wish to completely replace the restoration, this procedure is a viable alternative to extend the lifetime of the restoration and the satisfaction of the patient.[17]

Oftentimes, potential porcelain fracture can be detected by applying occlusal pressure. Figure 39.25 shows a fractured porcelain-to-metal fixed partial denture being evaluated in the mouth. Occlusal pressure from a cotton roll was enough to fracture the inadequately prepared tooth. About 2 mm of clearance is necessary in posterior restorations, to allow space for metal, opaque, and porcelain.

Contaminants

Contaminants are residual essential oils from various solutions: blood, saliva, debris from preparations, and various chemical agents. Many prevent the proper setting of cements and bases; others, such as compounds containing eugenol, inhibit polymerization of restorative resins. Generally, chemical contaminants and tooth debris prevent intimate adaptation of restoratives to the cavity walls and permit unsightly stains to occur, such as those discussed in the event of gingival retraction fluid contamination, leading to the eventual discoloration of dentin and esthetic failure of an anterior crown.

Failure to follow manufacturer's instructions

Manufacturers' instructions include the correct proportions for mixing materials. Many materials have components that, in the wrong proportions, are noxious to vital pulp tissue. These ingredients, if not completely mixed, will not perform optimally, as the finished material will lack homogeneity. In addition, they will not be as strong or as resistant to abrasion, they may be more

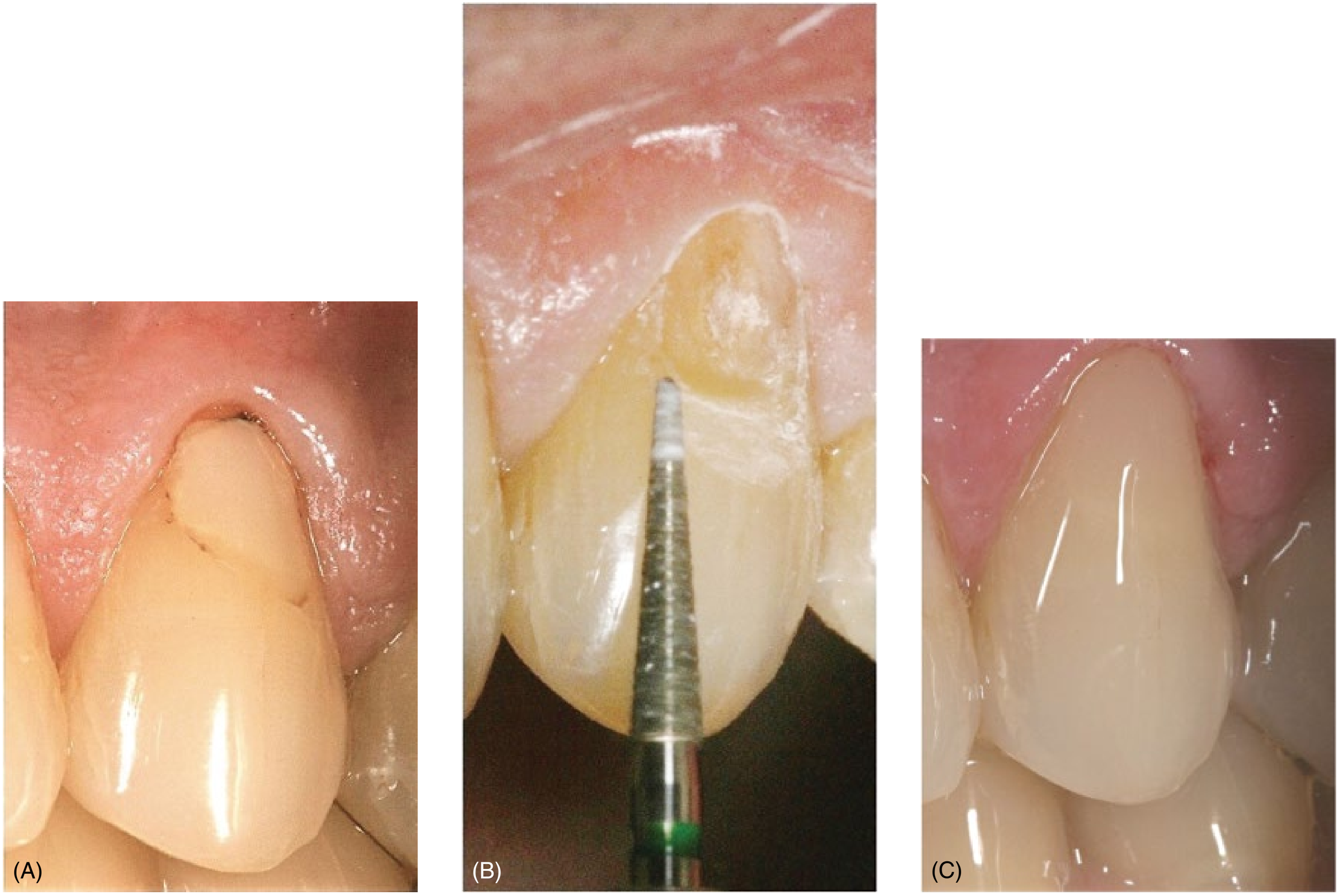

Figure 39.21 **(A)** This patient has microleakage and erosion around a class V on his maxillary left canine. **(B)** A long bevel is placed using the AC2 diamond, (Brasseler USA). **(C)** Final restoration shows the actual margin of the microfilled composite that extends beyond the bevel for ease and later repair, if needed (see Chapter 14 for technique).

Figure 39.22 **(A)** This patient fractured her left central incisor resin-bonded veneer due to her bruxism habit, uncontrolled during the day.

Figure 39.22 **(B)** To repair the Class IV fracture, a long bevel is first placed into the composite resin.

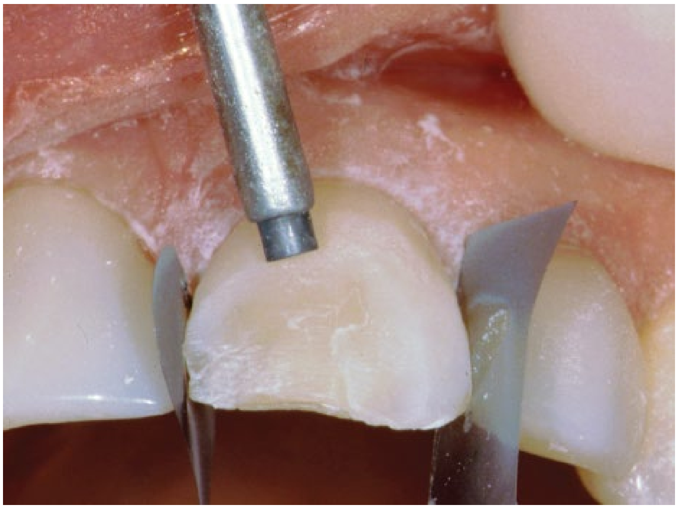

Figure 39.22 **(C)** Air abrasion is then used to prepare any remaining composite on the tooth surface, as well as the restoration itself, for maximum bonding with the new material.

Figure 39.22 **(D)** An eight-blade 9 mm carbide bur (ET 9, Brassler USA) is used to first contour the bonded restoration.

Figure 39.22 **(E)** It is also important to bevel the opposing incisors, to relieve any possible protrusive interference.

Figure 39.22 **(F)** The final result shows slight spacing, which protected these restorations for many years.

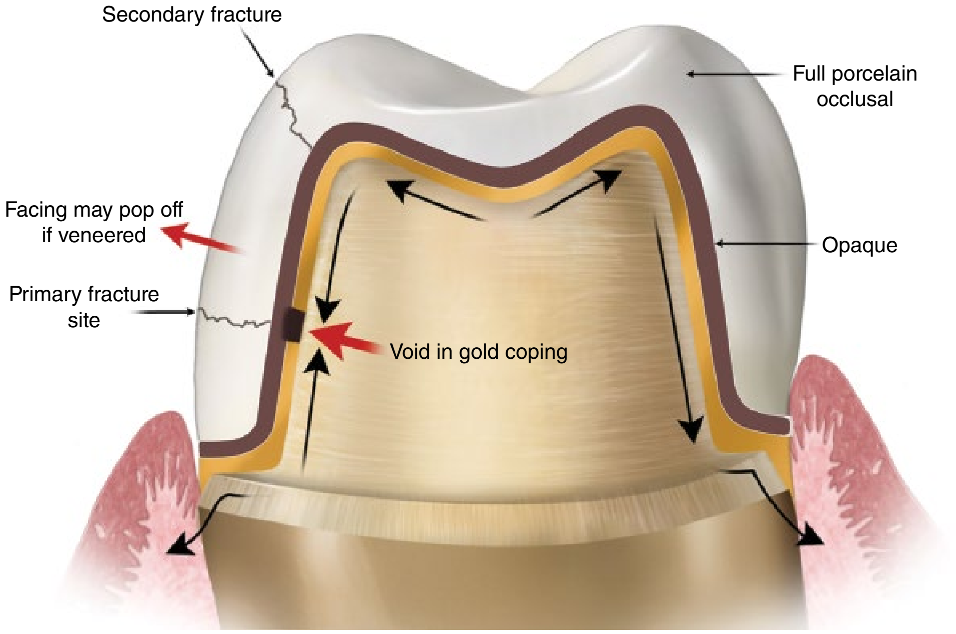

Figure 39.23 **(A)** One cause of possible esthetic failure in ceramometal restorations is fracture due to an insufficient metal coping.

Figure 39.23 **(B)** This ceramometal bridge fractured due to inadequate metal coping as illustrated in Figure 39.23A.

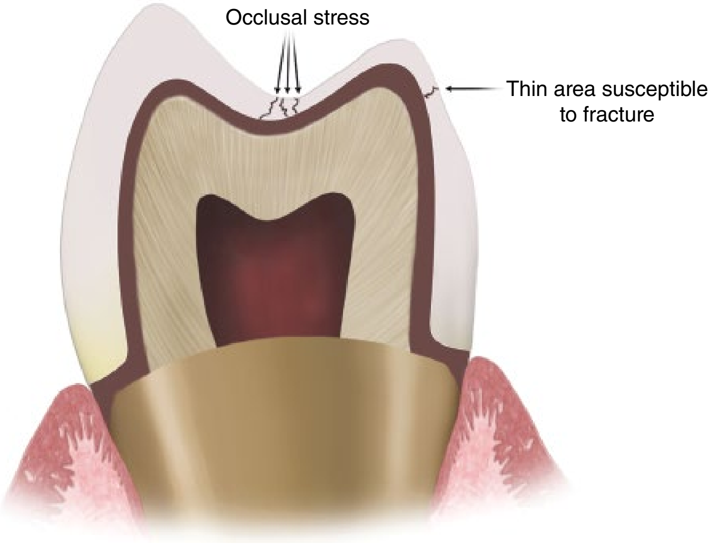

Figure 39.23 **(C)** A major cause of ceramometal restorations failure is inadequate thickness in the central fossa of posterior teeth. Although the clearance may be 2 mm in the preparation, if deep occlusal anatomy exists, then there might not be sufficient thickness of porcelain in this area to resist fracture.

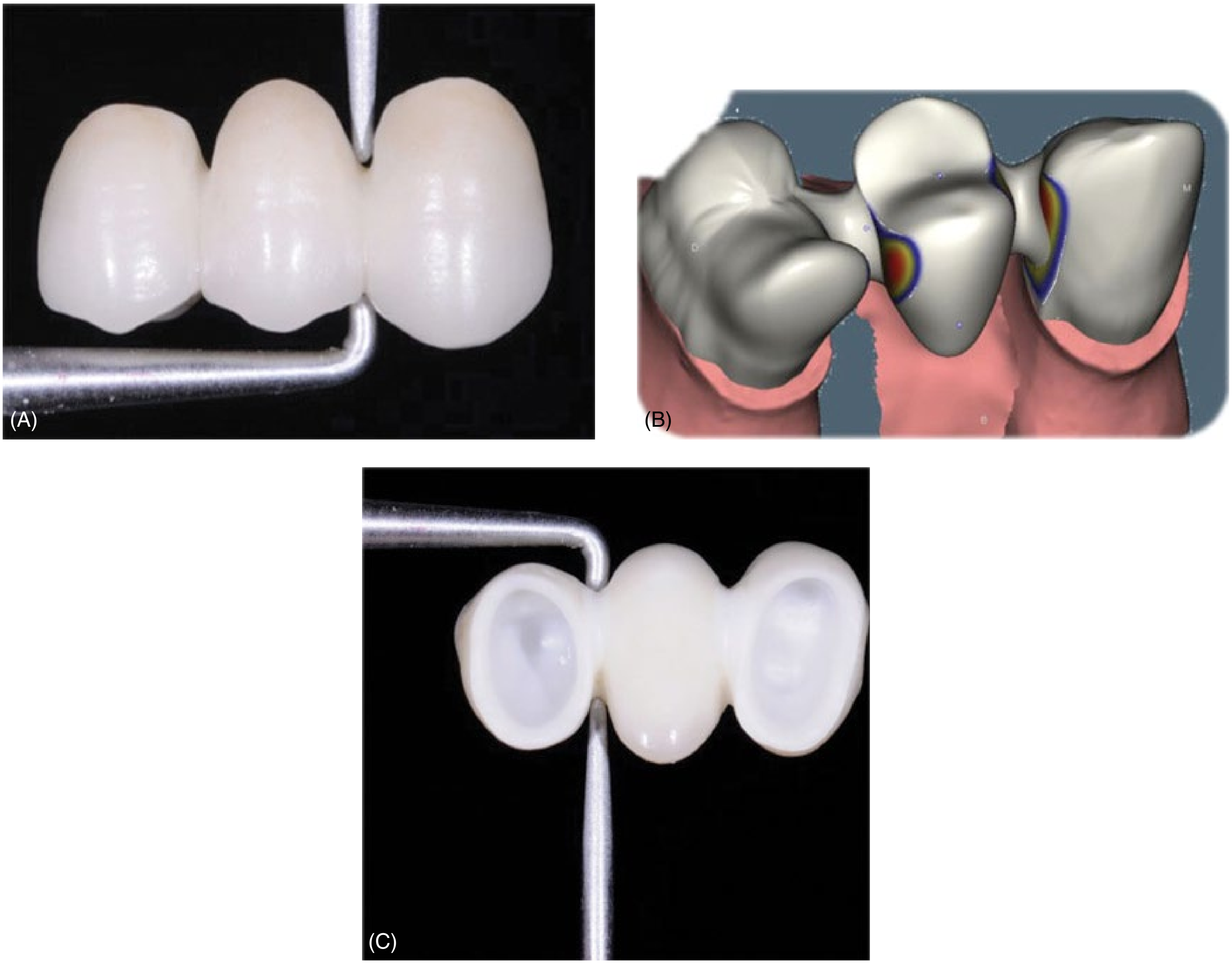

Figure 39.24 **(A–C)** There must be enough thickness of core zirconia on the connectors to support occlusal forces, in order to prevent fracture.

Figure 39.24 **(D)** Note the bulk of zirconia placed over the marginal ridge of the premolar, which would not have been possible without adequate reduction by the clinician.

Figure 39.25 Insufficient core support in ceramometal crown fractures at try-in appointment.

soluble in oral fluids, and they may not hold their shape as well as properly mixed materials.

In summary, there are legitimate problems that cause immediate or eventual failure of an esthetic restoration. In most cases, the cause is not a failure of the operator to perform acceptable clinical dentistry, but rather a lack of communication between dentist and patient about the patient's expectations and the achievement of such. Therefore, the treatment planning process and discussion is of utmost importance.

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PART 8
CHAIRSIDE PROCEDURES

Chapter 40 Tooth Preparation in Esthetic Dentistry

Ronald E. Goldstein, DDS, Ernesto A. Lee, DMD, and Wendy A. Clark, DDS, MS

Chapter Outline

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There are many important factors that need to be considered before attempting to prepare a tooth for crowning. Failure to evaluate these factors and plan accordingly can lead to both esthetic and functional failure. Thus, incorporating tooth preparation considerations during the diagnostic phase can also help determine not only the type of crown to be chosen but also the amount of difficulty that may ensue. In tooth preparation, function as well as esthetics must be carefully evaluated. Comprehensive planning must include the following four guidelines:

1. Ascertain the type and amount of reduction necessary to insure adequate thickness of the restorative material.
2. Study pulp architecture from radiographs before preparation is initiated and relate this to the type of preparation selected and its compatibility with the size and position of the tooth pulp in question.
3. Establish the character and thickness of the free gingival margin.
4. Select the proper type of margin for the chosen restoration.

Each of these considerations will be discussed at greater length in the chapter. It is vital that each be considered from the very outset of treatment planning and tooth preparation.

Tooth preparation for all-ceramic crowns

With the demand for improved esthetics and function, significant progress has been made in the field of dental ceramics. A number of ceramic choices are now available to dental practitioners, and with these come certain considerations in preparation technique.

Ronald E. Goldstein's Esthetics in Dentistry, Third Edition. Edited by Ronald E. Goldstein, Stephen J. Chu, Ernesto A. Lee, and Christian F.J. Stappert.

The first three types of restorations that are discussed (feldspathic, leucite-reinforced, and lithium disilicate ceramics) are collectively referred to as glass-ceramics. They have the same preparation requirements of at least 1.5–2.0 mm of incisal/occlusal clearance, 1.0–1.5 mm of axial reduction, and 1.0 mm marginal width. A wide chamfer margin may be used, but shoulder margin is preferred. An important guideline for the preparation of all-ceramic crowns is that the line angles be rounded. This refers to internal axial gingival walls as well as occlusal or incisal line angles. This diminishes the amount of point stresses the crowns will be subjected to during function, decreasing the risk of fracture.

The first all-ceramic crowns were made of feldspathic porcelain. This material choice is still available, and is often utilized as a veneering ceramic for ceramometal crowns or for pressable veneers. Owing to its lack of strength, its current application for full-coverage all-ceramic crowns is limited to milled restorations (VITABLOCS Mark II, Vita) in low stress areas and anterior teeth.

Adhering to preparation requirements is always important, but is especially critical with milled feldspathic restorations for two significant reasons. First, if these thickness requirements are violated or sharp angles are present in the preparation, there is a higher risk of fracture than other all-ceramic restorations. With this in mind, case selection is important for success with feldspathic materials. They should be limited to situations subject to less force, including anterior teeth and patients with no parafunctional habits. Second, as these are milled restorations, it must be considered that a computer will be reading the preparation. As such, a smoothly prepared margin becomes even more critical than with traditional restorations. Additionally, special consideration must be paid to the relationship of the axial walls to one another. Undercuts may present a challenge for the scanner and axial walls that are nearly parallel (8° or less of total occlusal convergence) may result in a more significant marginal opening.[1] Therefore, a slightly greater taper, or total occlusal convergence, may actually improve the marginal fit of crowns fabricated with computer-aided design/manufacturing (CAD/CAM) technology. Feldspathic restorations should always be bonded with a resin cement. Bonding imparts more strength to the restoration versus conventional cementation techniques. This additional chemical retention may also be beneficial for preparations that lack mechanical retention.

In the 1960s, leucite was added to porcelain frits for ceramometal crowns to improve compatibility between the materials. This change also improved the flexural and compressive strength of the ceramic. Leucite-reinforced ceramic is now utilized in pressable and milled all-ceramic crowns (IPS Empress and IPS ProCAD, Ivoclar Vivadent). With its increased strength (compared with feldspathic porcelain), this material can be used for single crowns in the premolar and molar areas in select cases.

Lithium disilicate ceramics are also available for pressed and milled all-ceramic restorations (IPS e.max Press and IPS e.max CAD, Ivoclar Vivadent). Their compressive and tensile strengths are significantly higher than leucite-reinforced ceramic. As such, this material may be used for posterior crowns as well as anterior bridges. These materials may be bonded with a resin cement or conventionally cemented with resin-reinforced glass ionomer cement.[2]

In addition to the glass-ceramics, another group of all-ceramic crowns is available. This group has an opaque core material of either alumina (NobelProcera, Nobel Biocare) or zirconia (LAVA, 3 M Espe). This type of restoration requires about 0.5 mm more reduction than the glass-ceramics. This allows for a core material of about 0.5 mm and enough space to esthetically block out the opacity of the core. Without adequate reduction, the opaque core will show through the veneering porcelain, resulting in an esthetic failure. Adequate reduction also decreases the risk of fracture of the veneering ceramic due to inadequate thickness.

Thickness or translucency in the gingival area

Evaluate the thickness of the free marginal gingiva. Usually, the gingival crevice is adequate to hide a gold bevel in ceramometal crowns. Some patients have a tendency toward a thin, translucent gingiva, which might reveal the metal collar as a blue line. This happens mostly in young people, but it can occur at any age. It is also not uncommon to see it in a tooth that is slightly labioverted. If the root shows through the labial tissue with very little matrix of bone covering it, there may be thin translucent tissue. In this case, it is best to use a full shoulder rather than a beveled shoulder margin. Either an all-ceramic crown or ceramometal with a butt joint can be used.

Soft-tissue health

To create an esthetically successful restoration, the gingival areas must be healthy and architecturally sound before restorative treatment is instituted. Oral disease control sessions with the hygienist need to be completed with sufficient time, so the gingiva will be in optimal health. This may necessitate conservative laser or other periodontal surgery to gain a functionally sound and cosmetically acceptable gingival relationship.

In cases where two teeth are so close together that it results in a lack of interdental space, a compromise procedure may be necessary. As described by Berdon, odontoplasty may be indicated when teeth, particularly anteriors, have become rotated to the extent of actually approximating. This causes a lack of space for a normal bony septum height and can result in a periodontal pocket. This area is extremely difficult to keep clean because of the positions of teeth and the gingival papillae. Ideally, the teeth should be orthodontically repositioned to allow for a proper amount of space between each root; however, this is not always practical. Because adequate space must be provided for contact between the buccal and lingual papillae, careful removal of a portion of the tooth, crown, or root may provide the necessary space (Figure 40.1A–I).[3]

If gingival recession results in exposed cementum, consideration must be made after surveying radiographs to determine the gingival depth that can be achieved in the preparation. It may be impossible to axially reduce the tooth to the ideal dimensions for ceramometal restorations. If so, several alternative approaches are available:

Figure 40.1 **(A–C)** This patient wanted immediate correction of his discolored maxillary right lateral crown and labially placed right cuspid without orthodontics.

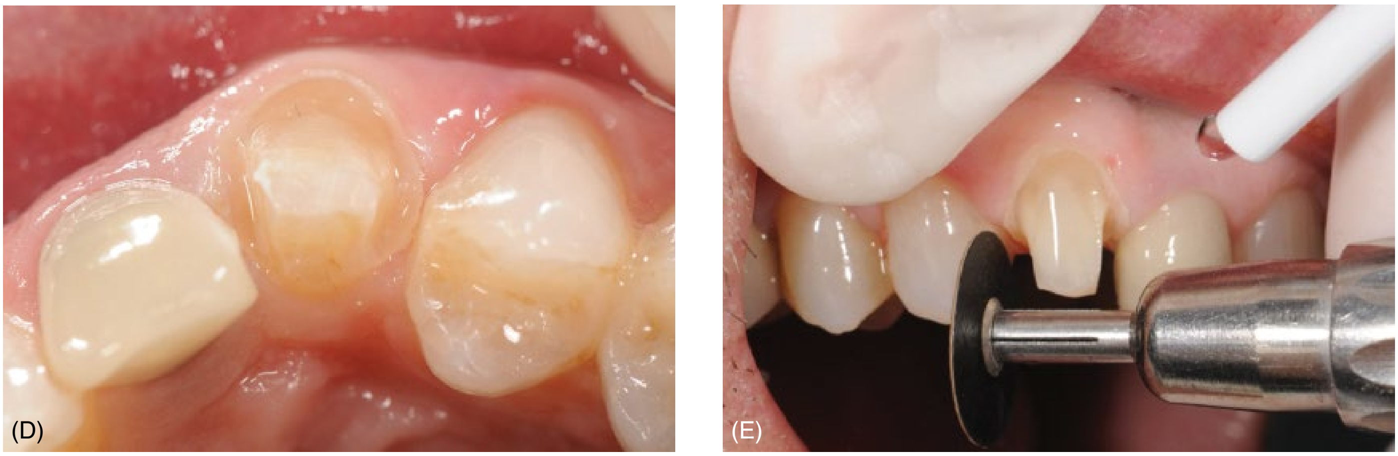


Figure 40.1 **(D, E)** Basic tooth preparation shows lack of space between the cuspid and the adjacent lateral incisor and first bicuspid. Therefore, the first bicuspid was slightly reduced in addition to the distal of the lateral incisor.

1. Use another type of restoration. For instance, an all-zirconia crown requires much less tooth reduction. A minimum of 0.5 mm is necessary (although 1.0 mm is ideal) for sufficient thickness of the crown, according to manufacturer's recommendations (Bruxzir, Glidewell). The all-zirconia crown can also be finished to a very fine cervical margin.
2. If there is an extremely low lip line, showing a metal gingival collar may be acceptable. Using a ceramometal crown, the cosmetic appearance of such a metal collar may be improved by air brushing the exposed metal surface. Describe these alternatives and the reasons for their use to the patient. Explain how much metal will show and how often the metal

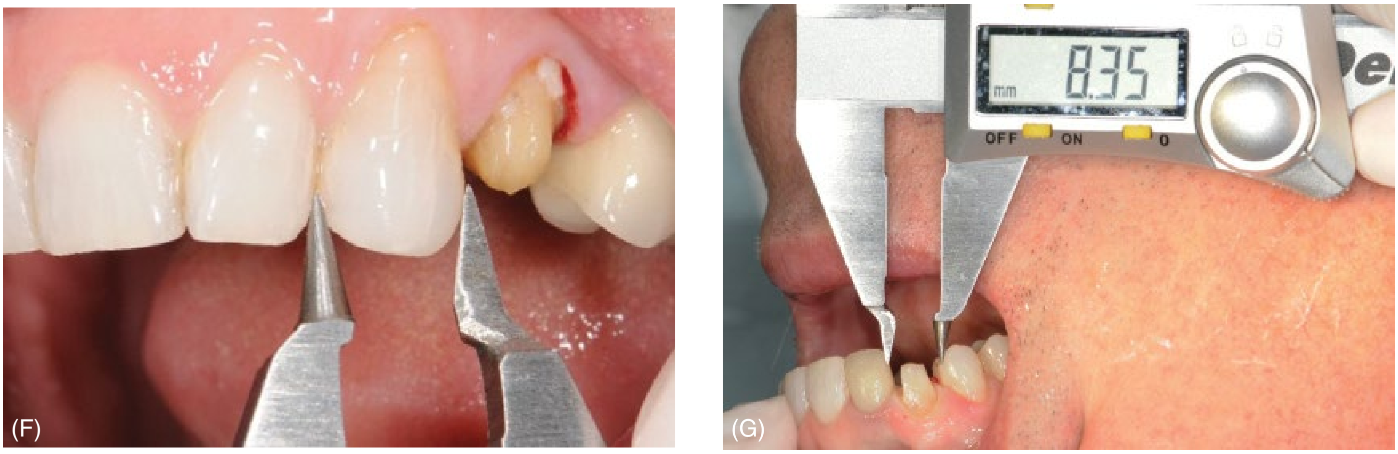


Figure 40.1 **(F, G)** The width measurement of the left cuspid (8.35 mm) now matched the space for the new right cuspid crown.

Figure 40.1 **(H)** A vacuum-formed matrix of the wax-up is inserted over the prepared tooth showing labial space for the final crown.

Figure 40.1 **(I, J)** Although not perfect, the compromised labial reduction pleased the patient. Note, further labial reduction may have led to pulpal injury.

collar will be seen when the patient speaks or laughs (Figure 40.2A and B).

3. If a high lip line is present, a porcelain butt joint should be used with a ceramometal crown. When tissue shrinkage exposes cementum or if there has been an excessive amount of eruption, it may not be necessary to reproduce the incisal length. In fact, more often the teeth should be shortened rather than lengthened to coincide with the normal lip line and obtain a symmetrically balanced restoration.

Figure 40.2 **(A)** As a result of the tissue recession on the labial aspect of the lateral incisors, subgingival preparation would result in distorted tooth morphology and margins on cementum. To improve retention and decrease the risk of pulpal trauma, a supragingival metal margin was selected by the practitioner and patient.

Figure 40.2 **(B)** Even with the patient's highest smile line, the supragingival metal collar is never visible.

Positioning the gingival margin for esthetics

When the word esthetics is mentioned, one might think that margins are automatically placed subgingivally. Not so. If the patient has a low lip line, there is little reason for this. A long metal collar, or a supragingival margin, can certainly be classified as esthetic as long as the patient understands that this area will not be seen. Pritchard warns of the possibility of gingival irritation due to prosthetic material in the gingival crevices[4] and points out the Silness study where the most favorable periodontal condition around bridge abutment teeth was when margins of castings were more than 2.0 mm from the gingiva.[5] This would seem to agree with a study on the effect of marginal placement on the gingiva by Larato,[6] who examined 546 three-quarter and full cast gold crowns of 268 patients. He found that 84% had inflammation when the gingival margin was below the tissue. When the margin was even with the tissue, only 22% were inflamed. When the margin was above the tissue, only 16% exhibited inflammation. Nevertheless, most esthetic restorations do need subgingival placement. There is no such thing as one ideal location for this margin, as it varies with the case and type of problem presented. (It also varies according to which authority you consult.)

Owing to esthetics, root sensitivity or caries, adequate crown length for retention, or an existing restoration, margins may have to extend well into the gingival sulcus. Burch states that the margin should not be placed closer than approximately 1.5 mm to any part of the alveolar housing of the tooth (Figure 40.3).[7] According to Gargiulo et al., this distance is necessary to allow for a "biologic width" of connective tissue and epithelial attachments of the gingival unit to the tooth.[8] Without this distance, bone in the immediate area might be resorbed. Burch suggests that when the subgingival margin is too near the alveolar housing, a preliminary "crown-lengthening" periodontal surgical procedure should be performed, and adequate healing time should be allowed before final preparation and impression.[7] Though a subgingival margin placement frequently resulted in recession and histologic evidence of inflammation, Tarnow et al. found that the inflammation subsided and the gingival fibers began remodeling within 2 weeks of temporization. This study concluded that, though there was no preoperative way to predict the amount of recession that would occur, the gingival housing stabilized relatively quickly. It is important to note that the preparations in this study did not violate the biologic width.[9]

Although the gingival crest varies in size, Tylman states that the average depth in individuals older than 20 years of age is 0.8 mm.[10] He also warns that, in the case of persons 20 years old

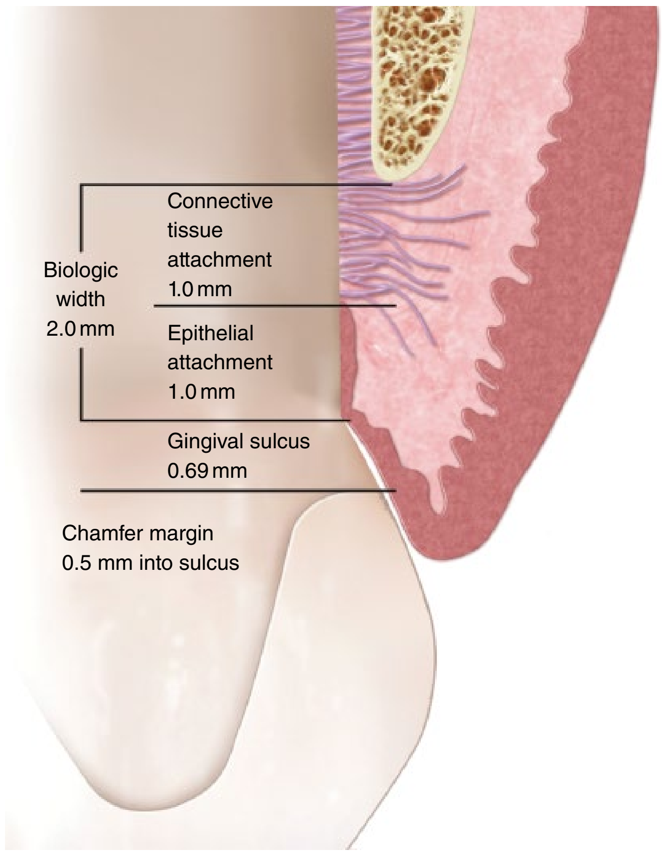


Figure 40.3 When preparing a crown margin subgingivally, it is important to be aware of tooth's sulcular depth and to avoid invasion of the biologic width. This figure illustrates the structures to consider in this histologic dimension.

or younger, the epithelial attachment may still be attached to the enamel, making the gingival crevice practically zero depth. Therefore, in these cases, it would be unwise to place the gingival margin entirely beneath the crest of healthy gingiva.[10,11]

Brecker feels that no matter how deep the gingival sulcus, the margin should extend slightly into that crevice.[12] Almost everyone agrees with Schweitzer, who states that the margin must not impinge upon the epithelial attachment.[13] Perhaps the easiest rule to follow is one stated by Johnston et al.[14] and Grieder and Cinotti,[15] who feel that the margin belongs midway between the coronal and apical borders of the sulcus. Beaudreau agrees that margins should be placed below the gingival crest to prevent sensitivity and recurrent decay and to provide subgingival support for the gingival unit.[16]

Esthetically, the reasonable conclusion is to extend the gingival margin far enough into the sulcus for a natural appearance and yet be able to determine marginal adaptation. Clinically, this means approximately halfway into a deep sulcus and three-quarters of the depth in a shallow sulcus. For example, in a patient with a healthy 2.0 mm sulcus, the gingival margin should extend 1.0 mm into the sulcus. In a 1.0 mm sulcus, the margin should be terminated at 0.8 mm or slightly above the base of the sulcus to provide for an esthetic result.

There have been numerous studies relating the marginal fit to gingival inflammation.[11,17–20] If the fit is not exacting, in relation to both tooth and gingiva, inflammation will occur. Therefore, the importance of the accuracy in this fit cannot be overstressed. For this reason, digital radiographs are taken at the try-in stage of every fixed restoration inserted in the mouth (in addition to careful clinical examination). The final lasting esthetic success depends on this procedure, regardless of what margin is chosen.

In summary, the consensus among leading authors and experts is that biologic width is approximately 2.0 mm. Therefore, subgingival margins should never invade this histologic dimension. As such, placing subgingival half the depth of the gingival sulcus appears to be the optimal for postrestorative gingival health.

Tooth reduction for the all-ceramic crown

An ideal tooth preparation for the all-ceramic crown is a balanced uniform reduction of tooth structure. Although this works perfectly in dentoform teeth, all too often perfect symmetry will be the exception rather than the norm. Fortunately, extra-strength core materials help to make it possible for an asymmetric preparation to function. Proper tooth preparation for the anterior porcelain crown is illustrated in Figure 40.4. Note especially the uniform reduction of tooth structure to provide an even thickness of porcelain. Also, observe the use of the shoulder margin labially and lingually.

Because porcelain is strong in compression but quite weak in terms of tensile strength, the full shoulder margin is always used in anterior restorations. Its width can vary from 0.5 to 1.0 mm and at times even to 1.5 mm. The shoulder is extended halfway or 0.5 mm (whichever is greater) into the gingival crevice at a slight apical angle (5°) from the long axis of the tooth. The incisal clearance should be 1.5–2.0 mm, with the flat surface at right angles to the surface forces of the occluding teeth.[14] The labial, mesial, distal, and lingual reduction should flow evenly and uniformly about the tooth to a depth of approximately 1 mm. Any sharp corners or angles must be rounded. The gingival margin should follow the cementoenamel line smoothly around the tooth.[21]

Shoulderless full porcelain crown

Many dentists still favor the use of the full porcelain crown without a shoulder.[22–25] A heavy chamfer margin is used instead beneath the gingival crevice labially and proximally, and it does not extend beneath the height of contour of the cingulum.[14] The main advantage is minimal reduction of tooth structure in the cervical areas. This type of preparation lends itself to the lithium disilicate or all-zirconia crown. Indications are extremely large pulp canals, bulbous teeth, exposed cementum, peg-shaped teeth, abnormally spaced or overlapped, small, thin, or delicate teeth, or teeth of teenagers or young adults.[23] In preparing endodontically treated teeth, the goal is to maintain as much natural tooth structure as possible, so using the chamfer or feather-type margin would be an important advantage. Therefore, preparing for an all-zirconia or ceramometal crown might be the best option.

Esthetic depth determination

A useful method of establishing an esthetic depth determination is based on the scribing technique advocated by Stein.[26] Initial cuts are placed using a measured 1.0 or 1.5 mm rounded diamond stone AC Diamond Series (Brasseler USA) to ensure uniform depth (Figure 40.5). A trench is cut completely around the gingiva on both labial and lingual surfaces (Figure 40.6A). Next, an incisal trench is cut in the middle of the labial and lingual surfaces with the same diamond (Figure 40.6B). Enamel reduction is then completed with a tapered cylindrical diamond stone (Figure 40.6C and D). The cylindrical stone is not used for the initial depth determination due to the difficulty that would be encountered maintaining the same depth in all areas of the preparation.

Step-by-step technique for the all-ceramic crown

1. **Esthetic depth cut** A key to the technique is the measured reduction of the horizontal and vertical aspects to a predictable depth. This is accomplished in two steps:
   (i) *Horizontal depth cut* Using a premeasured 1.0–1.5 mm round or AC3 or AC4 (Brasseler USA) diamond (Figure 40.6A), a trench is cut to the full depth of the diamond at the gingival level completely around both the labial and lingual surfaces for anterior teeth and the buccal/lingual for posterior teeth. To avoid tissue laceration, *take care to not extend into the gingival sulcus.* For lower anterior teeth and where significant gingival recession is present, a premeasured 1.0 mm round diamond should be used (AC4, Brasseler USA). The 1.0 mm depth cut is also specific for both lithium disilicate and all-zirconia full crowns as well.
   (ii) *Vertical depth cut* The vertical depth cut is continued using the same round diamond for the

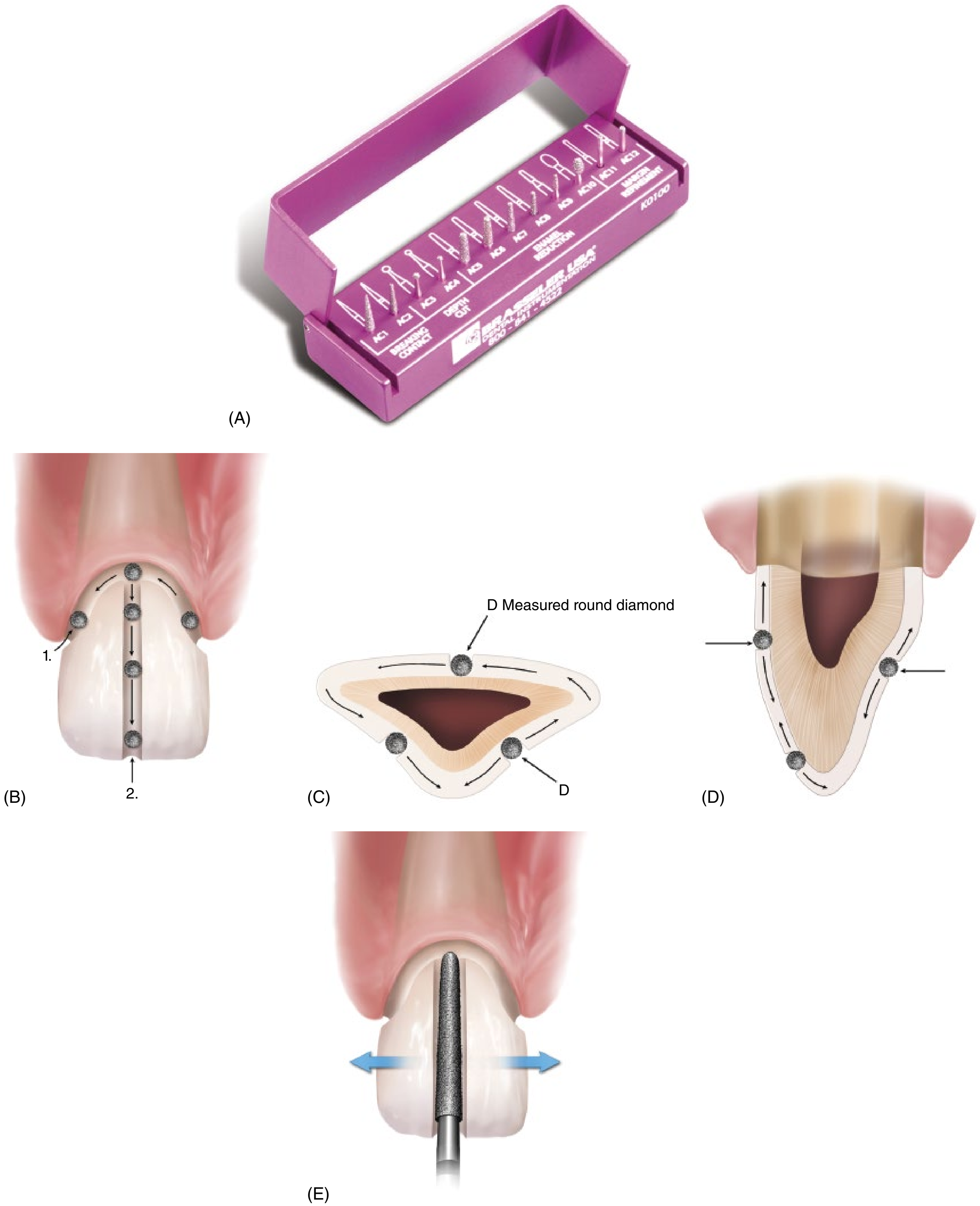


Figure 40.4 **(A–E)** Proper tooth preparation with uniform reduction and rounded internal line angles for an all-ceramic crown using a 12 diamond kit (BrasselerUSA K0100).

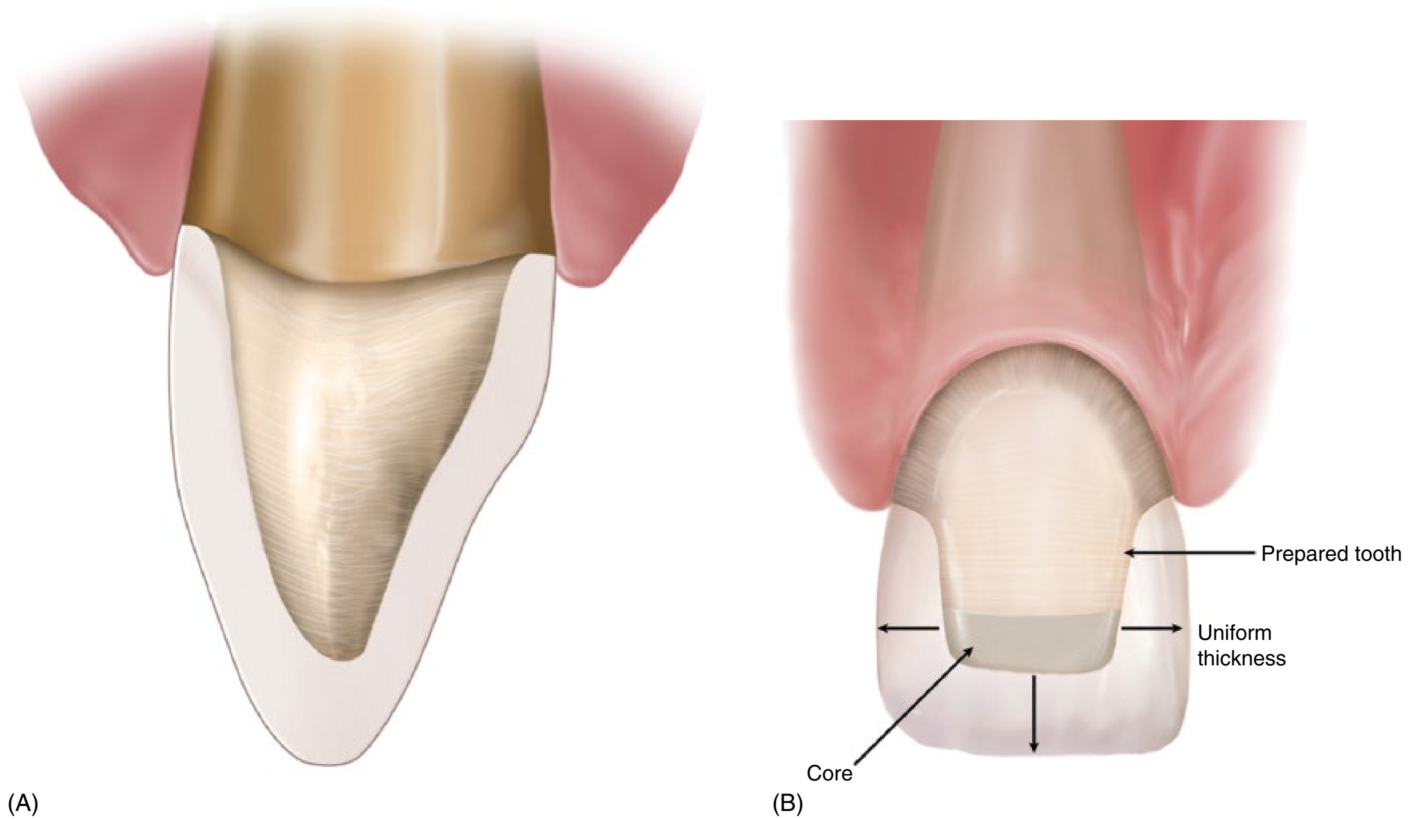


Figure 40.5 **(A, B)** The principles of uniform thickness for a typical all-porcelain crown.

gingivoincisal or gigivo-occlusal aspects. Starting at the center of the labial or buccal surface (Figure 40.6B), continue the depth cut from the cervical middle straight down to the incisal or occlusal edge. The depth of the cut is still controlled by the premeasured round diamond. Therefore, if you are increasing the depth of the buccal and/or lingual walls to 1.5 mm, then switch to the AC3 diamond, which is 1.5 mm thickness. Next, move to the incisal or occlusal surface. Since the incisal or occlusal clearance should be 1.5–2.0 mm, slightly more reduction should take place at these aspects.

Make sure you plan exactly how much reduction your preparation will require. For instance, you will not need full labial reduction if you are building out the tooth labially. However, you will probably want maximum lingual reduction in this situation.

2. **Bulk enamel removal** The esthetic depth cuts should now provide visualizations of the final tooth preparation form, so enamel can now be stripped away quickly while confidently retaining the correct depth thickness (Figure 40.6C and D). Use a very coarse round-end tapered diamond to remove both enamel and dentin, while maintaining a rounded internal angle, avoiding any sharp line angles (AC5 or AC7, Brasseler USA). For mandibular anterior teeth use the smaller AC7 for bulk reduction. This diamond will also be useful to reduce interproximal contacts to avoid any potential damage to adjacent teeth. In extremely small or narrow teeth, use the AC9 diamond.
3. **Incisal/occlusal clearance** Using the same round-end tapered diamond, reduce the incisal surface approximately 1.5 mm to obtain proper clearance (Figure 40.6E). When necessary, it may be possible to compromise the incisal reduction to 1 mm and alter the teeth in the opposing arch. However, if you are planning on all-zirconia crowns you could reduce as little as 0.5–1.0 mm occlusally if necessary. The important part of occlusal reduction is accounting for the type of occlusal anatomy that the patient requires. This means you must account for the depth of both fossae and grooves and prepare for equal thickness of porcelain in these areas as well. One way to test for adequate clearance is to use an occlusal clearance tab sprayed with colored disclosing material (Figure 40.6 F–H).
4. **Lingual reduction** A very coarse football-shaped diamond (AC10, Brasseler USA) is used to uniformly reduce the contours of the lingual surface of anterior teeth (Figure 40.6 F). The AC10 (Brasseler USA) is ideal to reduce the occlusal aspect of posterior teeth as well. Either a plastic or rubber thickness gauge can be used to make certain that your predetermined sufficient space is created. Also, if you are using a CAD/CAM intraoral scanner (Itero, Align) for your impression taking, the bite registration scan will easily show you if there is sufficient space. If not, you will be prompted to reduce more in those areas, so your restoration can be fabricated with sufficient thickness to avoid a potential fracture.
5. **Margin refinement** Preparation and refining of the shoulder margin are important steps of the universal procedure

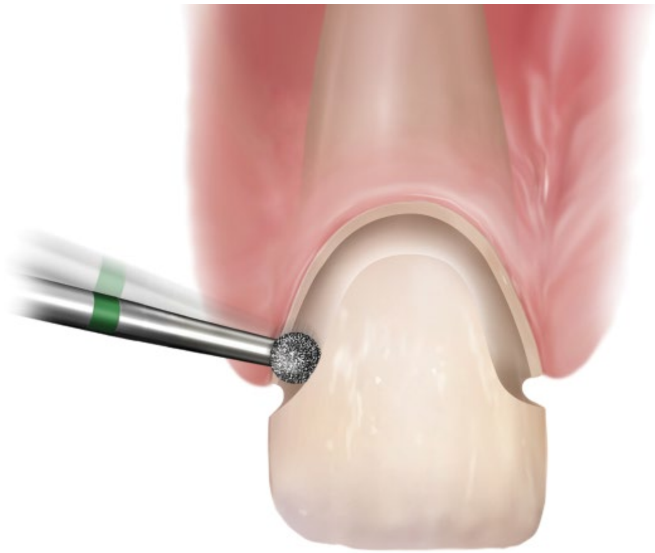


Figure 40.6 **(A)** Esthetic depth determination is both easily and quickly done using premeasured round diamond stones. A round diamond (Brasseler AC4) is used to create horizontal depth cuts at the gingival level, completely around the labial and lingual surfaces.

and are easily accomplished with a beveled-end cutting diamond (AC11 and AC12, Brasseler USA) shapes (Figure 40.6G). These diamonds have fine diamond particles on the flat tip only. When finishing subgingival margins to a smooth surface, the beveled corners and smooth sides of the tip help avoid lacerations by pushing soft tissue aside. It is very important to provide a clear, sharp outer margin, so the ceramist will have no problem determining the exact margin. A shoulder margin of approximately 1.0 mm is ideal for most all-ceramic crowns.

Tissue laceration can also be avoided by displacing the gingival tissue for several minutes with cotton retraction cord just prior to finishing the margin.

6. **Preparation finish** In the final step, the preparation is finished to a smoother surface using the same size but round-end tapered diamond used to make the original enamel reduction margin, but with medium diamond grit (AC6 or AC8, Brasseler USA). Make sure you eliminate all sharp line angle edges of the prepared teeth, as well as any sharp internal line angles.

Figure 40.6H is an example of the final preparation. A clinical example of this procedure can be seen in Figure 40.7A–P.

Porcelain-fused-to-metal restoration

Since its introduction into dentistry in the early 1950s, the ceramometal crown gained in popularity up until the new millennium, when the all-ceramic crowns achieved more popularity. However, the ceramometal crown continues to be a popular prosthetic choice for crowns primarily because it combines the strength and adaptability of metal with the esthetic beauty and durability of porcelain. However, this type of restoration does present some unique problems of construction and design, owing to the possibility of an interaction between the two

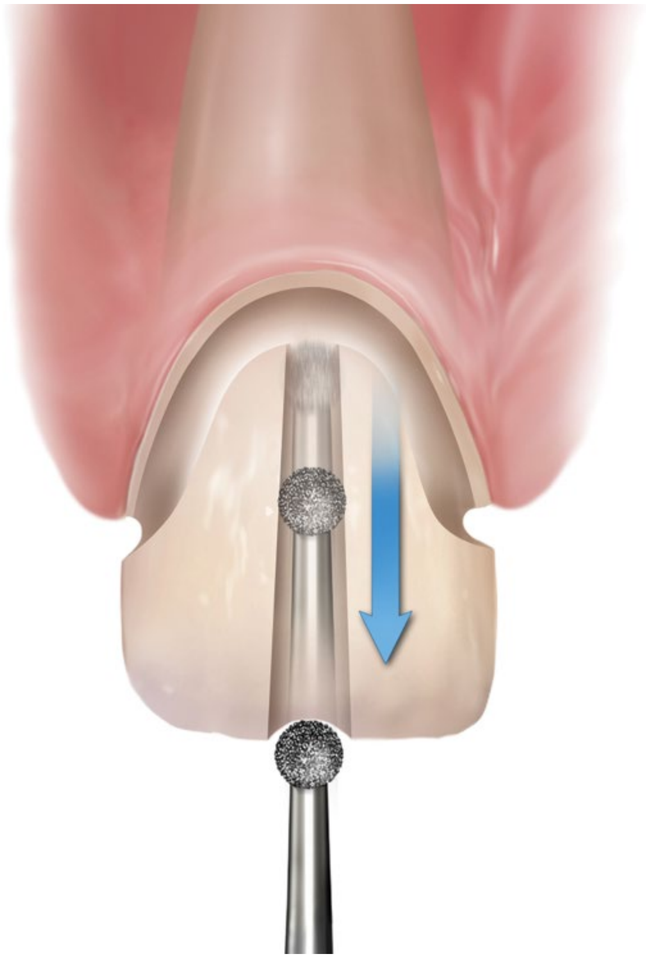
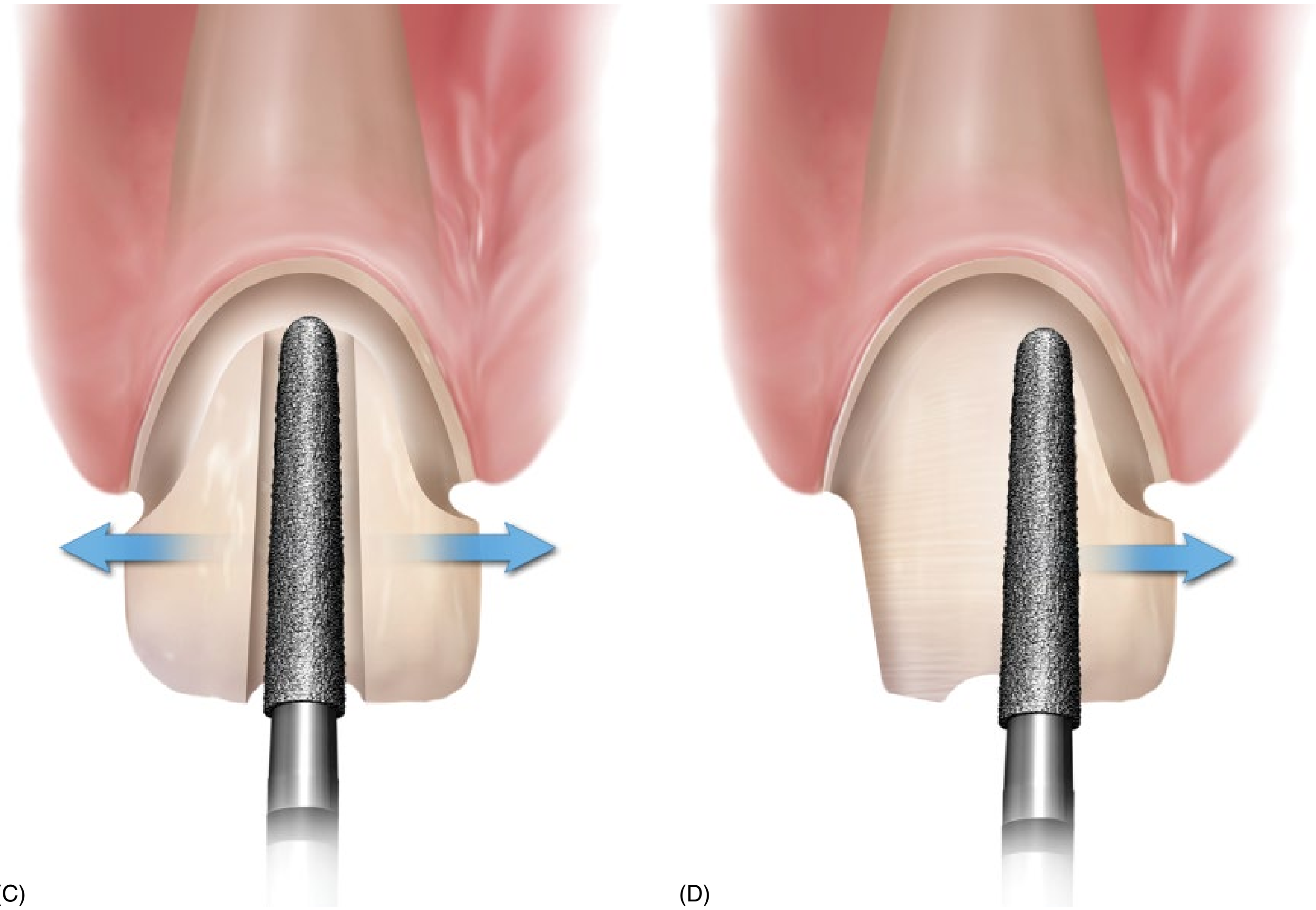


Figure 40.6 **(B)** Vertical depth cut. The depth cut is continued utilizing the same bur through the incisogingival dimension. This depth may vary depending on the final desired buccolingual dimension.

materials when porcelain is added to the metal coping. The preparation stage of the restoration can thus play a major role in the stabilization of this process.

The preparation of a tooth for ceramometal is exacting in the amount of tooth reduction necessary to obtain optimum structural and esthetic results. For instance, in the case of ceramometal it means reducing the tooth structure a minimum of 1.5–2.0 mm to obtain maximum esthetics.[27] The porcelain veneer should have a thickness of 1.5 mm axially and 2.0 mm incisally and occlusally;[28] anything less might result in compromised esthetics or create more serious esthetic problems, especially regarding color. On the other hand, thicker or uneven porcelain could result in structural weakness within the porcelain; it may crack during construction or after the crown is completed.

The principle of esthetic depth determination should also be applied to the posterior ceramometal preparation (Figure 40.8). In addition to the occlusal and labial, a gingival trench is also used. Figure 40.8C shows the desirable thickness of tooth structure necessary for porcelain, opaque and metal. A clinical example can be seen in Figure 40.9. A significant deviation from the minimum suggested thickness for the porcelain or metal may make the restoration structurally weak or esthetically unacceptable. Inadequate incisal and labial reduction (Figure 40.10A)



(C) (D)

Figure 40.6 **(C, D)** Bulk enamel removal. Following the vertical depth cut, an extra-coarse round-end tapered diamond (Brasseler AC5 or AC7) is utilized to remove enamel and dentin to the desired depth.

may result in porcelain fracture; in addition, it is the main cause of esthetic failure due to the opaque metal coping showing through. Inadequate lingual reduction may likewise be a causative factor in fractures (Figure 40.10B). Furthermore, the labial margin, where the thickness of metal may be limited by esthetics, is the part that most often appears to be subject to distortion. Other problems that may make this type of crown difficult to prepare are teeth that are tapered or have constricted necks.[29]

Labial tooth reduction for esthetics

The amount of labial tooth reduction can dramatically affect the esthetic result. Although there is general agreement on the approximate amount of tooth reduction necessary to accommodate metal, opaque, and porcelain, this amount can be altered by the esthetic needs, shape, size, and position of the individual tooth. Therefore, instead of an axial reduction of 1.5 mm, it may be necessary to reduce the tooth 1.75–2.0 mm to achieve the desired esthetic result. Naturally, the position and size of the pulp chamber are the limiting factors in tooth reduction. Since this varies considerably from tooth to tooth and patient to patient, there can be no rule that applies in every case. Study the patient's radiograph carefully to help determine exactly how much reduction will be possible. Note both the width and height of the pulp chamber before making any final decision on choice of retainers.

If the pulp chamber is large but the tooth is small, some type of compromise will be necessary if a ceramometal restoration is used. For example, if minimal occlusal stress is to be placed on the crown, in rare cases the metal can be thinned to 0.2 mm. Since the opaque is approximately 0.15–0.2 mm thick, the porcelain makes up the available difference. Therefore, the crown could be 1.35 mm in labial thickness if porcelain can be made thinner. If the maximum labiogingival thickness were only 1 mm, the resulting porcelain would be only 0.55 mm. Depending on the shade selected, this may be insufficient to achieve an esthetic result in the cervical third. If this compromise is not adequate, an alternate retainer would have to be selected.

As stated, the suggested thickness of metal for this type of restoration is 0.33–0.5 mm, but in areas of minimal occlusion, 0.2 mm may be used. This variation depends on the physical properties of the alloy for proper rigidity and strength of the restoration.

Tergis[29] believes that when there is insufficient reduction of tooth structure, several problems can result, such as the following:

1. The laboratory may construct an extremely thin casting in order to avoid overcontouring, which could result in metal or porcelain breakage.

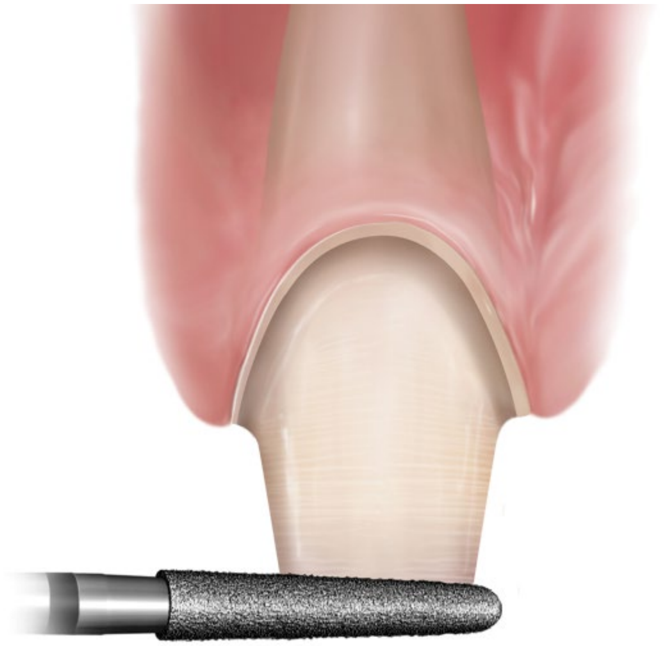


Figure 40.6 **(E)** Incisal clearance. Using the same round-end tapered diamond, incisal reduction is completed using the same round end diamond (AC5, Brasseler USA) to achieve proper clearance with the opposing dentition.

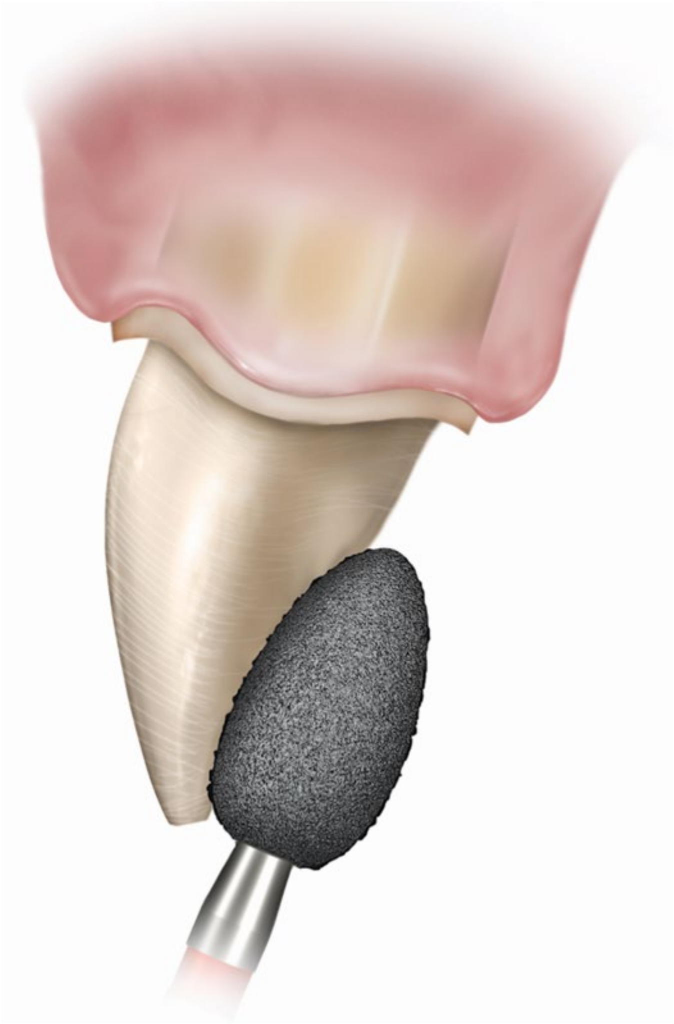


Figure 40.6 **(F)** Lingual reduction. The AC10 diamond (Brasseler) is used to obtain proper lingual reduction and contours.

Figure 40.6 **(G)** Margin refinement. Preparation and refining of the margin is done with the beveled end-cutting diamond (Brasseler AC11 or AC12). The beveled-end shape helps to prevent internal line angle undercuts as well as avoid gingival abrasion.

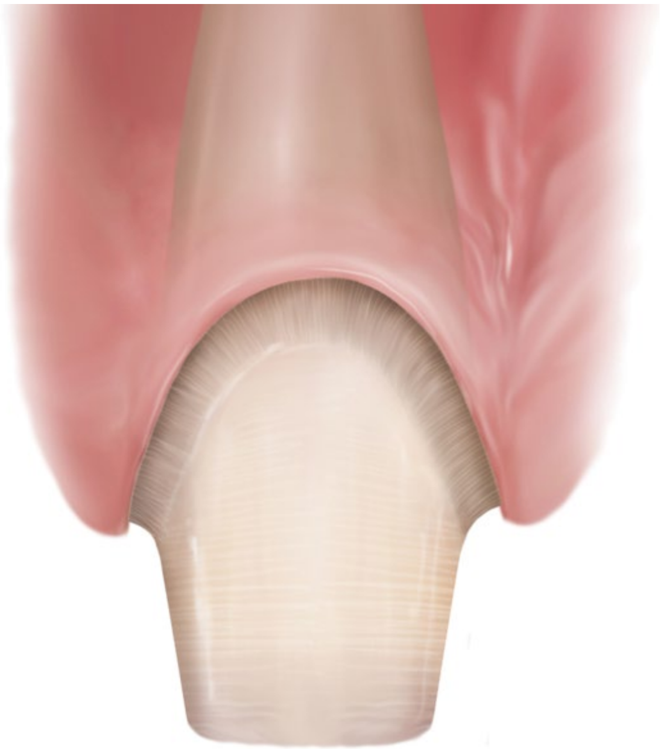


Figure 40.6 **(H)** Example of a supragingival margin all-ceramic crown preparation.

Figure 40.7 **(A)** The patient's maxillary right central incisor will be prepared for an all-ceramic crown.

Figure 40.7 **(B)** Completion of the labial horizontal esthetic depth cut.

Figure 40.7 **(C)** Completion of the labial vertical esthetic depth cut.

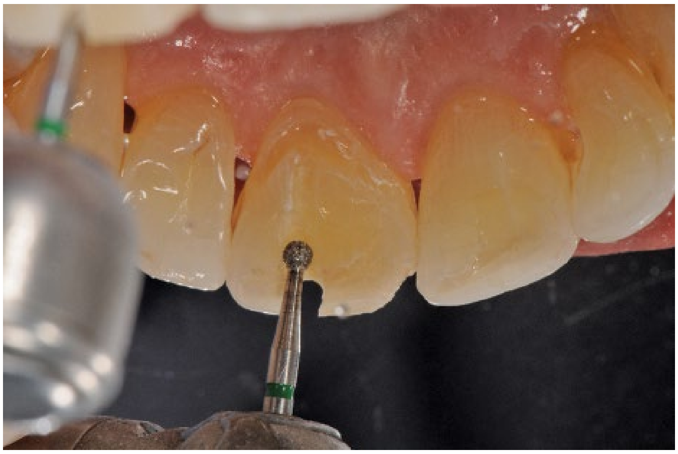


Figure 40.7 **(D)** Completion of the lingual vertical esthetic depth cut. Note also the completed lingual horizontal depth cut.

Figure 40.7 **(E)** Having completed the horizontal and vertical depth cuts, bulk enamel removal becomes predictable.

Figure 40.7 **(F)** At times, it may be necessary to change to the narrower diameter round-end coarse diamond (Brasseler AC7) to remove interproximal tooth structure without damaging the adjacent tooth.

Figure 40.7 **(G)** Bulk enamel removal on the lingual. The lingual shoulder is refined using round-end tapered extra coarse diamond (Brasseler AC5).

Figure 40.7 **(H)** Lingual reduction with the extra-coarse Brasseler AC10 helps create the proper lingual contour, particularly in the cingulum area.

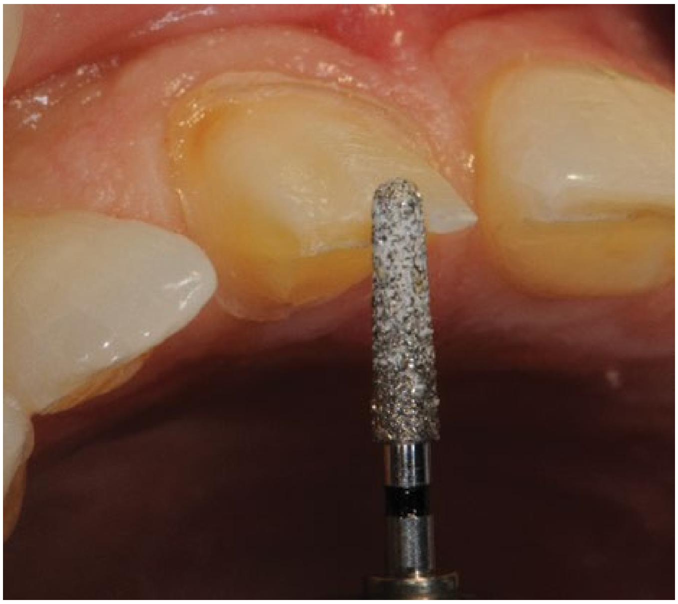


Figure 40.7 **(I)** Incisal reduction.

Figure 40.7 **(J)** Evaluate proper incisal clearance with the appropriate clearance tab. Here, a 1.5 mm clearance tab was used for lithium disilicate.

Figure 40.7 **(K)** Prior to subgingival margin placement, a retraction cord is placed to avoid tissue abrasion.

Figure 40.7 **(L)** The retraction cord is removed after 5–8 mins and the beveled-end cutting diamond (Brasseler AC11 or AC12) is used to prepare and finish the subgingival margin.

Figure 40.7 **(M)** The preparation is refined using the Brasseler AC6 fine diamond.

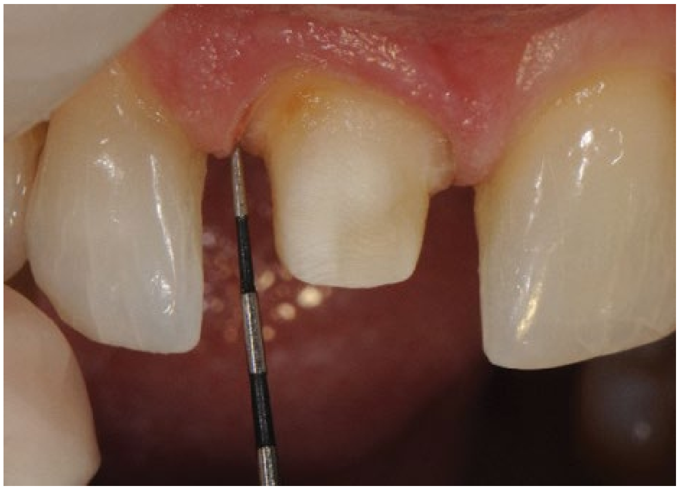


Figure 40.7 **(N)** The finished preparation.

Figure 40.7 **(O)** Finished preparation from the occlusal view. Note that the adjacent central and lateral incisors were prepared for porcelain veneers.

Figure 40.7 **(P)** Retracted view of completed lithium disilicate restorations.

2. The laboratory may use the proper thickness of metal and porcelain for strength and appearance, but the result may be an overcontoured crown.
3. A lifeless restoration may result if the laboratory maintains proper thickness in metal but reduces the bulk of porcelain too much.

If circumferential tooth reduction is allowed to become gradually thinner as it approaches the shoulder, it may result in (1) a lifeless looking gingival third due to thin porcelain, (2) overcontouring at the margin with traumatic pressure on the gingival attachment, or (3) porcelain flaking off because metal is too thin at the margin. The answer to all of these problems is consistent use of the "esthetic depth determination" when preparing teeth for full crowns.

The laboratory should not construct mere "facings," or one-surface (labial or buccal) veneers in ceramometal restorations, because these materials will not function successfully in this configuration. To gain the desired strength and durability of the ceramometal combination, there must be a degree of "wrap-around," as Tergis suggests.[29]

Porcelain colors at the gingival area are relatively intense and opaque. They readily hide the metal if the porcelain is at least 0.5–0.75 mm thick.[30] However, if the gingival shade is different from the opaque, a thicker layer of porcelain should be used. The thickness of porcelain must be increased toward the incisal third of the tooth to between 1.0 and 1.25 mm.[26] This allows for desirable translucency and esthetic characterization. Thus, the tooth reduction is uniform labially, mesially, and distally and requires a minimum of 1.5 mm of reduction in these areas. Incisally and occlusally, there should be a 2.0 mm clearance. Determine first if the opposing arch or teeth will need recontouring before attempting to reduce the tooth. However, with the all-ceramic crown, a 1.5 mm clearance is adequate. As mentioned previously, it should be remembered that a thickness of porcelain greater than 2.0 mm can result in structural weakness within the porcelain and might produce checking or cracking during construction or after case completion. These basic principles of reduction for the porcelain-fused-to-metal crown must be followed to assure a durable restoration that may be stained and contoured to achieve an esthetically pleasing result.

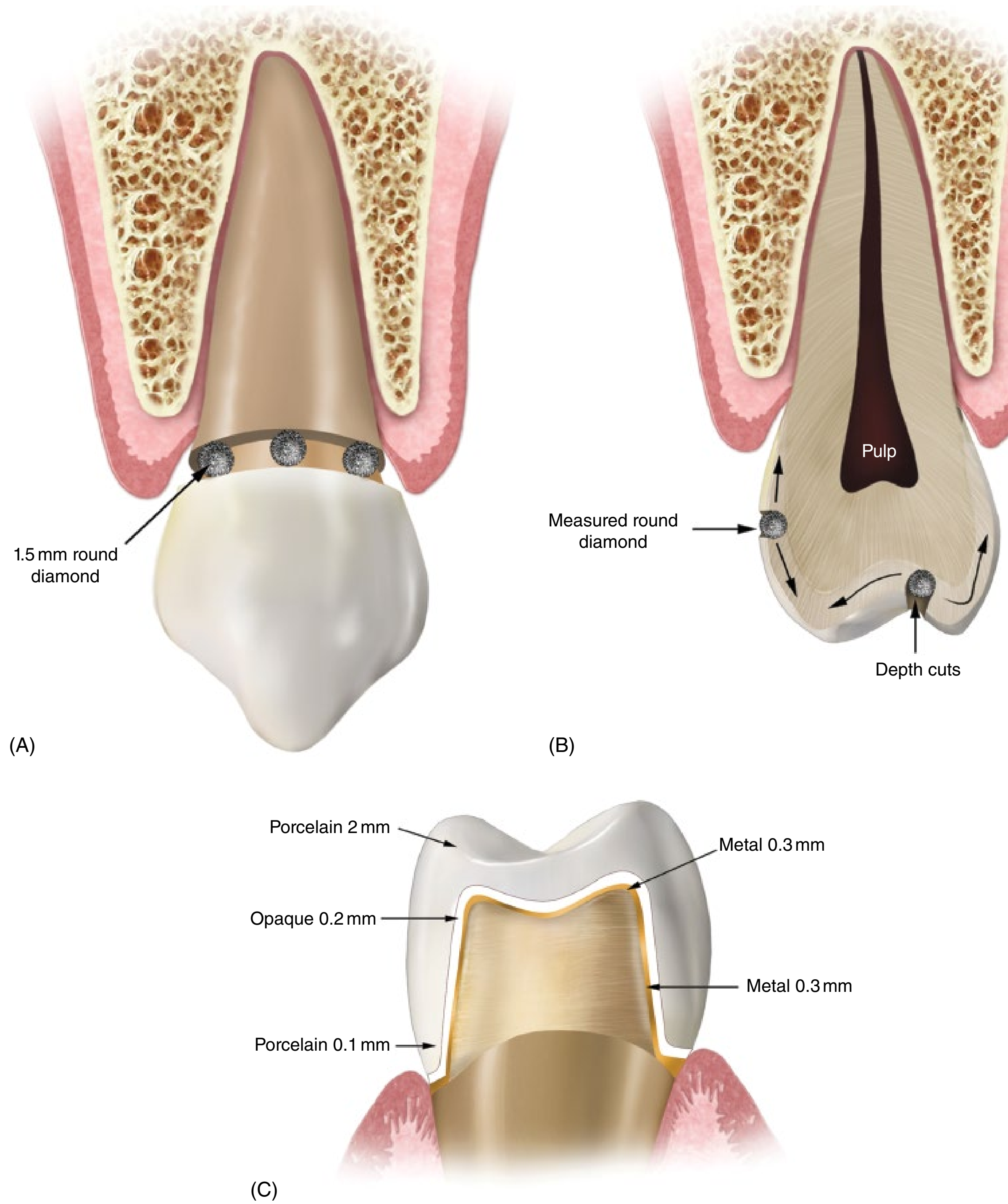


Figure 40.8 **(A–C)** As with the anterior teeth, esthetic depth determination is both easily and quickly done using premeasured round diamond stones.

The key to proper reduction is highly dependent on the overall esthetic result you desire. Thus, if you intend on building out a tooth to create greater harmony in the arch alignment, then less than normal tooth reduction should be planned. Conversely, if you need to reduce the buccal contour or alignment of a tooth, then even greater reduction might need to be planned. The important measurements are the end measurements, so that uniform thickness is achieved. Two techniques to verify your labial tooth preparation thickness are shown in Figure 40.11A–D. Note the special vacuform matrix of the wax-up used, with both incisal and gingival holes placed so the Goldstein Colorvue probe can measure in 0.5 mm increments.

Types of margins

The determination and preparation of the cervical margin is one of the most important and esthetically critical steps in

Figure 40.9 **(A–D)** These clinical figures show how the AC diamond technique can be utilized in posterior teeth as well.

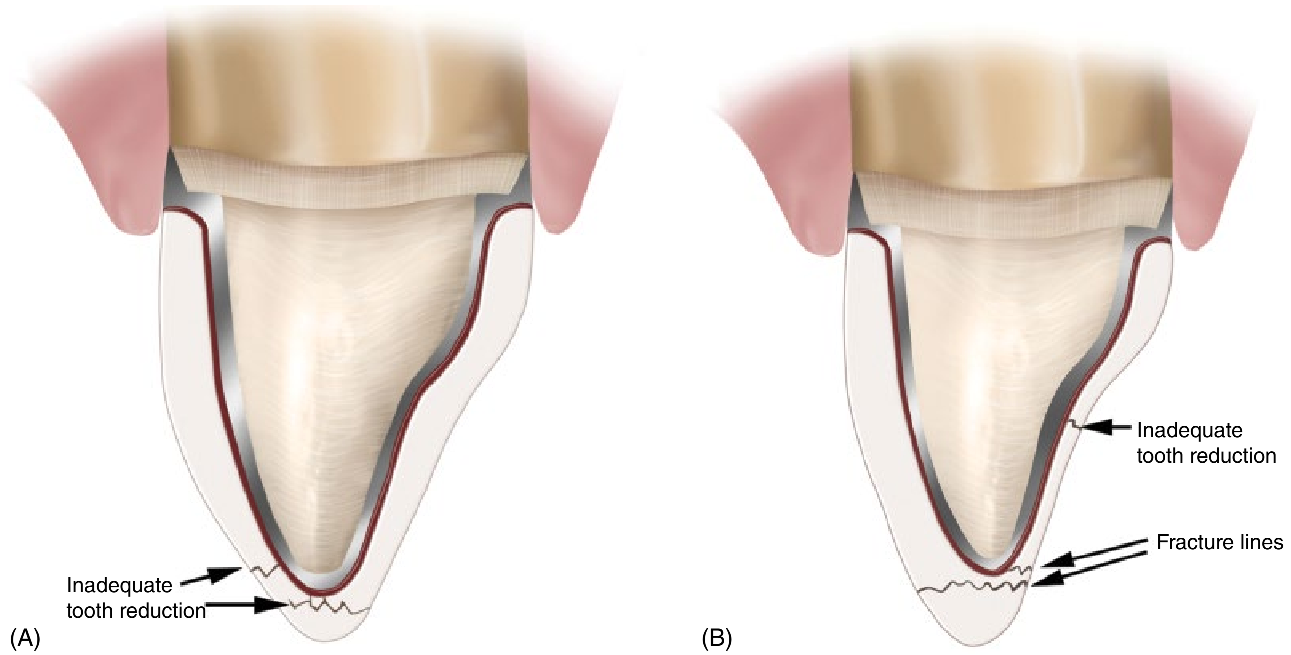


Figure 40.10 **(A, B)** Inadequate tooth reduction on the incisal or lingual aspects of a preparation can predispose the porcelain crown to fracture.

Figure 40.11 **(A)** A wax-up is completed to the contours desired in the final result and is duplicated in a laboratory silicone.

Figure 40.11 **(B)** The silicone is cut back for visibility and utilized chairside to confirm that there is adequate and uniform reduction for the final crowns.

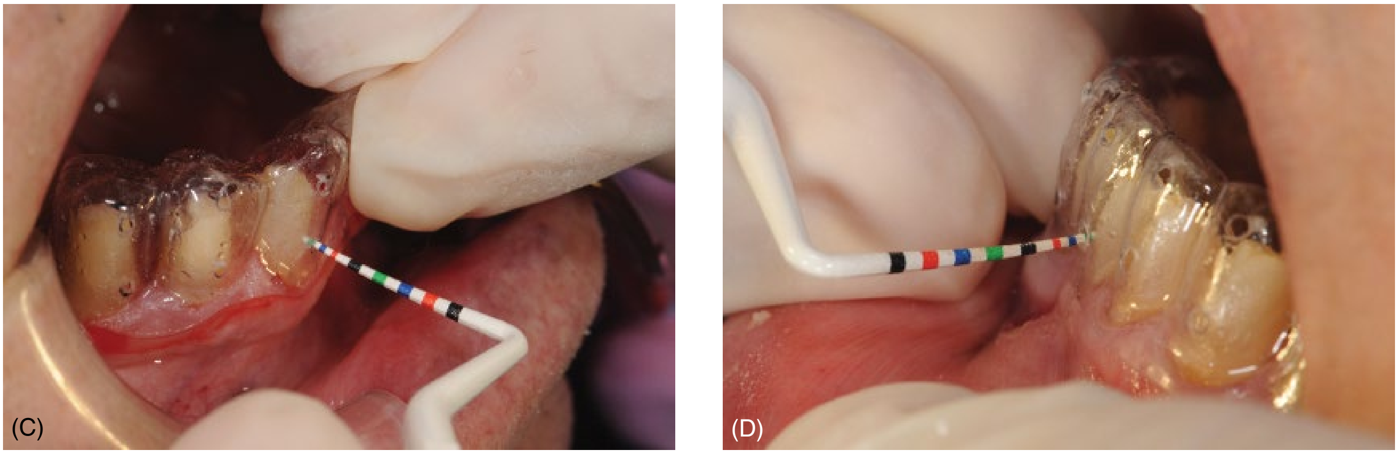


Figure 40.11 **(C, D)** Alternatively, a vacuum-formed matrix of the final wax-up can be utilized to visualize appropriate reduction. By making small, round access holes, an easy to see 0.5 mm Colorvue periodontal probe (Goldstein Colorvue Probe, Hu-Friedy) can determine whether you have achieved proper tooth reduction for adequate ceramic thickness.

tooth preparation. As Berman states, to provide adequate room for the terminal margin of the crown, the portion of the tooth in the sulcus must be adequately exposed either by retraction, laser, or electrosurgery.[31] If the shoulder is first prepared to the gingival crest and the tissue retracted for several minutes, then the shoulder can be lowered into the gingival sulcus without injuring the inner wall of sulcular epithelium. It is fully possible for complete crowns to enter the gingival sulcus without harming it. In preparing the margin, avoid making the undercuts or overtapering the preparation to prevent sacrificing maximum retention.

Unless there is adequate protection of the gingival sulcus during preparation, eventual exposure of the gingival margin may occur. For instance, a shoulder margin prepared with a tapered or straight diamond stone can lacerate gingival tissue as the shoulder margin is extended into the gingival sulcus. However, it is possible to prepare and finish this margin and also protect the sucular tissue through use of a beveled end-cutting diamond (AC11 or AC12, Brasseler USA). Unlike most end-cutting burs, the bevel on this diamond stone protects the adjacent gingival epithelium as the outer aspect of the shoulder is being prepared. Figure 40.12A shows how the design of the stone protects the adjacent tissue. A clinical photograph of an anterior full crown preparation during and immediately after tooth preparation is shown in Figure 40.12B. Note the absence of tissue laceration. Slower speeds are advised to retain proper control and thereby prevent unnecessary slipping.

The selection or type of gingival margin can have a most profound effect on esthetic results, depending on location of the tooth in the arch and the position of the margin subgingivally.[10]

The shoulder

The full shoulder margin is utilized most often when preparing anterior and posterior crowns[10] (Figure 40.13). It also provides the proper room necessary from a technical standpoint to produce a porcelain-fused-to-metal restoration that has esthetic qualities of contour and color. The shoulder preparation provides an adequate bulk of porcelain at the margin to protect against cracks or fractures, thus combining strength and esthetics. In their study of marginal distortion in porcelain-fused-to-metal restorations, Shillingburg et al. found that the

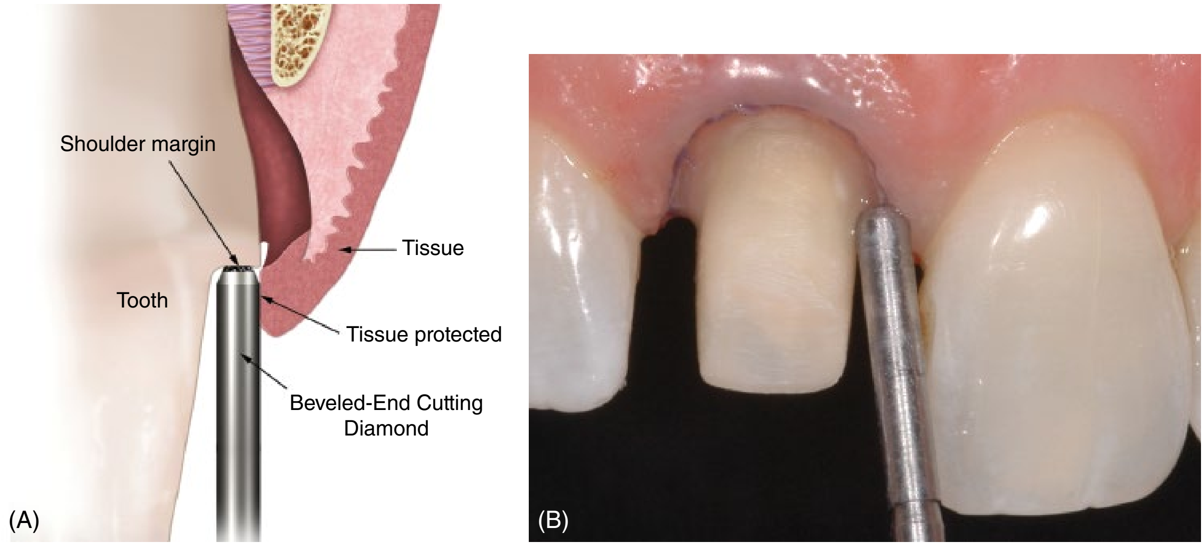


Figure 40.12 **(A, B)** This illustration and clinical example show appropriate use of the beveled-end cutting diamond (Brasseler AC11 and AC12) to finish subgingival margins while protecting the gingival tissue. Note the use of gingival retraction in (B).

labial margin, where metal thickness may be severely limited by esthetics, is the part most susceptible to distortion.[32] It has been our observation that porcelain chipping has occurred too frequently at a beveled gingival margin, especially when the metal was thinned down too much.

With the advent of more predictable bonding agents and cements that adhere to the restoration as well as the tooth, the all-ceramic margin becomes much more feasible in esthetic dentistry.

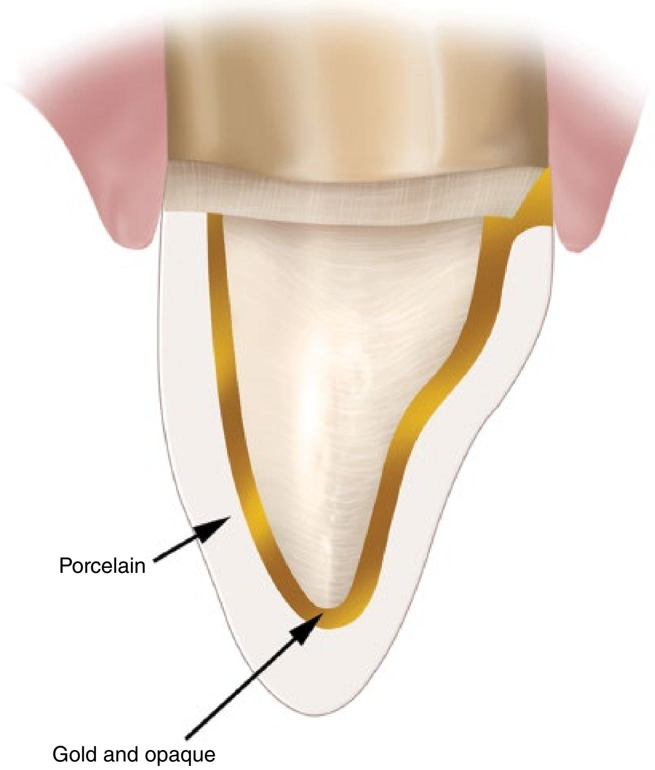


Figure 40.13 The use of a porcelain butt joint on the facial margin of a ceramometal crown may be used in the case of a thin or shallow sulcus.

Tooth preparation in periodontal problems

When possible, periodontal therapy should be completed before the tooth is prepared. There are times, however, when it is necessary that treatment splinting or temporization be instituted before periodontal surgical procedures such as grafting are performed. Generally, gingival margins will necessarily be further beneath the sulcus to allow for shrinkage or placement of a higher level of the gingival tissue. It is advisable to prepare the tooth as close as possible to where the final preparation is anticipated. Thus, there will be less likelihood of having to completely remake the temporary restoration to regain marginal integrity after periodontal therapy is concluded. Some alteration of the tooth preparation will be necessary, and the temporary splint may be repaired in lieu of constructing a complete replacement (Figure 40.14A–D).

One possible esthetic problem after periodontal surgery is the presence of larger interdental spaces. Closure of these spaces can usually be accomplished in the final crown form. Although this may require a greater mesiodistal reduction in the final preparation, some allowances for this can be made during the initial preparation and margin placement. Careful planning is a must in cases of loss of interdental space. Much less preparation may be required because of the need to fill in the missing interdental areas. Finally, the choice of adding pink ceramic or composite resin should be a consideration.

In cases of advanced periodontal disease where bifurcation or even trifurcations are involved, use the extra-long AC1 diamond to help create your margin. However, do not attempt a shoulder margin in these cases. Therefore, you may want to consider zirconia, where you can utilize a thin proximal margin.

Areas of crowded teeth

It can be frustrating to prepare crowded teeth. The basic problem is correct placement of mesial and distal margins, depending on

Figure 40.14 **(A)** This patient presented with a fractured porcelain veneer. Prior to final preparation and impressions, the periodontal problem of gingival recession must be addressed.

Figure 40.14 **(B)** The tooth was provisionalized at the ideal gingival level prior to surgery. This allows the periodontist to visualize the final gingival margin.

the adjacent tooth and space limitations. However, the further into the gingiva one goes, the less interdental space there is. Although, from a functional standpoint, it may be better to keep the margin supragingival, this may not be feasible esthetically. The amount of proximal tooth reduction available will most times determine the final position and size of the restoration (Figure 40.15A–E).

Other considerations in the preparation of crowded incisors are choosing a type and obtaining a proper margin. The choice of which margin to use depends upon the restoration desired and the limitations presented by the crowded condition. Several variables are involved, and each will now be considered separately.

Normal crown/root ratio with margin on enamel surface

Because of the available thickness, these teeth can be adequately prepared for either a ceramometal or all-ceramic restoration. There is usually enough thickness to adequately restore the tooth with an esthetic restoration. Thus, either shoulder or beveled shoulder margins may be employed successfully for ceramometal, and the full shoulder margin should be the choice for the all-ceramic crown.

Tissue shrinkage with exposed cementum

In this case, if the lip line is such that the lower teeth do not show, it is best to continue to keep the margins supragingival if possible. However, if because of caries, decalcification, or other problems the margins must be extended subgingivally, then the margins may have to be in cementum. This also means little or no space to obtain an adequate separation between teeth. Therefore, the safest way to prepare a margin is to utilize a thin-metal matrix band, carefully stripping it between the teeth and holding it there to protect the adjacent tooth from damage while preparing the tooth. The best margin is the shoulder type, since it would be difficult to obtain an adequate

Figure 40.14 **(C)** A connective tissue graft was completed with coronal positioning to the predetermined margin.

Figure 40.14 **(D)** Final lithium disilicate restoration completed after tissue healing.

Figure 40.15 **(A)** Retracted pretreatment view illustrating crossbite between the upper and lower left cuspids.

Figure 40.15 **(B)** The final restorations, with correction of the crowding and the crossbite. Pink ceramic was utilized at the gum line to create a more ideal tooth morphology.

bevel. However, if there is enough room for a bevel and if the patient has a lip line that will not reveal the neck of the tooth, the preferred treatment is to leave a gold cuff exposed. This would be the thinnest type of crown replacement available in the crowded areas.

Figure 40.15 **(C)** Occlusal pretreatment view. Note crowding on the left side.

Figure 40.15 **(D)** The adjacent teeth are reduced proximally with the AC2 (Brasseler) to allow for correction of crowding and to create space to lingually position the cuspid.

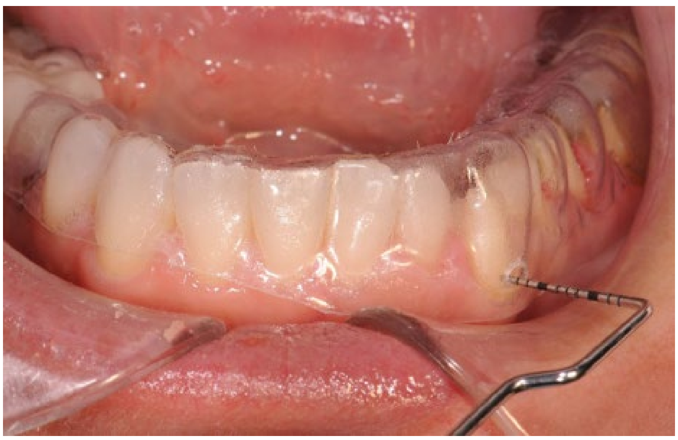


Figure 40.15 **(E)** A vacuum-formed matrix allows visualization of the desired final outcome. A periodontal probe through an access hole ensures that there will be adequate thickness of ceramic to achieve the desired contours.

The variables in each of these cases are (1) the crown/root ratio, (2) the amount of exposed root area, (3) the high lip and speaking line, (4) the esthetic concept and needs of the patient, and (5) the radiographic interpretation of pulp position and size.

Choice of materials

In the crowded tooth condition, the choice of materials may be limited to lithium disilicate (e.max, Ivoclar), full-contour zirconia (Bruxzir, Glidewell), or porcelain with a thin-metal coping (Captek) due to available tooth size. There simply may not be enough room for ceramometal. The esthetic nature of the full porcelain crown makes it an excellent restoration in lower anteriors when adequate preparation and shoulder depth are available. When there is not enough, an alternate would be the shoulderless full-porcelain crown, using a thin-metal coping (Captek), or even an all-zirconia crown with a slight chamfer margin.

Lower incisors can be the most difficult teeth to prepare. Because the roots are conical, and these teeth are thin and small, it is more difficult to obtain proper thickness for a proper margin. Compromises in preparation will have to be made; a different material should be selected—or a less esthetic result anticipated. The teeth should be studied carefully along with the radiographs to obtain information about how thick the restorative material may be. A frequently encountered problem is the fanned or labially tipped lower incisor. In this case, study the problem to determine exactly how much reduction will be permitted. Still using the AC4 round diamond to gain an esthetic depth control might not be possible to completely cut into the cervical portion of the tooth for the entire 1.0 mm thickness of the diamond. Occasionally, if the pulp has receded, it will be possible to reduce enough incisal and labial thickness to realign the tooth and restoration. This depends on the location of the pulp and the degree of labial inclination. If possible, it is usually best to strip these teeth and try to reposition them orthodontically before preparation.

Long crown/root ratio

This situation generally occurs following periodontal surgery. The objective in the crown/root ratio is to have a longer root than crown, therefore lowering the ratio. Esthetically, if the patient has a high lip line, it may present a problem unless the tooth is prepared properly. In the case of a deep overbite, it is possible to shorten the teeth for a more esthetic result. This may also be combined at times with cosmetic gingival surgery, if there is need for more tooth structure to be exposed. A second method is to carve and stain root contours to avoid unsightly long clinical crowns.

Extremely short teeth

Depending on the cause of their limited height, preparing extremely short teeth can be difficult. Since incisal or occlusal reduction for ceramometal needs to be approximately 2 mm, the stability and retention may be totally inadequate (Figure 40.9A–D). The all-ceramic crown may be a viable alternative, since the required occlusal reduction can be 1.5 mm. If this is not possible, then either an all-gold or all-zirconia crown can be the logical choice. Although the reduction for a full-zirconia crown can be as little as 0.5 mm, ideally you would want to reduce at least 1.0 mm for greater strength. If the solution is to use a zirconia core with porcelain buildup, it may be much safer to have a reduction of approximately 2 mm. If the reason for short teeth is occlusal wear, a decision to increase the vertical dimension of occlusion may be made. If this is the case, there would be no reason to reduce the occlusal surfaces or incisal edges 1.5–2.0 mm. Do as little incisal/occlusal preparation as possible to preserve tooth length. As an alternative, the opposing teeth may also need to be altered to provide adequate clearance (Figure 40.16A–E).

Pre-preparation checklist

- Evaluate tissue health and sulcus depth.
- What type of margin will be best for health, esthetics, and longevity?
- Evaluate need for pretreatment periodontal procedures.
- Can you predict and allow for future gingival shrinkage/recession?
- Study pulp size/shape on pretreatment radiograph.
- Will endo likely be needed?
- Does the smile line limit your margin type?
- Will tooth position (crowding, etc.) affect choice of materials?

Preparation checklist

- Internal preparation line angles round and smooth.
- Adequate occlusal/incisal clearance for chosen material.
- All margins smooth and clearly visible from intended path of insertion.
- Adequate proximal and buccal space for ceramist.
- Is retention adequate?
- If not, consider metal collar for porcelain-fused-to-metal crown or bonding technique for all ceramic.

Figure 40.16 **(A)** An occlusal indicating spray (Occlude, Pascal Dental) is applied to an occlusal clearance tab to allow transfer to the teeth.

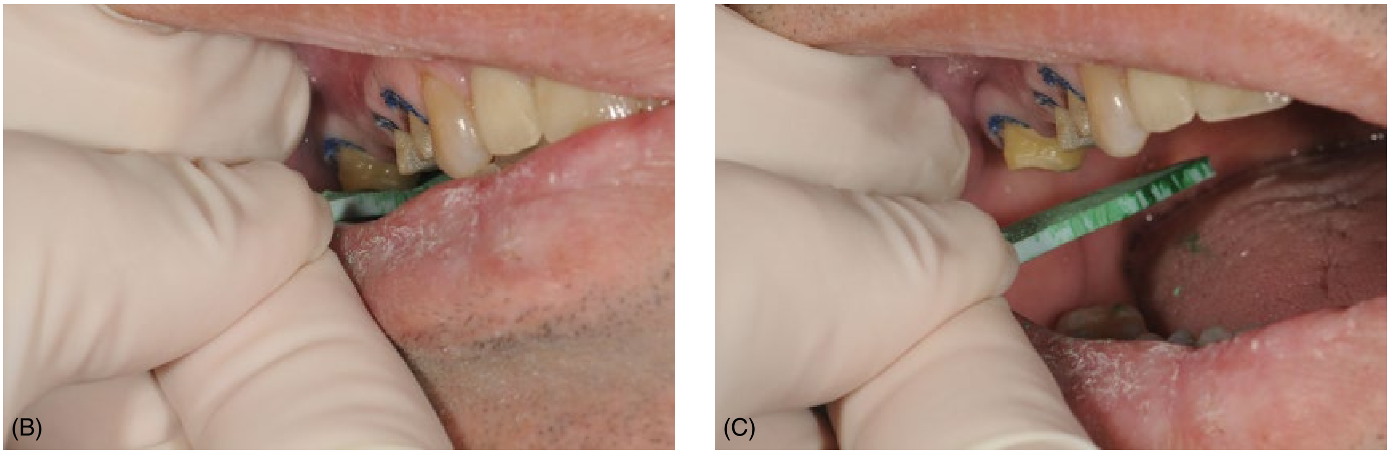


Figure 40.16 **(B, C)** The clearance tab is positioned between the teeth with the clearance in question—in this case, the upper and lower second molars.

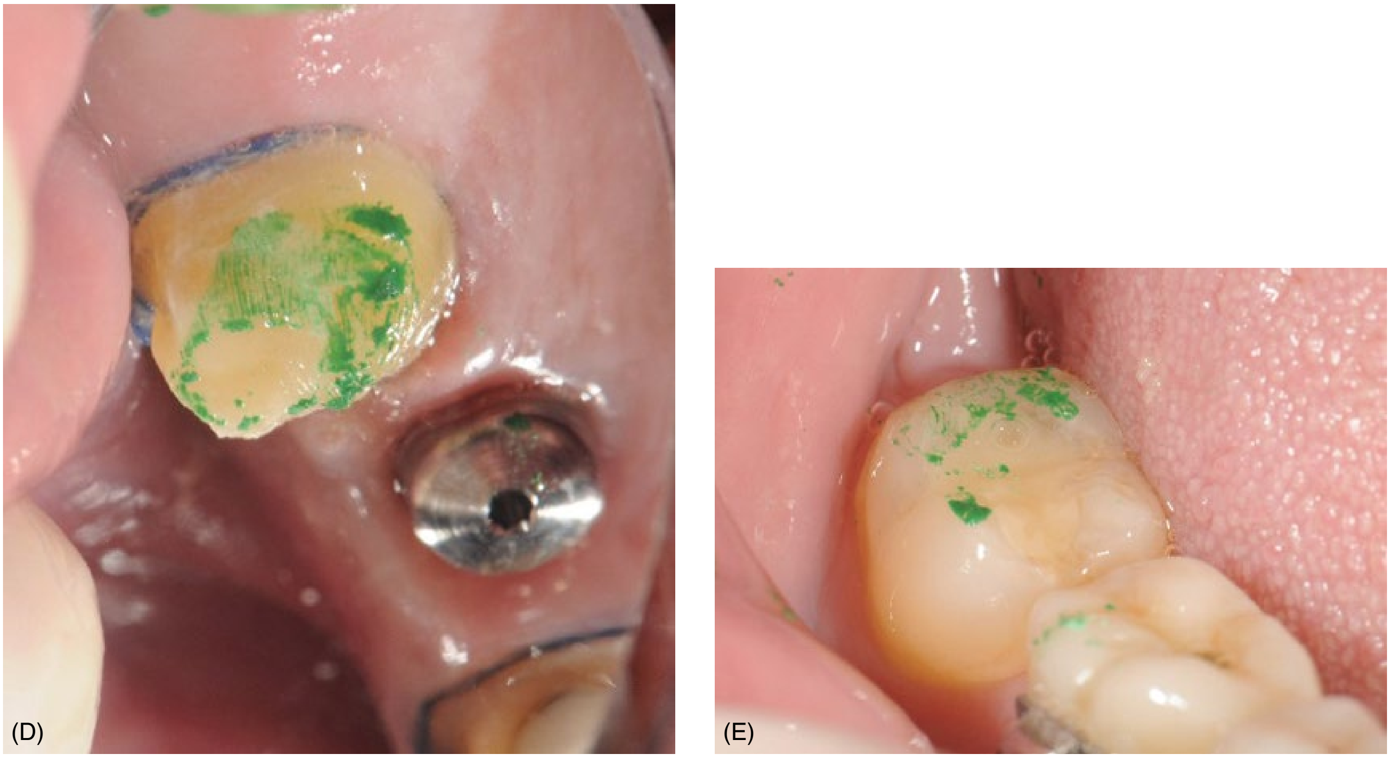


Figure 40.16 **(D, E)** The indicating spray is transferred to both the prepared tooth and its antagonist, allowing for additional adjustment on either tooth.

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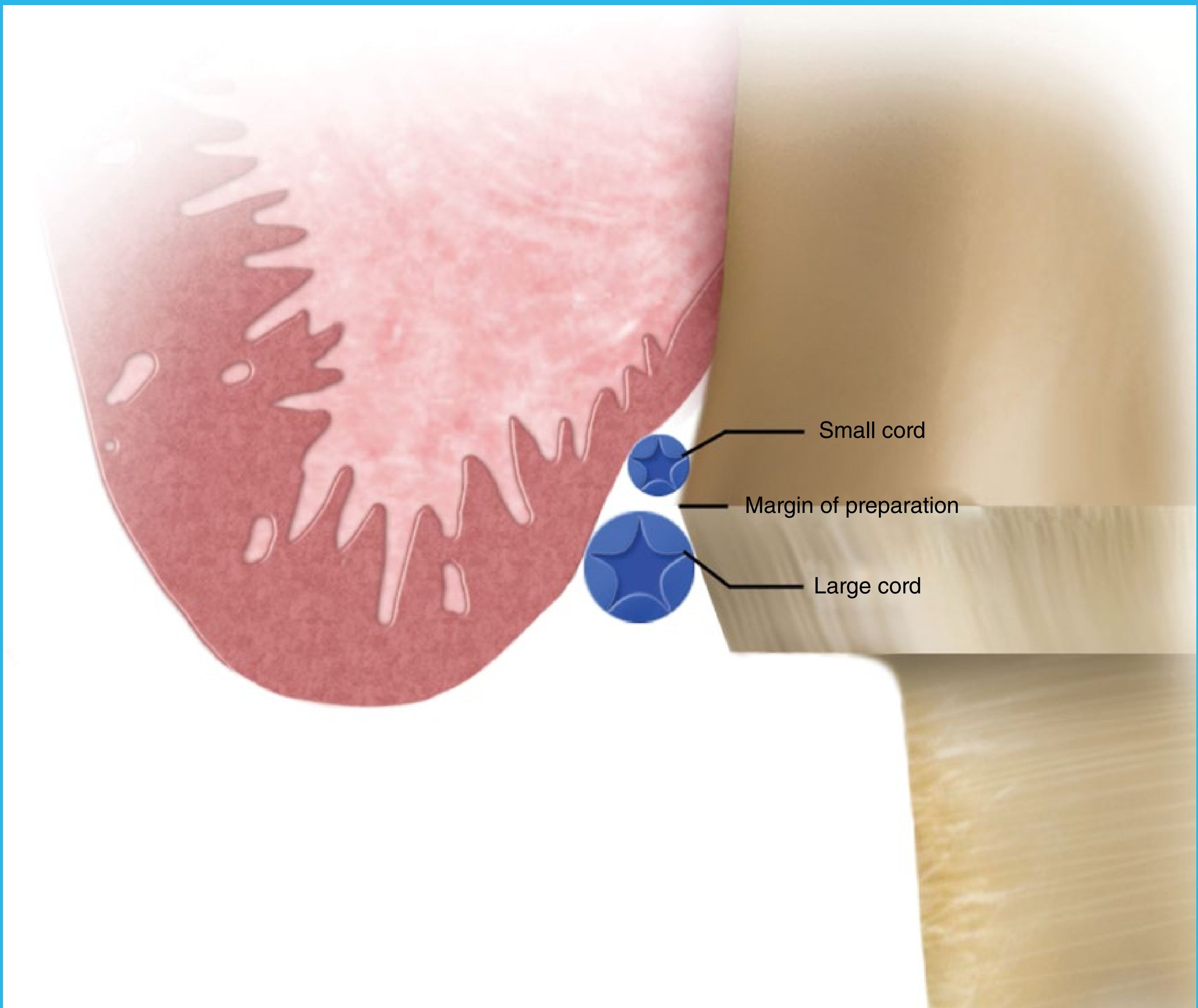
Small cord
Margin of preparation
Large cord

Chapter 41 Impressions

Ronald E. Goldstein, DDS, John M. Powers, PhD, and Ernesto A. Lee, DMD

Chapter Outline

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A restoration may look good when it is inserted, but to remain an esthetic success it must also continue to fit well. The ability to construct an accurately fitted crown depends on mastery of the impression technique. No single technique is suitable for every situation, so it is best to have several impression techniques available. This chapter will discuss both conventional and digital impression techniques.

Impression materials are used to accurately record the dimensions and spatial relationships of oral tissues. Silicone and polyether elastomeric (flexible) impression materials are the most common types used for restorative dentistry. Polysulfide (rubber base) and hydrocolloid impression materials are much less common now. Recently, digital impressions prepared from intraoral scanners have become popular.

Desirable features of elastomeric impression materials include appropriate viscosities for the desired technique (e.g., syringe/tray), easy to use, 4 min working/setting time, adequate detail reproduction, easy to disinfect, compatible with dye materials, adequate shelf life, and cost effective. Important properties include elastic recovery, flexibility, and tear energy.

Preparation of soft tissues

Five common methods for the preparation of soft tissues are retraction cord, paste systems, conventional electrosurgery, bipolar technique, and diode lasers. The most important first step in making a perfect impression is adequate preparation of

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the soft tissue. Failure to clearly display all the margins of each prepared tooth leads to an unacceptable impression regardless of which impression material or technique is chosen.

Tissue retraction

Achieving long-lasting esthetic tissue around crowns depends upon the dentist's ability to create, record, and restore the gingival margin. Restorative dentistry (and particularly esthetics) can be influenced dramatically by the type of retraction procedure used. Improper methods can permanently damage the epithelial attachment, causing gingival recession, either before or after the final restoration is inserted. No attempt at gingival retraction should ever be attempted on inflamed or swollen tissue. Periodontal problems must be treated prior to impression, in order to obtain predictable esthetic results.

Although various methods of gingival retraction are currently in use today, any method, to be considered adequate, must fulfill certain criteria:

1. The method must provide access of the impression material beyond the cervical margins of the prepared teeth (Figure 41.1).
2. Retraction must provide enough space around the cervical margin for an adequate bulk of impression material.
3. The method must eliminate seepage or hemorrhage during the setting of the impression material.
4. The retraction method should be as nontoxic as possible to the patient and to gingival tissues.

Two-appointment procedures

This method is usually used when the periodontal tissue is not in a healthy condition, usually due to improperly fitting restorations. First, the teeth are prepared and a well-fitting temporary restoration is made. There are several advantages to this method. By the second appointment the tissue should be in excellent condition and therefore permit removal of the temporary restoration and use of light retraction cord procedures. Sometimes virtually no retraction is necessary to obtain clearly defined margins, if the temporary restoration fits well. Hemorrhage is practically eliminated by this method; however, the main advantage is being able to see and predict the gingival crest height. If shrinkage has occurred and there is not enough gingiva covering the margin, the preparation can be altered slightly before the final impression is made.

Retraction cords

By far the most popular form of tissue displacement before making impressions is retraction by cotton cord. There are several types of cord, with different weaves, thicknesses, and whether or not the cord is impregnated with hemostatic chemicals. Figure 41.2 shows various types of commercial retraction cords. Hemodent (Premier Dental Products Co.) contains no epinephrine and is available in solution or cord. Several manufacturers (e.g., Ultradent and Dux Dental) make cord saturated with epinephrine-type compounds. These cords are very popular and produce good results, but many patients react unfavorably to the epinephrine. In Timberlake's double-blind study of tissue retraction in 100 patients,[1] he observed that the absorption of epinephrine hydrochloride and its effect on the heart produced elevations in pulse rate and blood pressure (as much as 16 mmHg); therefore, the use of epinephrine is contraindicated in patients with coronary disease, hyperthyroidism, diabetes, or exposed capillary beds.

Placement of retraction cords

A cord is selected that is thin enough to fit into the gingival sulcus between the gingival attachment and below the margin of the prepared tooth. It is carefully placed using gingival retraction

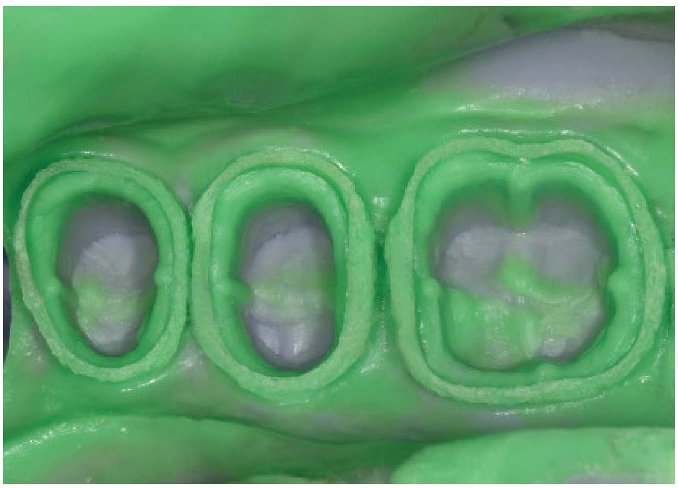


Figure 41.1 The first requirement of any gingival retraction method is to clearly see and capture the cervical margins of the prepared teeth. Extending the impression material beyond the margins makes for more accurate trimming of the die by the technician.

Figure 41.2 Retraction cords in various sizes from two major manufacturers (Ultrapak, Ultradent, and GingiGel, Dux Dental).

instruments. The cord is cut so that it may be completely located with no excess covering the gingival margin of the tooth. Be very careful of not compressing the tissue when you place the cord between the tooth and tissue.

There are basically two methods of retraction using cord. One technique involves placing cord and removing it to make the impression. The second technique consists of placing two cords and leaving the first one in while the impression is made. A variation of these methods involves leaving one or two cords in for a longer period of time (up to 10 min) and removing all cord before making the impression.

One-cord technique

Choose the largest cord to fit into the sulcus. Figure 41.3A is a cross-section of the correct placement of the retraction cord in the gingival sulcus. Saturate it in hemostatic agent (Hemodent, Astringedent), carefully fold into the gingival sulcus, and then leave for about 5–15 min. At times it may be necessary to insert a second cord to make sure the top of the sulcus does not "fold back" over the margin (Figure 41.3B). Remove both cords before making the impression. Figure 41.3C shows the tissue immediately after gingival retraction ready to receive the impression

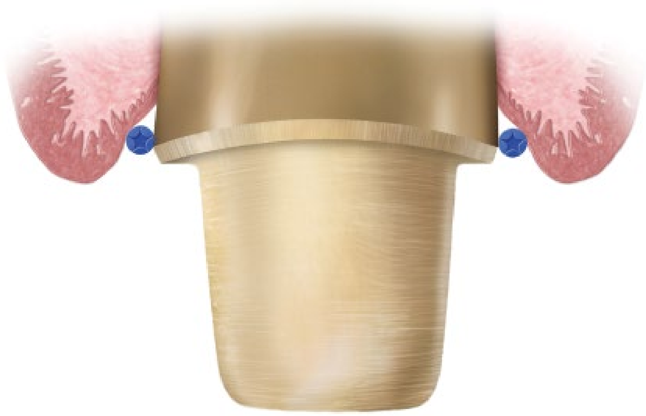


Figure 41.3 **(A)** The use of a single-cord technique in displacing the tissue before impression.

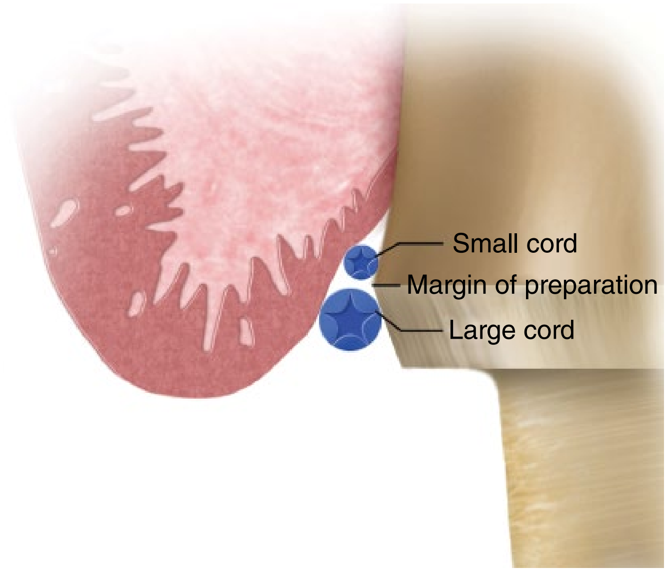


Figure 41.3 **(B)** The use of a second cord when a single cord is not sufficient to expose the prepared tooth beyond the margin. This image also serves to represent the two-cord technique.

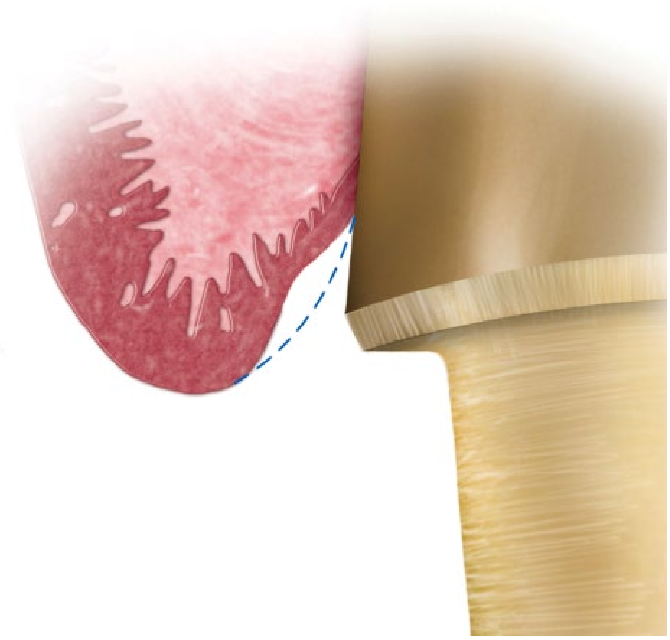


Figure 41.3 **(C)** The tissue immediately after gingival retraction using the one-cord technique ready to receive the impression material.

material. A proper-sized cord produces gingival retraction and little, if any, tissue damage.

Two-cord technique

Use a small diameter cord (size 00) followed by a size 0. The second cord, of larger diameter, is placed in the gingival sulcus, covering the prepared tooth margin and mechanically displacing the pericoronal tissues (Figure 41.3B). Pack and keep the cords in place for 5 min. Before making the impression, be sure to wet the 0 cord before removing it to prevent it from sticking to the tissue and causing bleeding. Then make your impression, finish and cement your provisional restoration before removing the 00 cord. (Figure 41.3C). Control hemostasis with astringents such as ferric sulfate and aluminum chloride. Pack a dry cord and then apply the astringent. Note that ferric sulfate will interfere with the setting of addition silicone impression materials, so rinse the area thoroughly before making the impression.

Tips on double-cord technique

1. Depending on the type of margin, make sure you have an adequate area beyond your margin so the laboratory technician will not have any problem trimming the dyes.
2. If using a shoulder margin it is easier to place your retraction instrument on the shoulder and then slide the cord into the sulcus rather than just pushing the cord in the sulcus. This method can help avoid pinching the tissue.
3. Let the type of tissue guide you as to how long to leave the gingival retraction cord in place. This can vary from 4 to 10 min, especially if the tissue is seeping.

Problems with retraction cords

Problems or damage from gingival retraction can come from several causes:

1. If there is too much pressure on the cord as it is placed in the sulcus, it is forced deeper than necessary and too far past the marginal area. This can be remedied by using a small-gauge cord that can fit more easily into the depth of the sulcus, followed with a larger size cord if necessary.
2. Using an instrument that is too large for inserting the cord can be injurious. Many anterior teeth are so small that if a large-size gingival retraction instrument is used, the tissue may be damaged. This is especially true for mandibular incisors (Figure 41.4).

   If too much pressure is used to place the cord, there is danger of severing the gingival attachment fibers. This causes eventual shrinkage of the gingival attachment, exposing the previously prepared margin. If the patient is seen for insertion of the restoration a short time later, the tissue may not have had time to shrink to its permanent position. Therefore, the restoration may be covered when it is placed but may become exposed sometime later.
3. A retraction cord or other material, or a chemical like zinc chloride that is too caustic to the tissue, if left on the tissue too long can cause permanent damage.
4. Leaving the retraction cord in the sulcus too long can create ischemia in the area.

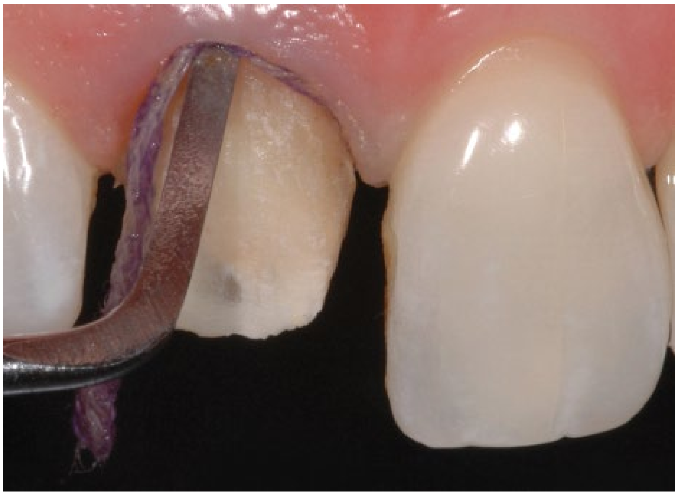


Figure 41.4 It is important to use a proper size cord and instrument when placing the cord to avoid unnecessary pressure and injury to the tissue. An interproximal carver is thin, flexible and works very well.

Figure 41.5 This is a good example of a proper retraction for a full maxillary arch impression showing no bleeding and adequate tissue displacement.

Remember that before a good elastic impression can be made, there must be no bleeding, and adequate marginal exposure is absolutely necessary (Figure 41.5).

Electrosurgery

This procedure can be especially useful when there is an overgrowth of tissue and just packing cord would not alleviate the problem and when simple retraction methods by the cord are insufficient. It is also helpful in situations where the tissue level is inconsistent with esthetics. A slight gingivectomy even at the tooth preparation stage will displace tissue and may also enhance your esthetic result. When using this method of retraction for anterior full crowns, extreme care must be taken to avoid loss of

Figure 41.6 **(A)** Electrosurgery was chosen to remove excess and inflamed tissue to allow healing before the final impression is made.

Figure 41.6 **(B)** Note tissue color and healing 24 h following the electrosurgery.

gingival crest height, which might prevent an esthetic result. The angle of the filament must be held with very special care when removing the inner surface of the gingival sulcus. Avoid removing more than 1 mm apical to the gingival margin. Figure 41.6A and B shows the type of gingival crevice that should be created by this method. After cutting is completed, the sulcus is cleansed with 3% hydrogen peroxide, either in a spray bottle or with cotton pellets. Although this should adequately control hemorrhage, retraction with cord can still be used in combination with electrosurgery. However, studies show that electrical retraction procedures can cause an appreciable loss of gingival crest height. For this reason, electrosurgery may not afford the best means of gingival retraction when examined in terms of gingival repair. However, if your patient's tissue is thick and fibrous rather than thin and transparent, then either electrosurgery or laser should be suitable to use. The downside to electrosurgery is the possible permanent shrinkage of gingival tissue. At all times, the most important consideration is to respect and preserve the biologic width.

The *bipolar technique* unit (Bident, Pearson Dental) is distinguished by not needing to have an external ground to place behind the patient. It cuts by molecular resonance, not by an advancing explosive spark that can produce both excessive heat and possible charring. There are two prongs that extend from the handle, but only one cuts, whereas the other acts as the ground. Being able to remove the excess tissue in a bloodless environment means you can make your impression immediately.

Diode lasers function by the absorption of light energy into the biologic tissue. All lasers perform by two functions: they either vaporize the target tissue or stimulate a tissue response. Tissue vaporization occurs as the temperature is raised to a vaporization point instantly and tissue components turn into a gas as the cells expand and explode. The tissue components that absorb the light energy are called chromophores. Water is considered a primary chromophore as the oral cavity is composed of 70% water. Other chromophores include hemoglobin and melanin, which play a minor role. Matching the wavelength of the laser with the chromophores in the target tissue is one of the primary considerations in selecting a laser.

An 810 nm diode laser is used specifically for soft tissues as its wavelength is best suited to be absorbed in the hemoglobin, melanin, and water that are present prevalently in the soft tissues. The diode laser has the ability to precisely cut, seal, and coagulate the lymphatic vessels, blood vessels, and nerve endings while vaporizing the target tissue. Any gingival tissue that is covering a tooth during preparation and impression can be easily removed and homeostasis achieved quickly with less trauma, giving improved and faster postoperative healing. Using a diode laser for gingival troughing of the subgingival preparations before impression is helpful, as it exposes the preparation margins and helps capture an accurate impression—free of bleeding.

Ideally, if cotton cord will adequately manage sufficient tissue displacement, then that is what we normally use. However, if there is diseased tissue or an abundance of tissue that needs to be displaced, then either the diode laser or electrosurgery can be utilized. The laser also coagulates as it cuts, for a clear and blood-free environment; it reduces postoperative sensitivity and inflammation by sealing nerve endings to stop the flow of histamine; it enables faster healing and less trauma to the tissue by cutting only micrometers deep; there is less chance of infection and more comfort for the patient, and better visibility for the clinician (NV Microlaser, DenMat) (Figure 41.7).

The laser is similar to electrosurgery, in that it cuts away the offending tissue. However, skilled clinicians can accurately remove just the amount necessary to make a good impression. Nevertheless, for a six-unit anterior tooth restoration, cotton cord may be more predictable with less chance of permanent gingival displacement.

Impression materials

Silicone impression materials

Addition silicone (polyvinyl siloxane, PVS) impression materials are most commonly used in the dental office, whereas the condensation silicones are primarily used in the dental laboratory for duplicating procedures.

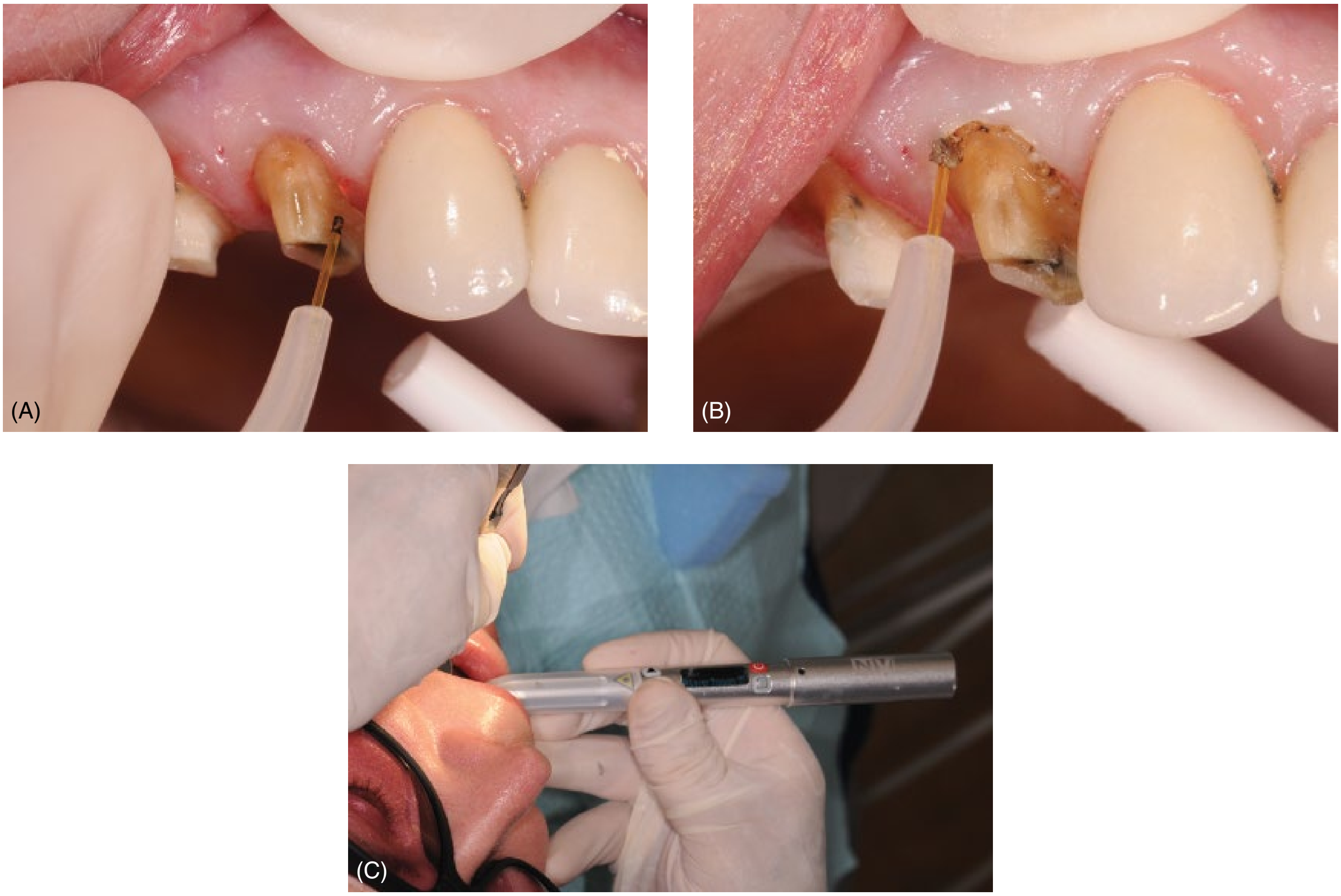


Figure 41.7 **(A–C)** When needed, the diode laser can be an effective instrument to create gingival troughing before final impression. The NV Microlaser (DenMat) is a lightweight, self-contained, programmable, and easy to use clinical laser.

Addition silicone

The material is supplied as two pastes or putties, one of which is the base and the other is the catalyst. Many consistencies are available, including light (syringe, wash), medium, heavy, monophase, and putty. In most instances the two pastes are mixed from a cartridge using an automix gun with static mixing tips or a dynamic mechanical mixer (Mixstar eMotion; 3M ESPE Pentamix 3) (Figure 41.8). Two-putty systems are usually mixed by hand kneading. The newest addition silicones contain nonionic surfactants that achieve increased wettability.

The addition reaction occurs between vinyl and hydrogen groups with no by-product being formed, so the addition silicones are dimensionally stable. If hydroxyl groups are present in the addition silicone, then a side reaction results in the formation of hydrogen gas. Some manufacturers add a hydrogen scavenger (platinum, palladium) to capture the gas for a short period of time so a die can be prepared.

Latex rubber gloves contain sulfur compounds that adversely affect the setting reaction of addition silicones. These compounds can be transferred to the prepared teeth and soft tissues during preparation of the tooth and placement of a gingival retraction cord. These compounds can also be incorporated into putties when mixed by hand. Use vinyl or nitrile gloves to avoid contamination. Rinse the preparation and soft tissues with 2% chlorhexidine to remove contaminants.

Condensation silicone

The material is supplied as a base and catalyst in the form of pastes or putty–liquid. Mixing of the paste–paste or putty–liquid systems is done by hand spatulation on a paper pad. A by-product is water or ethanol, the evaporation of which causes shrinkage. This shrinkage can be minimized by use of the putty–wash technique. The setting reaction is accelerated by moisture and heat.

Polyether impression materials

Polyether impression materials are supplied as light, medium, and heavy consistencies. Mixing is either done by hand, using auto-mix gun with a static mixing tip, or with a dynamic mechanical mixer. There is no volatile by-product. Increased temperature and humidity accelerate the setting time. Contamination with water can cause an expansion of the setting material and should be avoided.

Figure 41.8 Motorized automatic mixing unit (AUTOMIX 3 M). *Source:* Reproduced with permission of 3 M™ Company—Oral Care Solutions Division.

Properties and clinical relevance

There are a number of physical and mechanical properties that affect the performance of impression materials. A comparison of these properties for addition silicones and polyethers is given in Table 41.1.

Working and setting times

Working time is a measure of the maximum time available before the impression should be seated in the mouth. Working times of addition silicones vary from 40 s to 5 m with a typical time of 2–2.5 min. Polyethers have working times of 2.5–3.3 min.

Setting time is a measure of how long the impression must remain in the mouth before removal can occur. Setting times of addition silicones vary from 1 to 5 min, with a typical time of 2–4 min. Polyethers have setting times of about 3.3 min. The accuracy of an impression may decrease if the impression is removed from the mouth too early. A slight improvement in accuracy may result from leaving the impression in the mouth for an additional 30 s.

Detail reproduction and wettability

An impression material must reproduce small details and transfer these details to the gypsum die or cast. Detail reproduction is influenced by the viscosity of the impression material and its ability to wet the tooth structure and soft tissues, especially in the presence of moisture. Wettability is best with a hydrophilic impression material that forms a low contact angle (20–60°) with tooth structure. Poor wetting results in bubbles and voids, often requiring remaking of the impression. Addition silicones are formulated to be hydrophilic by the addition of surfactants or by modification of the polymer structure. Polyether impression materials are naturally hydrophilic.

Table 41.1 Comparison of Properties of Polyether and Addition Silicone Impression Materials

Property	Addition Silicone	Polyether
Working time	Very short–medium	Short
Setting time	Short–medium	Medium
Wettability of tissues	Good–fair	Good
Shrinkage on setting	Very low–medium	Very low–medium
Flexibility during removal	Low–very high	Medium–high
Elastic recovery	Very high	Very high
Tear energy	Low–high	Low–medium
Gas evolution after setting	Yes	No
Detail reproduction	Excellent	Excellent
Dimensional stability	Excellent–good	Good

Flexibility

Flexibility is a measure of the ease of removal of the impression from the mouth. An impression that is stiff may be locked into undercuts in the oral structure and be difficult to remove. Flexibility of addition silicones varies from low (<2%) to very high (11%). Flexibility of polyethers varies from medium (2.5%) to high (8.5%). The significance of knowing which material and its flexibility can be of the utmost importance. If you are making an impression of short abutments or crown preparations, the flexibility range is of little importance. However, if you are making impressions of larger prepared teeth and have undercuts then a more flexible material is quite important. Otherwise the impression material can latch into the undercut areas and be difficult or impossible to remove. In general, the polyvinyl siloxane materials will be the easiest to remove.

Elastic recovery

When an impression is removed from the mouth, it is subjected to tensile and compressive forces that could result in distortion. The set impression must be sufficiently elastic that it will return to its original dimensions with minimum distortion (<3%). Elastic recovery of addition silicones varies in the range 98.9–99.9%. Elastic recovery of polyethers varies in the range 98.2–99.7%.

Tear energy

Tear energy (tear strength) is important because the impression in the sulcus must resist tearing upon removal. Tear energy of addition silicones and polyethers varies in the range 0.4–2.2 kJ/m^2.

Dimensional stability

Dimensional change (shrinkage) occurs when an impression material sets and may increase during the time the impression is stored. At 24 h, the shrinkage of addition silicones varies in the range 0.08–0.42%. The shrinkage of polyethers varies in the range 0.07–0.27%. After 1 week, the shrinkage of addition silicones varies in the range 0.08–0.40%. The shrinkage of polyethers varies in the range 0.21–0.55%. Some addition silicone impressions are sufficiently stable that a second pour of gypsum can be made several weeks after the impression was made.

Manipulation of impression materials

There are a number of steps necessary to achieve a quality impression. Troubleshooting the impression after removal from the mouth can save time and money should the impression need to be remade. Our advice is to always make a backup impression in the event the laboratory injures the die. It may also be helpful to have an untouched backup model if there is a question about the fit of the final restoration.

Criteria for a good impression and troubleshooting tips are summarized in Table 41.2. Tips for the dental assistant and the clinician for improving impressions are listed in Table 41.3.

Selection of a tray

Trays are available in full-arch, quadrant, and double-arch varieties and are made of metal or plastic. Be sure to select a tray of proper dimensions and extension. A rigid tray is desirable to minimize distortion during the impression procedure. It is best to use a rigid tray even if the impression material itself is rigid. Double-arch trays are popular because they record both the preparation and the occlusion of the opposing arch. They are best used when recording the preparation of a single tooth. Occasionally, a custom-fitted tray will need to be premade in the event your stock trays do not adequately cover all the teeth. Even a very narrow arch may require a special arch-fitted tray. If your patient tends to gag easily, consider either using a lower tray on the upper arch, or cut out part of the palatal section on the upper tray. Finally, you may need to remove part of the linguogingival tray extensions of the lower tray if your patient cannot open their mouth very wide for easier removal when making the lower impression.

Table 41.2 Troubleshooting Impressions

Criteria for a Good Impression	Troubleshooting Tips
Impression is uniformly mixed	Make sure dispensing tips (base and catalyst) of cartridge are open.
Impression is supported by the tray	Make sure impression material is uniformly distributed in the tray.
Multiviscosity materials blend and adhere to each other	Make sure the low-viscosity material is recording the desired detail.
No major defects are visible	Make sure there are no voids or tears. When injecting the syringe material, leave the tip in the material to avoid trapping air.
Impression adheres to tray	Make sure the impression has not detached from the tray.
Occlusal relationship is registered	Make sure the double-arch impression recorded the opposing occlusion.
The tray is visible in the tooth	Make sure you do not press the tray preparation area so hard that you touch the tooth preparation or have “stops” in the tray.

Table 41.3 Tips for Improving Impressions

Tips for dental assistants

Apply the proper adhesive to the tray and allow it to dry completely.

Make sure the tips of auto-mix cartridge are open.

Minimize bubbles when loading the impression tray.

Pay attention to working times to achieve desired viscosity and detail.

Tips for clinicians

Select a tray of adequate size and extension. Ensure that the tray allows space for 2–4 mm of impression material. Provide occlusal stops if needed.

Be sure to rinse away the ferric sulfate solution, because it can interfere with the setting of addition silicone impression materials.

Seat the impression in a timely fashion. Minimize movement of the tray after seating to minimize distortion. Do not remove the tray too early to minimize distortion.

Remove the tray with a uniform motion to minimize distortion—do not rock or twist the tray.

Tray adhesive

Both addition silicone and polyether impression materials require a tray adhesive for metal and plastic trays. The adhesives vary with the type of impression material and are not interchangeable. Although some trays have perforations and other retention modes, use of a tray adhesive can minimize distortion when the impression is removed from the mouth. Be sure to allow the tray adhesive to dry before adding the impression material.

Impression techniques

Three common impression techniques are a single-viscosity (monophase) technique, a dual-viscosity (light-bodied/heavy-bodied) technique, and putty–wash (one-step or two-step) technique (Figure 41.9). Use of a preimpression surface optimizer (B-4, Dentsply) can be a help to gain greater detail and avoid any bubbles.

Special impression techniques

Occasionally, there will be a need to make impressions of specific areas that conventional techniques cannot do. For instance, when necessary to repair pontic areas of an existing bridge capturing the soft tissue is essential (Figure 41.10A–J). Also, there may be times when, after final impressions are made, an additional tooth may require extraction (Figure 41.11A–I).

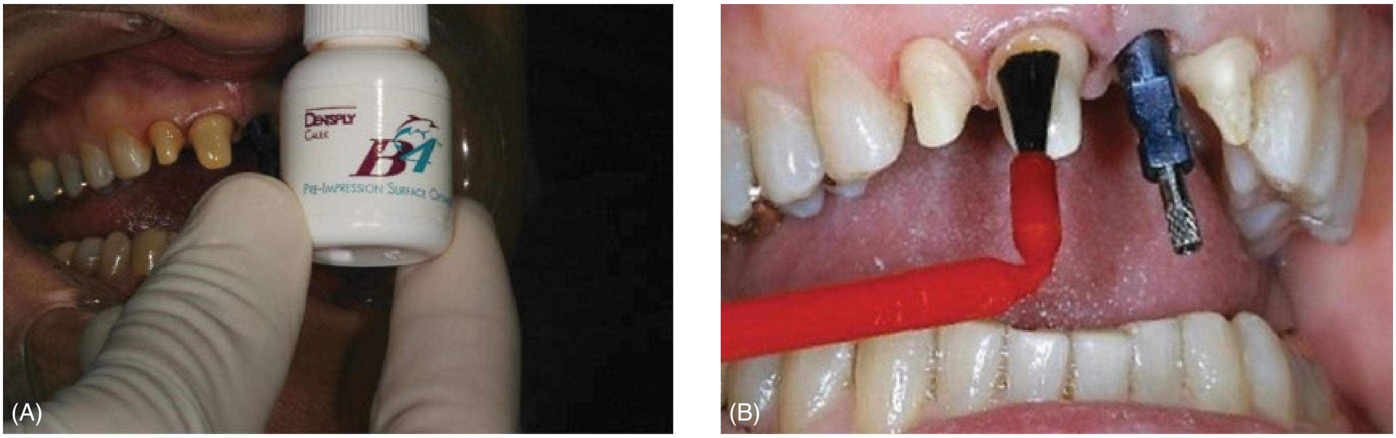


Figure 41.9 **(A and B)** A preimpression surface optimizer (B4, Dentsply Caulk) helps in gaining better sulcular detail free of bubbles.

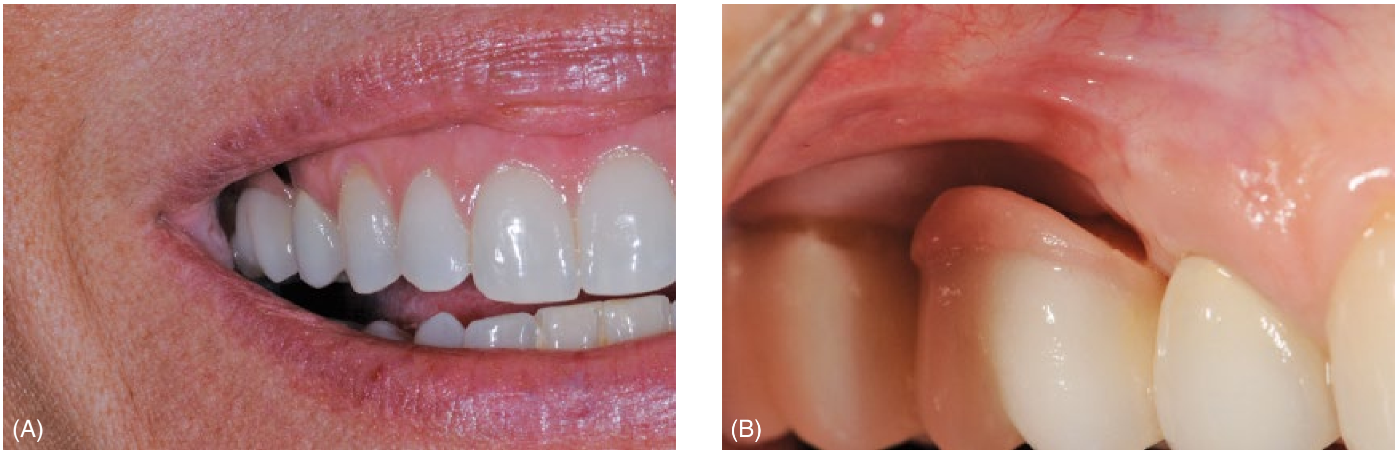


Figure 41.10 **(A, B)** Patient presented with tissue defect above a pontic of a three-unit fixed bridge which concerned the patient esthetically when she smiled.

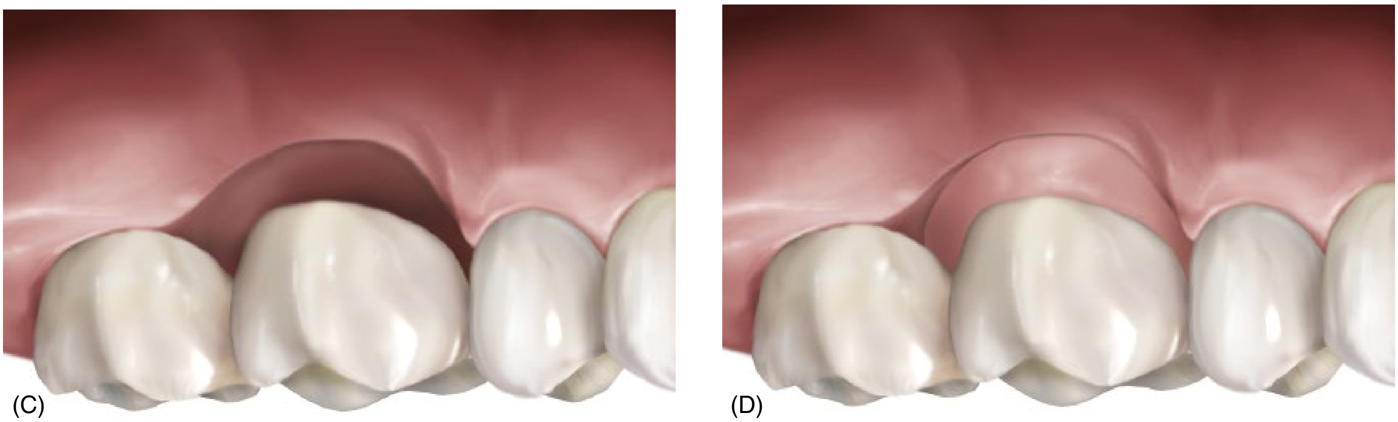


Figure 41.10 **(C, D)** To avoid replacement of the bridge, these diagrams illustrate the plan to create a pink porcelain gingival extension that could be bonded to the existing bridge.

Single-viscosity technique

A monophase impression can be made from either polyether or addition silicone impression materials but is most commonly made from medium-viscosity polyether materials. The shear thinning of these materials allows them to be injected into the preparation and placed into the tray with minimal slumping. This type of technique works best for capturing supragingival margins, since little or no pressure is needed to go subgingivally.

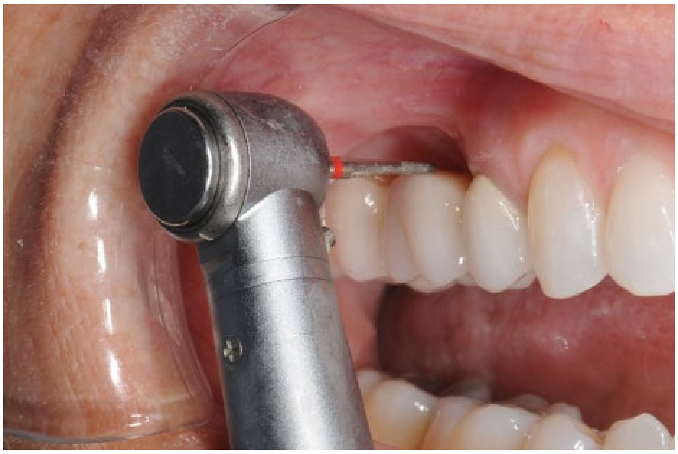


Figure 41.10 **(E)** The first step was to carefully remove the remaining gingival extension and create a platform where a new extension could be fabricated and bonded.

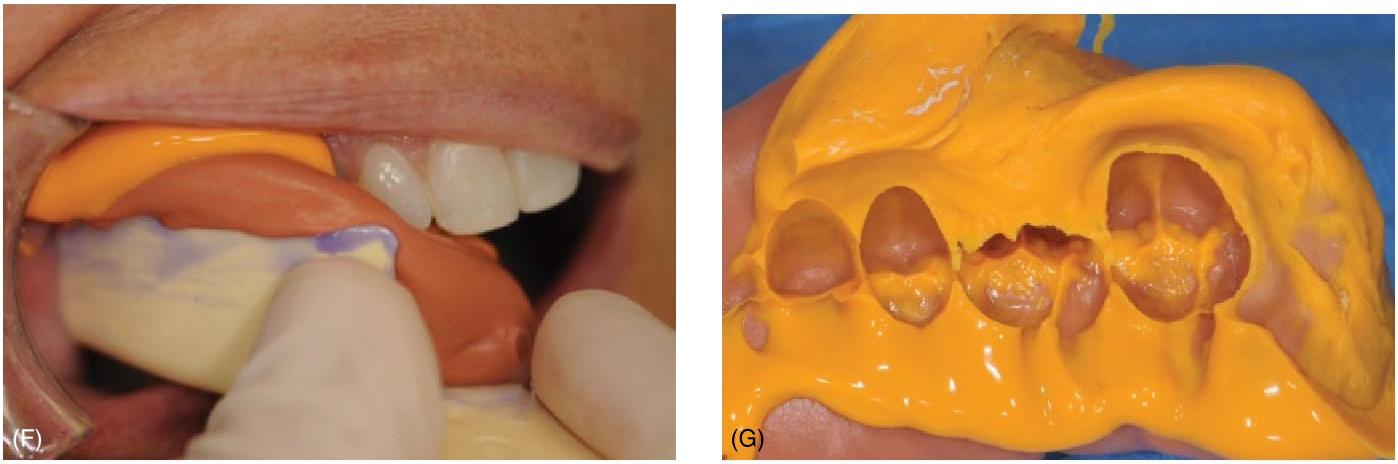


Figure 41.10 **(F, G)** A quadrant tray was partially sectioned so that a labial approach technique could be utilized, which allowed easy removal of the set impression material.

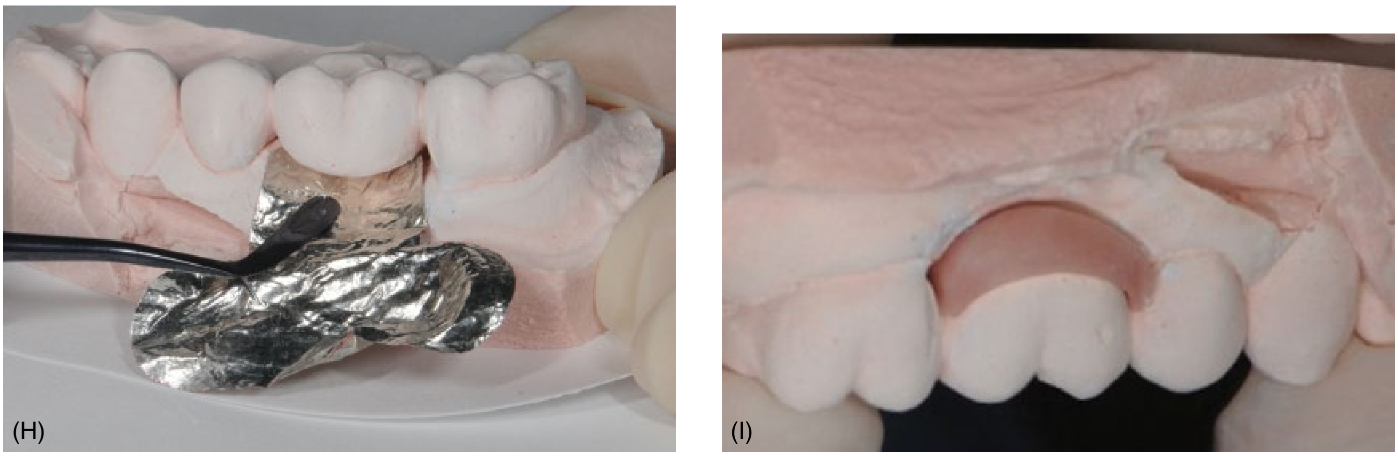
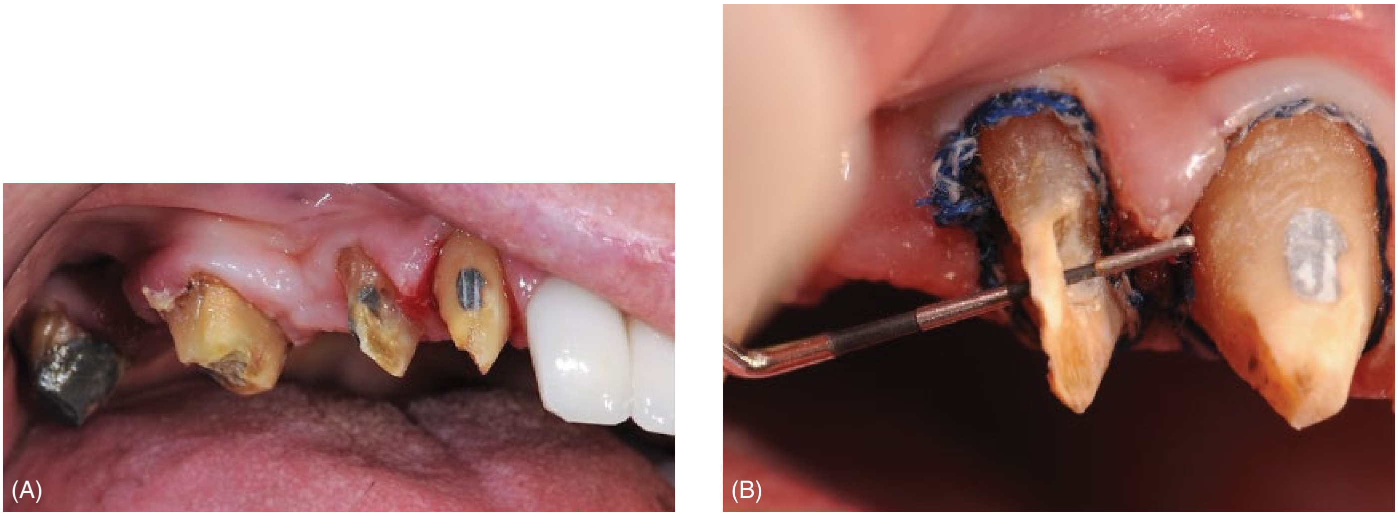


Figure 41.10 **(H, I)** The poured model clearly showed where the porcelain piece could be fabricated.

Figure 41.10 **(J)** A piece of dry foil was molded to the pontic area. This protected the tissue from the porcelain etch as well as kept a dry field as the porcelain extension was bonded to the bridge.

Figure 41.10 **(K)** The final result shows the pink extension bonded to place while allowing for the patient to be able to maintain the area using both dental floss and Hydro Floss oral irrigator.



(A)

(B)

Figure 41.11 **(A, B)** During preparation stage for full mouth complex rehabilitation, the maxillary right first bicuspid was found to be hopeless due to extensive decay and an endo-perio lesion.

Figure 41.11 **(C)** The tooth was extracted the same day that final impressions on the maxillary arch were made.

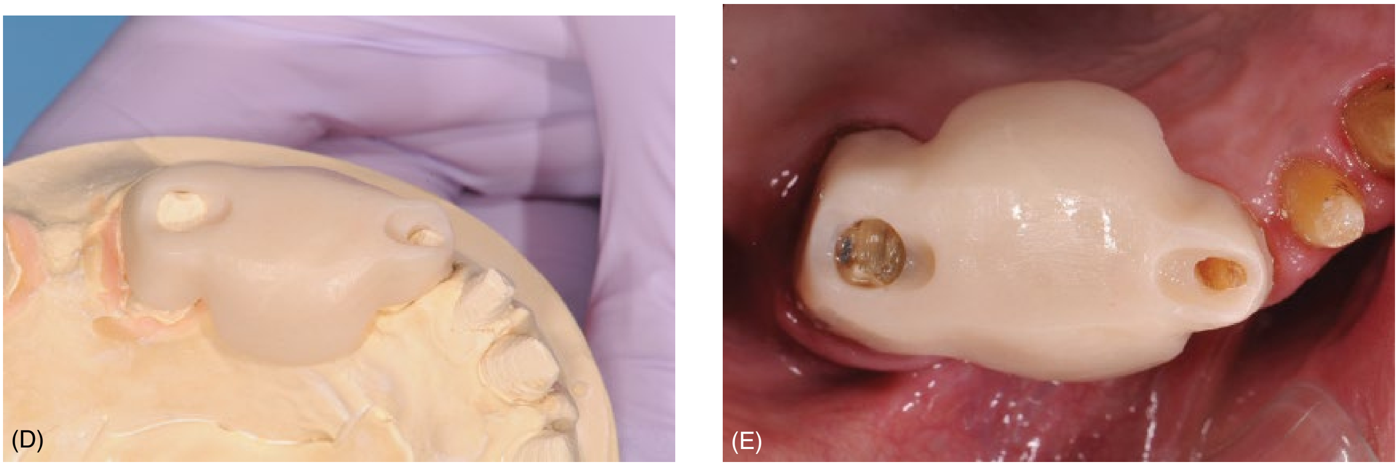


Figure 41.11 **(D, E)** To avoid remaking the entire impression at a later date, the laboratory fabricated a special form fitting tray to be able to capture the healed ridge.

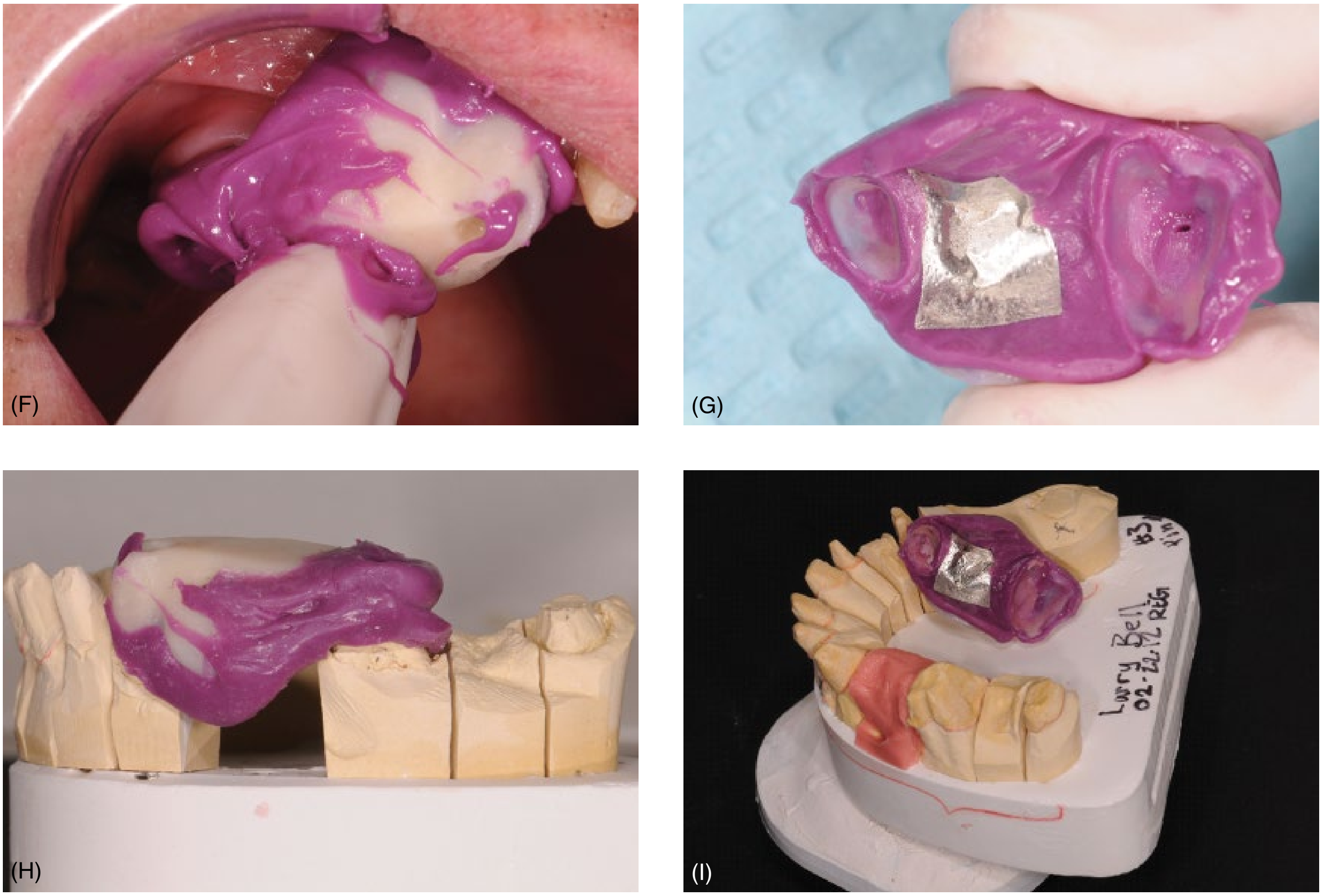


Figure 41.11 **(F–I)** The special tray allowed the impression tray to perfectly capture the healing ridge, which was transferred back to the model to pour and fabricate a new die for the healed pontic area.

Dual-viscosity technique

In this technique, a light-bodied material is injected with a syringe into the preparation. The clinician may want to gently blow the syringe material into the sulcus to verify coverage of all light body margins. At the same time, the heavy-bodied material is mixed, placed in the impression tray, and inserted in the mouth. Both impression materials bond and set together. Best accuracy is achieved with a custom tray. This technique works best when margins are at or just into the gingival sulcus, requiring little hydrostatic pressure.

Putty–wash technique

There are two basic versions using the putty–wash technique. In the first technique, the assistant mixes the putty material and depending on how many prepared teeth to capture the dentist begins to insert the syringe material (Figure 41.12A–F). The goal is to finish inserting the material at the same time as the tray is ready to go into the mouth. Failure to coordinate this time factor can cause inadequate blending of the putty/syringe material, resulting in possible voids or "folds" at the junction of the putty–syringe interface.

An alternative to this technique consists of air blowing the material into the sulcus. One advantage of this technique is to make certain no air bubbles are trapped around a margin. After the first layer is thinned via air blowing (Figure 41.12G and H), a second layer of syringe material is applied (Figure 41.12I and J), and then the tray with the putty material is pressed into place (Figure 41.12 K and L). It is also a good idea to place a layer of syringe material along the body of the putty material approximately where the teeth will be. Because timing is so important, try to utilize an extra assistant, technician, or hygienist to help you to blow the material when doing a full arch. A main benefit of either of the putty/syringe techniques is that the hydrostatic pressure you can achieve by pressing the tray to place helps you capture an excellent margin by recording to the base of the sulcus (Figure 41.12 M). Therefore, if you are using an all-porcelain margin or full shoulder, you need to capture the root extension just below or above the margin so the technician has a clear understanding of exactly where your margin is (Figure 41.13).

The second technique requires two steps in which a preliminary impression is made with the high-viscosity material or putty before the cavity preparation is made. Provide space using a thin plastic sheet. After the tooth is prepared, inject the low-viscosity (wash) material into the preparation and then reinsert the preliminary impression. Vents in the preliminary impression will minimize distortion as it is reinserted.

Figure 41.12 **(A)** A putty–wash technique will be used to impress this maxillary right incisor, which has been prepared for a porcelain veneer and tissue retracted with knitted cord (Ultradent).

Figure 41.12 **(B)** A standard fitted maxillary plastic tray has been prepared by cutting off the palatal part, which allows you to easily remove excess syringe material.

Figure 41.12 **(C)** The assistant has removed her gloves and washed her hands before hand mixing the putty material, which must be homogenously mixed with no streaks.

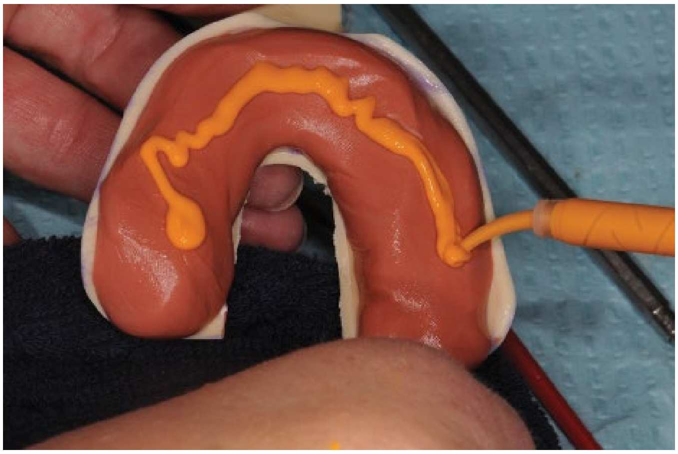


Figure 41.12 **(D)** Once the mixed putty is evenly loaded into the tray, the light body syringe material is applied to enhance binding of the light body to the putty material.

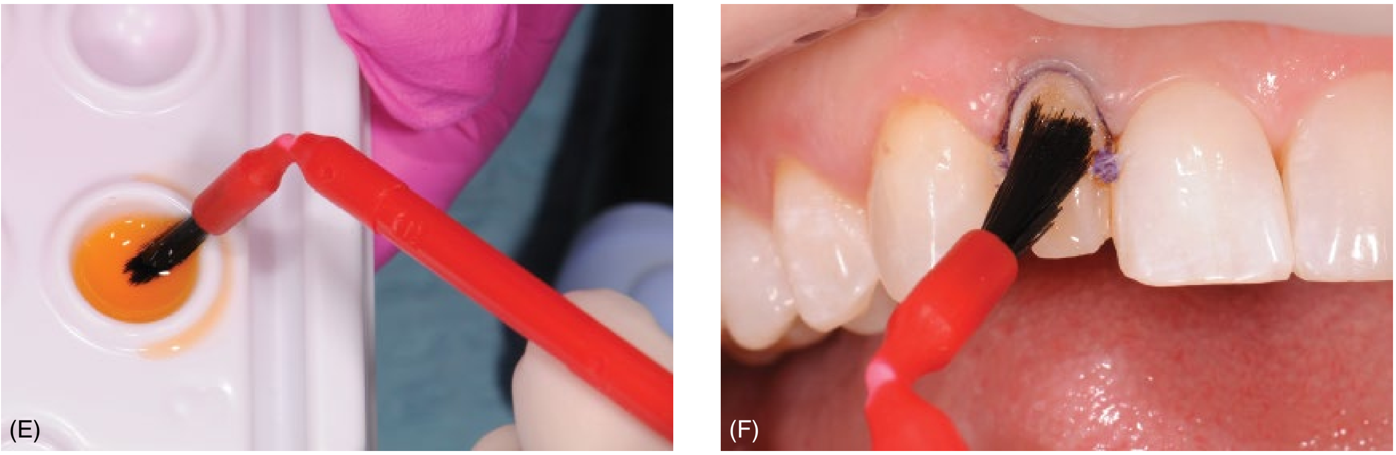


Figure 41.12 **(E, F)** As the assistant is mixing the putty material, the surface optimizer (B4, Dentsply Caulk) is applied to the prepared tooth as the cord is removed.

Figure 41.12 **(G)** A small amount of the light body material is first applied around the margins.

Figure 41.12 **(H)** Next, lightly apply air to make sure there are no bubbles and that there is even distribution into the sulcus.

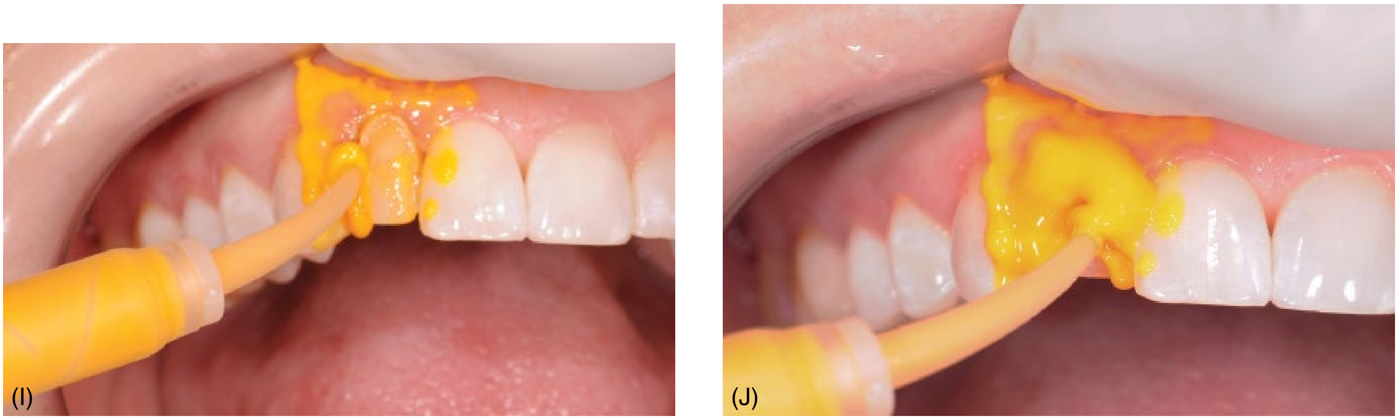


Figure 41.12 **(I, J)** A second application of the light body is applied all around the tooth.

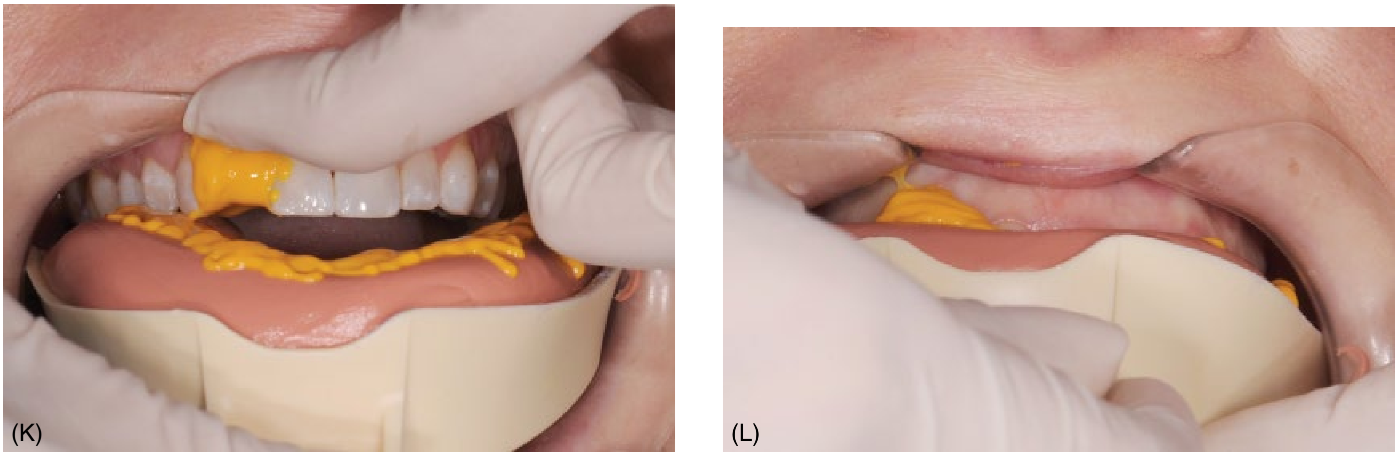


Figure 41.12 **(K, L)** The tray is carefully lined up with the maxillary arch and inserted using a slight vibrating motion with firm hydrostatic pressure. Be careful not to let the tray touch any part of the teeth as the tray is consistently held in place while the material sets. Once the material is set, the seal should be broken in the posterior area, and the tray should be removed in a firm and steady motion.

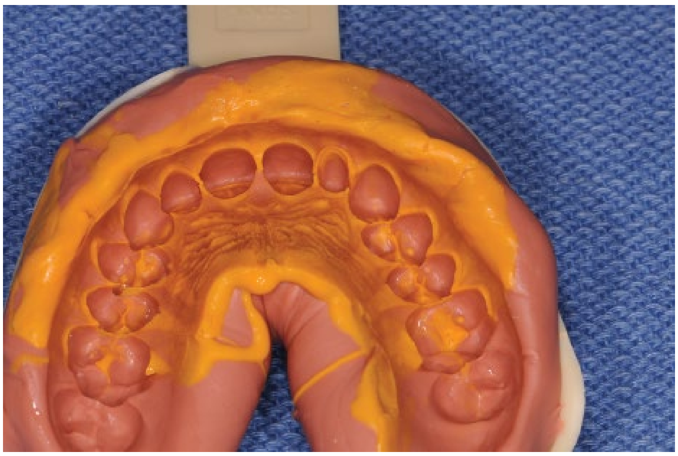


Figure 41.12 **(M)** The final impression shows the uniformity of the light body and putty material with no bubbles around the margin. Note the sulcular detail that was achieved.

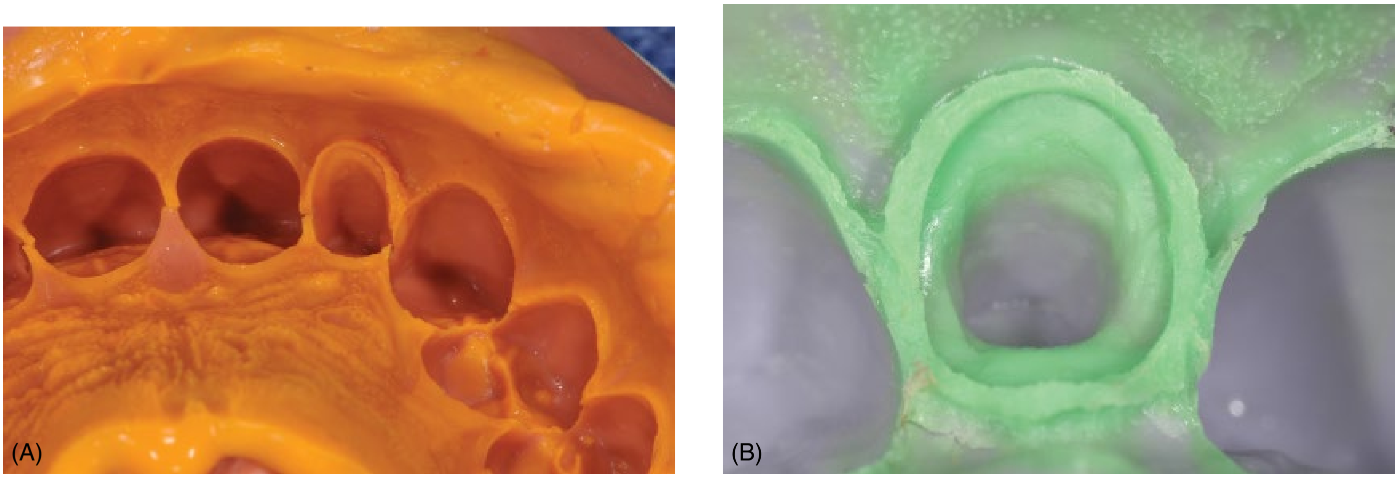


Figure 41.13 **(A, B)** This is a good example of capturing the root extension just above the margins so the technician has a clear understanding of where the margins are.

Removal and trimming of impressions

Although it is always preferable to make full-arch impressions, if there is an accurate impression but a slight discrepancy in an area it may be both feasible and important to make an extra quadrant impression which captures a perfect tooth impression of your abutment tooth or teeth. In this way the bite registration can be better made using the full-arch impression but the actual scanning or wax-up can be made of the quadrant impression for accurate margins.

Addition silicone and polyether impressions are accurate on removal as long as they have been allowed to set for the proper time in the mouth. Break the seal in the posterior area of the impression and then use a firm, steady motion to remove the impression. Trim unsupported areas of the impression before pouring the gypsum to minimize distortion.

Make multiple impressions

Once you have gone to all the time and trouble to make excellent preparations, retract the tissue, and make an impression, the last thing you or especially your patient wants is to have an accident in the laboratory causing you to have to repeat the last two procedures. Therefore, it is essential for you to have an accurate backup impression. This "extra" impression will allow you to pour an additional stone model whereby any questionable margins or possible inaccuracies can be double checked (Figure 41.14). In the event you are using one of the impressions to make your temporaries you will need three accurate impressions so that two can be reserved to construct the final restoration.

Disinfection of impressions

A variety of disinfectants is available, including neutral glutaraldehyde, acidified glutaraldehyde, neutral phenolated glutaraldehyde, phenol, iodophor, and chlorine dioxide. Addition silicone impressions can be disinfected by immersion following manufacturers' directions. Polyether impressions can change dimensions on immersion in some disinfectants, so only short times (2–3 min) in chlorine-type disinfectants are recommended for polyether impressions. Some clinicians prefer to disinfect polyether impressions by a spray and wipe technique.

Preparation of gypsum dies

Before pouring the gypsum die or cast, rinse the impression with water and then shake it to remove the excess water. Laboratory technicians will typically spray the impression with a surfactant to improve the wettability of the gypsum on the impression.

Other impression materials

Agar Hydrocolloid

Agar is an accurate impression material still used by a small number of dentists. It produces acceptable impressions if margins are exposed as a result of retraction or electrosurgery or if margins are supragingival. Agar has low tear strength and is susceptible to distortion with storage. Store the impression in 100% relative humidity and make the dies within the first hour.

Compound/copper band

The compound/copper band technique is useful when the preparation has a margin at the base of the sulcus. It may not be your preparation but an existing prepared tooth that you are faced with reproducing. Although an ideal solution may be crown lengthening, that may not be a viable esthetic or functional possibility. Therefore, the age-old technique of fitting an annealed copper band filled with soft compound may well be your best bet. Compound impressions are susceptible to distortion with storage, so prepare dies immediately.

Digital impressions

Digital impression systems allow the dentist to make a digital impression in place of a traditional elastomeric impression. Three of these systems (CEREC AC, PlanScan, CS 3500 Scanner) offer the option of in-office design and milling but also allow design and milling by dental technicians. Three other systems

Figure 41.14 **(A)** Back-up impressions are important, especially in cases involving multiple teeth, to be able to double check any questions of accuracy of the die system.

Figure 41.14 **(B)** Multiple back-up impressions are essential when a full-arch impression includes most or all the teeth in one arch.

(3 M True Definition Scanner, iTero Intra Oral Digital Scanner, TRIOS Color) produce digital impressions that require design and milling at a dental laboratory or milling center. All of these systems can produce models from their digital files.

Computer-aided design/computer-aided milling (CAD/CAM) can produce restorations directly from the digital impression data. Milling centers and dental laboratories offer these services. Restorations can be milled from a variety of materials, such as composites, feldspathic porcelain, leucite-reinforced ceramic, lithium disilicate ceramic, resin–ceramic, and zirconia. Wax patterns and acrylic provisional restorations can also be milled. The dental laboratory can use digitally produced models to produce restorations by traditional methods. See Chapter 46 on CAD/CAM.

Tips on digital impressions

Digital impressions require clear visualization of the margins. Tissue must be managed properly by exposing the margins to capture clear, accurate images. Deep subgingival margins can be recorded more easily with an elastomeric impression. If desired, the impression or the model can then be scanned. Digital impressions can be time consuming in large cases involving multiple teeth.

Mounting casts

In order to proceed with the fabrication of the crowns, the dental laboratory technician will require accurately mounted casts. Depending on the practitioner's preference and the case complexity, a facebow transfer may be performed to mount the upper cast. Figure 41.15A–E demonstrates the steps of this procedure.

Once the upper cast is mounted, the lower cast will be related to it with an interocclusal record. The following section reviews several techniques and considerations.

Interocclusal records (bite registrations)

Occlusal registration

Perhaps as essential as obtaining an excellent impression is obtaining an accurate interocclusal record. According to Dawson, "the price for inaccurate bite records is wasted time,

Figure 41.15 **(A)** A rigid polyvinylsiloxane bite registration paste is applied to the bite fork.

Figure 41.15 **(B)** The bite fork is centered in the mouth and fully seated over the preparations until the material is fully set.

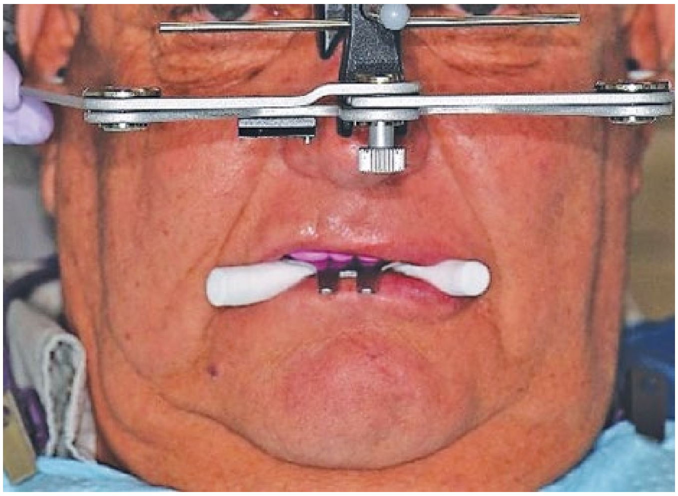


Figure 41.15 **(C)** The interpupillary line leveling rod is set parallel to the patient's eyes and the nasion and facebow adjustment screws are tightened.

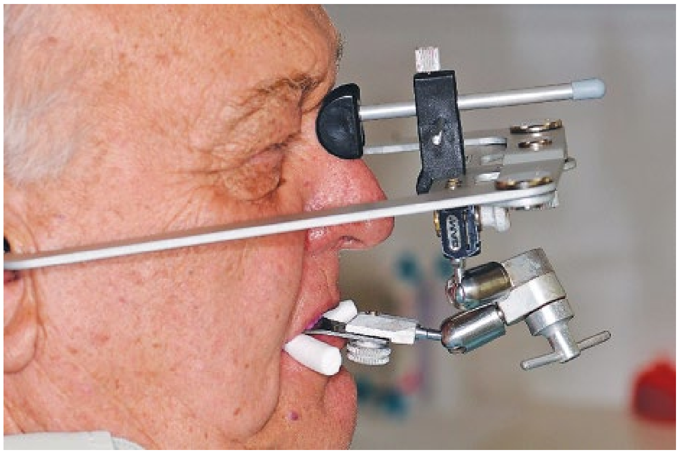


Figure 41.15 **(D)** The toggle is stabilized with one hand while tightening the toggle with the other hand. Make sure the toggle is fully tightened before removing.

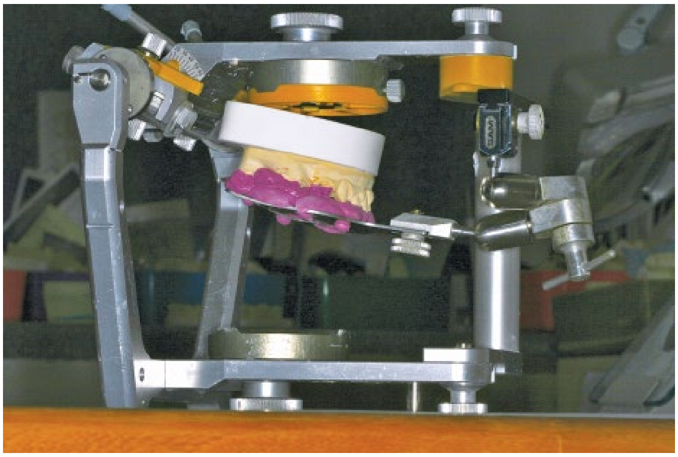


Figure 41.15 **(E)** The cast is seated in the facebow transfer, which is adapted to your semiadjustable articulator of choice (pictured: SAM 3).

compromised results, and a lack of predictability."[2] He continues by specifying five criteria for accuracy when creating these records as follows:

1. The bite record must not cause any movement of teeth or displacement of soft tissue.
2. It must be possible to verify the accuracy of the interocclusal record in the mouth.
3. The bite record must fit the casts as accurately as it fits the mouth.
4. It must be possible to verify the accuracy of the bite record on the casts.
5. The bite record must not distort during storage or transportation to the laboratory.

Many of these errors were common when practitioners were routinely using waxes for their records. At present, most practitioners use a rigid polyvinyl siloxane material that is specifically made for interocclusal records (Regisil, Dentsply; Blu-Mousse, Parkell). These materials are so accurate that it is imperative that the detailed anatomy is trimmed so that it can be accurately transferred between the casts and the mouth.

There are many techniques that may be employed with these materials. Goldstein describes a predictable technique if the vertical dimension is not being altered.[3] After preparation and before placing the registration material, determine where occlusal stops exist on opposite sides of the arch. Verify this with thin, 0.0005″ (0.0127 mm), occlusal registration strips (Artus Corporation, Englewood, NJ). The assistant should stand behind the patient and place the occlusal registration strip in the verified place and have the patient close into occlusion. The dentist then syringes the bite registration material around the preparation without the patient moving. If the strip loosens, the patient has moved or opened slightly and the bite registration will not be accurate (Figure 41.16A–C).

The safest sequence of therapy to maintain and record the patient's existing occlusal relationship is to use existing landmarks, either by measurement or by quadrant tooth preparation. For instance, if the entire arch is to be restored for full crowns, the teeth in one of the posterior quadrants should be prepared

Figure 41.16 **(A)** When vertical dimension is not being altered, verify occlusal stops in the areas of the arch not being treated with thin, 0.0005″ (0.0127 mm), occlusal strips (Artus Corporation) and have the patient bite into centric. The assistant stands behind the patient as the dentist syringes the bite registration material around the preparations and other teeth.

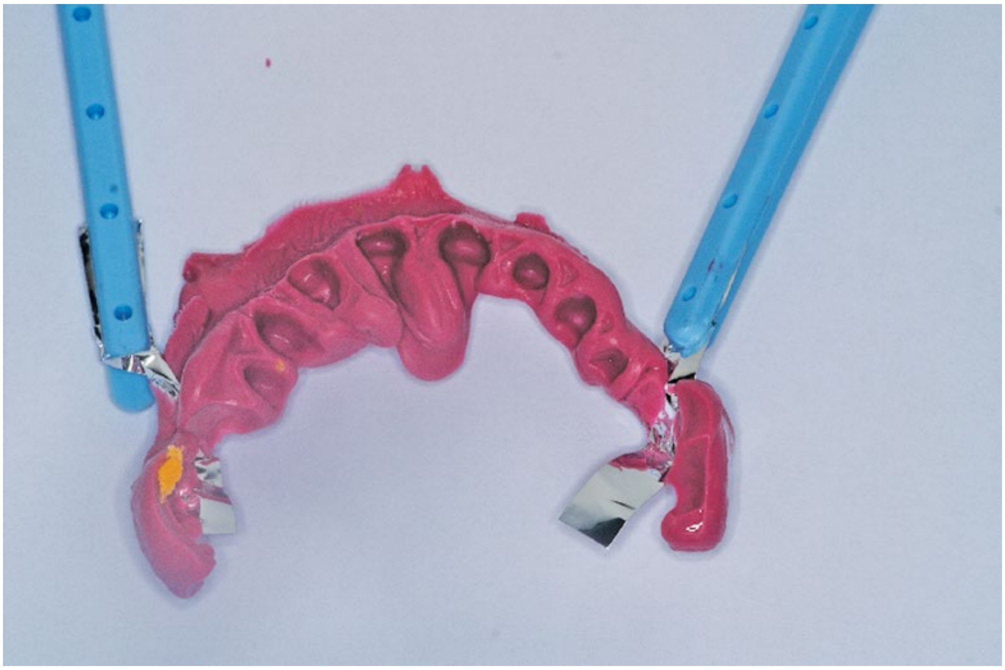


Figure 41.16 **(B)** An example of a correct bite registration where the patient firmly held the occlusal strips in place without opening.

first, and then accurate quadrant bite registrations should be made to be used later (as seen in Figure 41.18A–F). Next, the opposite posterior quadrant of the teeth should be prepared and the procedure repeated using the previously recorded quadrant bite registration. If the opposite posterior quadrant is used, then the anterior stops can help to preserve accuracy in the second bite registration. Then the anterior teeth would be prepared and both of the previously recorded quadrant bite registrations would be in place and linked together by incorporating the prepared anteriors. In this fashion, the patient's original occlusal relationship is preserved and can be used for mounting the models in the laboratory.

Another technique that has proven effective in the authors' practices is the employment of acrylic (GC Pattern Resin LS, GC America, Inc., Alsip, IL) to create anterior stops (Figure 41.17). Nevertheless, the occlusal registration strips verify that the patient is accurately closing into any remaining posterior centric contacts. For a procedure that involved the reconstruction of a full arch with no alteration of the occlusion, the dentist should try to temporarily leave the second or third molars untouched and reconstruct them at a later date. Thus, the dentist always has a posterior natural occlusal stop to verify the occlusion throughout and even after seating the final restorations.

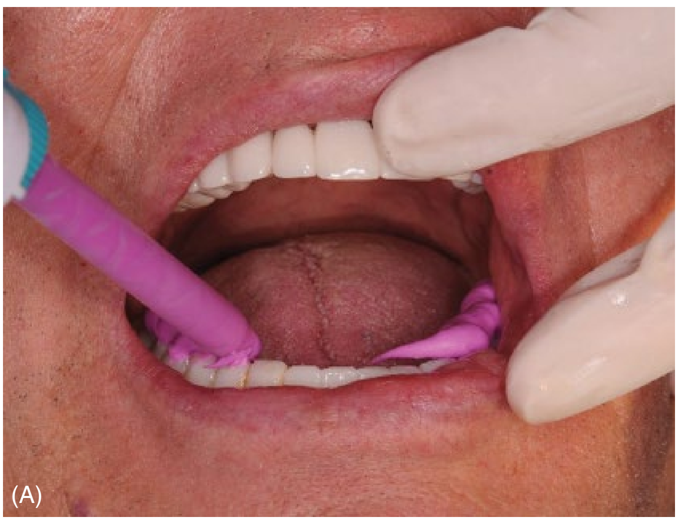
Figure 41.16 **(C)** If your patient is under sedation, it is important to both hold the occlusal registration into place and support the patient's chin to make sure no opening occurs.

Figure 41.17 Acrylic resin (GC America) can also be used to create anterior stops in full arch cases to help secure an accurate bite registration. Blu-Mousse bite registration material, (Parkell).

Full-arch final bite registration

The final bite registration procedure is based on the accuracy of the temporary bite registration technique described earlier. First, a central bite registration is made that will be cut and used to make certain the patient closes into centric occlusion on each side as the opposite side is finally recorded (Figure 41.18A–F).

If the vertical dimension is being increased, you will not be able to maintain these centric stops, and an alternative technique should be employed. There are techniques described in the literature in which an increase in vertical can be transferred to the casts. When the patient's desired vertical has been established, through temporaries or a removable splint, a dot is drawn on the patient's nose and another on the patient's chin. The distance between the two dots is measured extraorally, with calipers (Dentagauge 2, Erskine Dental). The calipers are kept at this position, and this vertical dimension is verified throughout the occlusal registration process. For additional stability, the anterior segment of temporaries can be removed, Vaseline applied to the prepared anterior teeth, and a composite or acrylic jig can be fabricated over the prepared teeth. When the posterior temporaries are removed, the anterior jig can be seated and the occlusal registration material can be placed on the remaining prepared teeth.



(A)

(B)

Figure 41.18 **(A, B)** Final bite registration is made by alternating the temporary restorations in place from one side to the other. The first step is to make an accurate full-arch bite registration in centric using rigid bite registration material (Regisil® PB™ Bite Registration Material by Dentsply).

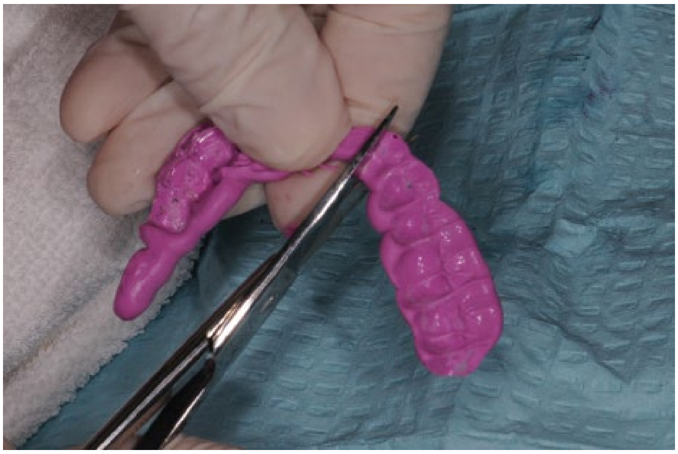


Figure 41.18 **(C)** The centric bite registration is cut so that each side can work independently.

Figure 41.18 **(D)** With the temporaries in place on the right side plus using the segmented bite registration index, a bite registration is made on the left side maxillary and mandibular crown preparations.

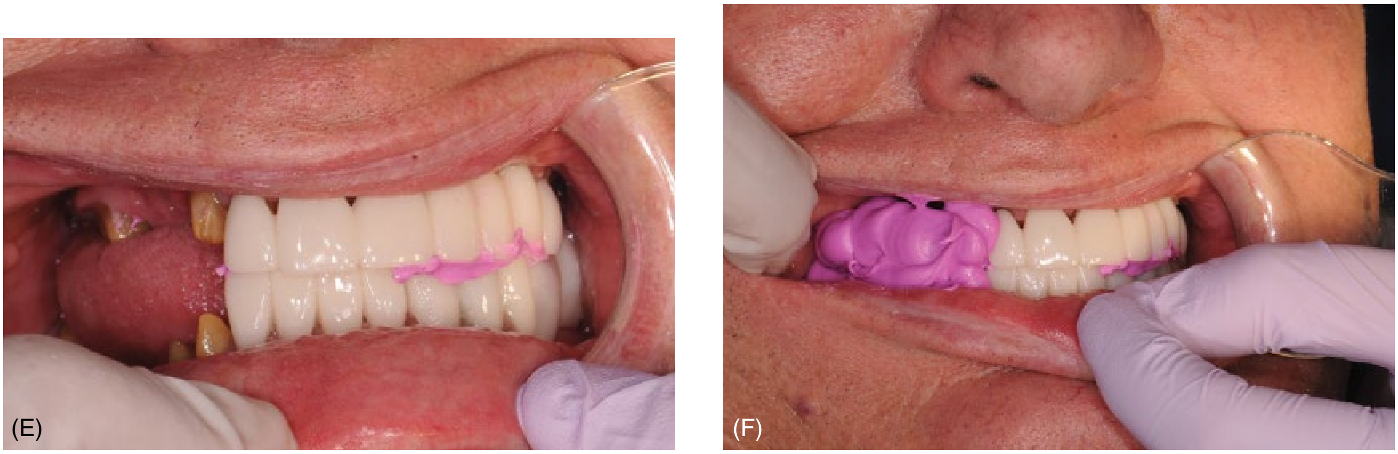


Figure 41.18 **(E, F)** Next, the same procedure is repeated by using the temporaries and centric bite registration on the left side to obtain an accurate registration of maxillary and mandibular crown preparations on the right side.

Alternatively, if the practitioner is utilizing a joint-based position, any number of anterior deprogrammers may be used. These include a Pankey jig, a Lucia jig, a leaf gauge, an NTI appliance, or a similar anterior deprogrammer fabricated by the practitioner. These allow the temporomandibular joint to be seated in the centric relation position without occlusal interference. Once the restorative position has been determined, a mark is drawn on the appliance where the lower incisors contact. The appliance remains in place as the registration material is placed on all the occlusal surfaces. The position can be verified by confirming that the lower incisors are still touching the mark once the bite registration material has set. The appliance can be seated on the upper cast at the time of mounting to provide an anterior stop.

If the practitioner elects to use a digital impression, the same techniques may be used with different bite registration material. Specially formulated polyvinyl siloxane materials are made with opaque fillers to prevent scatter when scanning the registration (Virtual CADbite, Ivoclar). Alternatively, the occlusal surface of the prepared arch and the opposing arch can be captured with the digital impression system (iTero, Lava Chairside Oral Scanner C.O.S.). The interocclusal relationship can then be determined digitally.

Summary

The impression step is perhaps the most critical in the entire process of creating esthetic restorations. Perfect-fitting prosthetic restorations are so dependent on accurate impressions. It is so costly to have an improper fitting crown or fixed partial denture, and this cost is certainly magnified when doing extensive prosthetic treatment. So it is essential that the entire dental team be aware that materials are technique sensitive. The same holds true when making an occlusal registration. Meticulous technique must be achieved in order to avoid complication in proper form and arrangement of the final restoration.

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Chapter 42 Esthetic Temporization

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Chapter Outline

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Although patients tend to be concerned about their looks before treatment, this concern may increase especially after tooth preparations have been made for prosthetic restorations. The concern may be justified unless temporary restorations are made to be esthetically acceptable as well as functional. The old rule of not making the temporary esthetic because it need not be as good as the final restoration is unjustified. Esthetics and function are both served by well-made, carefully fitted temporaries, especially since a continuous attractive appearance is important to most every patient. The esthetic temporary satisfies the patient, and a satisfied patient will allow the dentist the time necessary to construct a successful final restoration. In contemporary dentistry, provisional restorations provide more than an intermediate functional and protective covering device for teeth that have been prepared for an indirect restoration. They are the second step after the trial smile to more clearly achieve the patient's esthetic goals, and to learn what is ideal occlusally, phonetically, and esthetically. If a trial smile was not utilized, then the temporary must take its place and the final ceramic restorations should not even begin to be constructed until the patient is completely happy with the temporary with shade, shape, and arrangement. Otherwise, there is no assurance your patient will be happy with your final result, which can be a costly gamble for you to make.

This chapter will focus on various techniques for achieving an esthetic temporary veneer, crown, or splint, the benefits derived from spending time in the provisional stage, and how to communicate the most important information learned in this stage to the laboratory to be replicated in the final restorations.

Esthetic uses of temporization

The main purpose of any form of temporary coverage is to provide maximum protection for the tooth and surrounding tissues while the final restoration is constructed. It is also critical for the

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gingival margins and proper interproximal contours to be correct to avoid periodontal problems which can potentially affect your final restorations. Many dentists utilize the dental assistant to make the temporaries, so make sure they are well trained so they can create perfect margins. There are also several other important functions that temporization can and should offer. The most important criteria for selecting the right type of temporary restoration include patient comfort, treatment time, laboratory cost, occlusal clearance, ease of removal, durability, and ease of modification.[1]

Trial smile

If a preliminary trial smile was created for your patient, then the temporary restoration should mimic the changes requested by your patient. If this step was not done, then esthetic imaging and a good wax-up should be shown to the patient if changes are scheduled to be made. However, the temporary restoration will also act as a "trial smile" for your patient, giving them adequate time to voice any changes requested (Figure 42.1A–E). This process could take considerable time, depending on (1) the extent of changes, (2) your patient's ability to make decisions, and/or (3) the need to revise or make changes to the temporary. We have had patients who make up their mind quickly and yet others that have taken months to finally be pleased enough to move on the final restorations. For these reasons, it is advised to have your laboratory hold any efforts to create the restorations until your patient states they like the form, shape, and color of your temporary. If only slight adjustments are required then you can usually assure the patient that you will incorporate those changes in the final restoration. We have seen instances where patients wanted longer anterior teeth but at the final porcelain try-in insisted on major changes, including shortening of the crowns, only to see the beautiful inlaid incisal porcelain disappear. Thus, always add any desired length to the temporary rather than assume your patient will be happy with you or your ceramist's estimate of how much length to add in the final restoration.

Sometimes it is necessary to exaggerate the appearance of intended alterations during the temporary stage. For instance, in cases where incisal length will be added to make the patient look younger, it may be wise to make the temporary slightly longer than the intended restoration. Patients may react cautiously to longer teeth, and feel they are too long. Overlengthened acrylic temporary teeth can easily be cut back to a more acceptable result as the patient wishes. Then the laboratory can proceed with much more accurate incisal length.

Decision making

Ultimately, patients must make a decision, and hopefully it will be the right one for them. The entire dental team wants the patient to be happy with their restoration, so it is a joint effort to help that patient arrive at the decision-making process in an orderly, nonrushed manner. The benefit of temporary restorations is that they can help your patient to both see and feel the planned final restoration in order to judge it. Wearing provisionals helps to understand what is possible both functionally and esthetically and offers patients an opportunity for involvement in making modifications before the final restorations are constructed.

Despite all your best efforts, there may be times when your patient does not listen to your advice and makes the wrong decision. This is especially why *you must make it perfectly clear before beginning on the final restoration that if the patient later changes their mind and wants the restorations done over, the financial responsibility will be totally their own* (Figure 42.1A–E).

When you plan on making major esthetic changes, such as opening vertical dimension, you may want to plan on not taking final impressions until you are certain your patient is both functionally and esthetically pleased. Sometimes this can take up to 3 months or more during which adjustments may be required. With the temporaries in the mouth you can determine how far from the margin the interproximal contacts should be placed and if the patient can clean with the new tooth contours.[2] It is rare that a patient does not have some modification in mind. Often these modifications are subtle, easy to perform, and can pertain to tooth contours or embrasure shapes. At times the patient's esthetic goal cannot be achieved; if so, explain why it cannot be done before it is sent to the laboratory instead of after the fact, which might sound like an excuse to the patient.[3] In general, there will almost always be limitations to each patient's problems, so the sooner the patient understands and accepts this fact the better.

If you are making indirect temporaries that will be worn for extended periods of time, you should make multiple accurate impressions that may also be suitable to construct the final restorations, since there may be a good chance these impressions may suffice as the final impressions. However, the chances are there can be tissue or other changes that may require you to make new impressions for the final restoration. So, it is advisable to take as much time as possible between the temporization stage and the impression for the final restoration, as changes can take place in gingival, pontic, and marginal areas. When this happens, the temporary restoration can be altered to take care of the discrepancy. If a fixed partial denture is being replaced, there may be hypertrophied tissue. If this is the case, allow enough time for shrinkage and adjust the temporary accordingly. If the patient suggests any esthetic change, this and any other alterations should be done before the new final impressions or try-in appointment.

Tooth movement

In some cases, temporary restorations become a critical element in the treatment process and may be in place for several months or years. Long-term temporization is necessary in cases when patients require orthodontics or periodontal surgery.[4–8] If defective crowns are present and need to be replaced, a long-term temporary should be placed to allow the patient to complete orthodontics prior to completing the final restoration, ensuring a better final result than if the final restoration was completed prior to orthodontics.[3] If a tooth is broken and does not have an existing crown present, it is generally better to restore the fractured tooth with direct composite, have the orthodontics completed, and then complete the definitive restoration.

Figure 42.1 **(A)** This lady presented to her original dentist to improve her smile.

Figure 42.1 **(B)** These are the temporary restorations the dentist made for her.

Figure 42.1 **(C)** Although the final ceramic restorations were functionally excellent, they did not satisfy the patient's esthetic needs, so she came to our office to see if we could improve her smile.

Figure 42.1 **(D)** New temporary restorations were created to mimic her smile when she was younger. It is important for patients to wear temporary restorations long enough so any esthetic changes can be made before the final restorations are fabricated.

Figure 42.1 **(E)** After wearing the temporary restorations for 3 months, the patient felt secure in having the final crowns fabricated and delivered. The patient was very pleased with her final smile and stated that we exceeded her esthetic expectations.

Phonetic concern

Whenever arch forms or the relationships between maxillary incisors and the mandibular incisors are modified, the patient's ability to pronounce certain sounds may change.[2,9] For instance, leaving 1–2 mm between the closed upper and lower incisors may lead to the "lisping S" because of the inability to limit the airflow between upper and lower teeth.[3] However, most difficulties in speech are temporary and easy to adapt to. If not, the lingual of the maxillary incisors can be built out to help close the gap. Major changes in the lower arch involve the patient's tongue getting used to the new position, and at times this could be a problem requiring additional visits to solve the problem.

Wearing temporary restorations provides a patient with a chance to feel the changes in occlusion between the teeth and any phonetic changes that have been created. If the patient cannot adapt to the changes the dentist has created, it is vital to know this and make the needed corrections prior to sending the case to the laboratory.

Protection

In addition to being both esthetic and functional, provisional restorations protect the pulp from chemical, thermal, and mechanical irritants and protect the prepared teeth from caries. The sedative properties of cements containing eugenol can help promote the formation of secondary dentin and relieve the hyperemic response that occurs after operative procedures.

Eugenol does have one disadvantage: it tends to react unfavorably with both acrylic and composite resin and may interfere with any future addition or repair of the restoration. Thus, if the temporary restoration will be worn for an extended period of time you may choose to use one of the temporary cements that does not contain eugenol.

It is essential that the temporary restoration provides all the marginal support, not only for the tooth, but for the surrounding tissues. Otherwise, tissue damage that could well prevent any type of esthetic result can develop before the final restoration is placed.

The correction of damage due to a poorly fitting temporary often necessitates surgical alteration of tissue and may leave an unattractive result. For this and many other reasons, it is absolutely essential to construct a well-fitting, attractive-looking temporary restoration that maintains interproximal contact.[4] The temporary restoration must protect the tissue, otherwise the gingiva may become inflamed and become both a functional and esthetic failure around the final crown or bridge (Figure 42.2A–C).

The establishment and maintenance of an environment conducive to periodontal health is dependent upon the anatomy of the temporary restorations. Coronal contours must provide convexities that can deflect food from the gingival crevice. Proper embrasures protect the interdental papillae and underlying alveolar bone. Margins that approximate the finished restoration are essential for gingival health.

Requirements

There are many forms and types of temporary crowns and fixed partial dentures. Regardless of the interim temporary, certain principles must be followed to insure a successful restoration.[5] The temporary must provide adequate esthetics and a healthy

Figure 42.2 **(A)** This patient left her original dentist due to the poor esthetics and ill-fitting temporaries that made her gums sore and bleeding. She felt that if that was the best the dentist could do then she needed to find a new dentist.

Figure 42.2 **(B)** Esthetically improved and well-fitting temporaries were made that allowed the tissue to heal. During this time, an esthetic evaluation of the patient showed the patient how her smile could be enhanced by including more of her anterior teeth in the final restoration.

Figure 42.2 **(C)** The patient was pleased with her final ceramic restorations, which were much more proportionate than what had initially been planned.

environment for the prepared teeth and surrounding structures. It must be retentive but easy for the dentist to remove; it must be comfortable to the patient and work as an insulator and sedative for the underlying pulp. It should also be economical—with respect to the dentist's time and the patient's expenses. The temporary restoration best suited for function, economy, and esthetics is either a composite resin or acrylic crown or bridge that can be easily changed and fitted with correct crown contours for the patient. In the case of a nonvital tooth, be careful of the type of temporary cement you choose. Remember, the nonvital tooth will tend to be more brittle and could fracture when removing the temporary crown or bridge, so either use a softer cement or put a small amount of Vaseline in the harder cement mix, which will help you remove the temporary when necessary. Always have your patient hold hot water in the mouth to "loosen" or soften the cement bond and then either carefully tap or remove it with hemostats or special removal pliers in a vertical motion.

Specific types of temporization

Computer-aided design/manufacturing

This chapter features some of the most popular means of constructing temporary restorations. However, one of the newest and most accurate is via computer-aided design/manufacturing (CAD/CAM). This technique does require advanced planning, but the results can be most impressive. If you have a milling unit in your office it becomes an easy solution to scan your preparations and mill the designed temporary. However, if you need to send the scanned preparations to a laboratory in your vicinity it could still be sent back to your office within the day. My suggestion is to use the temporary/temporary technique described later in this chapter to keep the tissue from invading your margins during the waiting time.

An alternate technique, still using an outside laboratory, is to have them create the CAD/CAM temporary without final margins in advance. This would require you to finalize the temporary chair side.

Vacuform technique

The type of restoration used routinely for temporization of fixed restorations is either a quick-cure acrylic or composite resin made with the vacuform process. It can be used for making temporaries directly in the mouth or indirectly as a removable prosthesis (Figure 42.3A–J).

If fabricated intraorally, the clear vacuform matrix allows you to see exactly what is being formed in acrylic or composite. Any spaces or bubbles can be dealt with before the material is hardened. If necessary, realign the material to achieve more accurate margins. This improves the chances for future esthetic success by minimizing gingival irritation. Also consider filling in any bubbles or voids or even adding to the crown with flowable composite resin. This can be quite helpful if your temporary is shy of occlusion.

Figure 42.3 **(A)** Preoperative view of patient's old restoration.

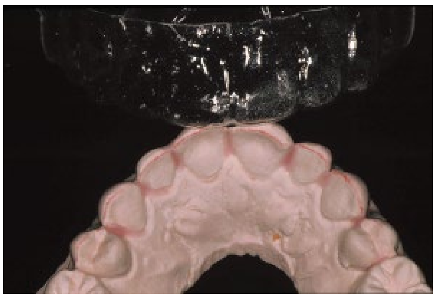

Figure 42.3 **(B)** Vacuform clear matrix fabricated on wax-up model and quick-set model poured after preparing the teeth.

Figure 42.3 **(C)** Applying cold-curing acrylic mixture into egg shell.

Figure 42.3 **(D)** Gently press incisally on the prepared model.

Figure 42.3 **(E)** Allow excess to escape from the vacuform essix matrix.

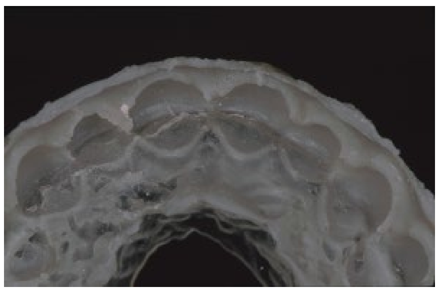

Figure 42.3 **(F)** Essix matrix and set acrylic become one, now ready to trim excess with diamond bur and disc to finalize removable temporary for porcelain veneers.

Figure 42.3 **(G)** The essix removable temporary being placed intraorally.

Figure 42.3 **(H)** Retracted view of the final porcelain veneers and crowns in place.

Figure 42.3 **(I)** Final smile of patient postoperative view.

Figure 42.3 **(J)** Final result headshot.

Temporary veneer requirements

The first requirement for temporary veneers is to consider the length of time the temporaries will need to be worn. In fact, if little or no enamel is prepared and the turnaround time is short, will a temporary restoration be necessary?

Direct bonding

For a single veneer the best and easiest method is to directly bond the temporary with composite resin (Figure 42.4A–E). Tooth shades are easier to match, and there should be no problem with the temporary staying in place even with a 1 mm etch. Temporaries for multiple teeth may be quickly made utilizing either a vacuform matrix or a silicone index for more detailed anatomy, especially if you have first constructed a good wax-up model. Cementing the temporaries can be more problematic because your typical temporary cements tend to break down quickly, especially with patients who are not careful with their eating habits. However, you must also be careful when selecting more durable cements even when not etching the tooth preparations because some can be difficult to remove. If the tooth is nonvital then you should cut the temporary restoration off rather than risk a fracture of the prepared tooth.

Figure 42.4 **(A, B)** In cases of single-veneer temporization, to better ensure the temporary stays in place, first spot etch the center of the tooth and rinse thoroughly.

Figure 42.4 **(C–D)** Direct bonding of the composite resin will serve as the temporary.

Figure 42.4 **(E)** The patient was happy with the esthetics, shade, and fit of the temporary veneer.

Figure 42.5 **(A)** This photographic model wanted to improve her smile with 10 maxillary porcelain veneers.

Indirect technique

The best method to have maximum esthetics and fit is to have the laboratory construct the temporary veneers (Figure 42.5A–G). These will no doubt be joined for greater stability and can either be removable for easy cleaning or cemented in place (Figure 42.5H). Detailed instructions about how to clean and change eating habits are best printed out. In the event you feel the need to etch a small patch of enamel (1–2 mm) and use a temporary resin cement, or even flowable composite make sure you remove all aspects of the resin before trying in the final porcelain veneers. At times it will be necessary to combine both full crowns and veneers in a single indirect temporary for maximum esthetics (Figure 42.5I–K).

Temporary splinting

Composite resin treatment splinting

Immediate stabilization of loose teeth can be done using either acrylic or composite resin combined with preimpregnated glass fibers. This technique is an economic interim solution either before or after final treatment (Figure 42.6A–L). The advantages are immediate immobilization of all teeth, to be followed by any other treatment necessary while the teeth are stabilized. In postorthodontic cases where veneers will be used, if the teeth eventually begin to separate, lingual splinting with a fiber/composite technique can be quite helpful (Figure 42.6A–L).

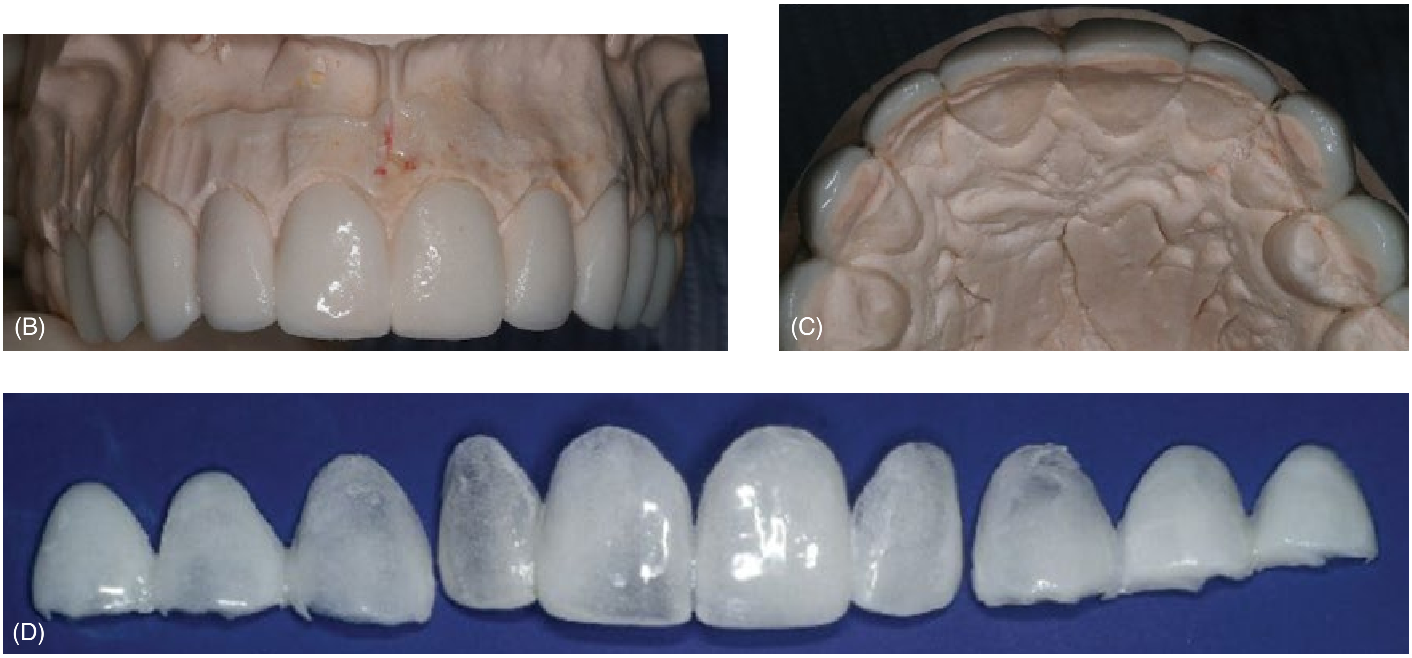

Figure 42.5 **(B–D)** Full-arch impressions were taken using polyvinyl siloxane and the temporary veneers were constructed in the laboratory in three sections.

Figure 42.5 **(E)** After fitting and patient approval, the three sectioned temps were bonded to the teeth with a tooth colored flowable composite.

Figure 42.5 **(F, G)** The final result was esthetically pleasing enough that the model was able to continue with her photo shoots during the 3 weeks it took to construct her final veneers.

Figure 42.5 **(H)** The best method to have maximum esthetics and fit is to have the laboratory construct the temporary veneers joined for greater stability.

Figure 42.5 **(I)** Full crowns on the maxillary centrals and laterals plus more conservative veneer preparations were done for this patient.

Figure 42.5 **(J)** Because esthetics and retention of the temporaries was of major concern for the patient, an indirect temporary connecting the crowns to the veneers was made.

Figure 42.5 **(K)** At the time of the final seating of the restorations, the temporary was removed. Note the microleakage that occurred in the veneer area.

Figure 42.6 **(A)** This patient had a removable orthodontic appliance (Invisalign) to improve her malocclusion as well as to close the space between her right cuspid and lateral. Porcelain veneers were then placed, but the space continued to open.

Figure 42.6 **(B)** A new Invisalign tray was fabricated to help close the space. However, the space continued to open during the day as soon as the patient would remove the orthodontic appliance.

Figure 42.6 **(C)** Both porcelain and enamel are etched.

Figure 42.6 **(D–F)** Next, a layer of flowable composite is applied, followed by application of the fiber material (Dentapreg). After polymerization, the cover strip is peeled away.

Figure 42.6 **(G)** Occlusion is checked with microthin red articulating paper.

Figure 42.6 **(H)** Occlusion needs to be carefully adjusted, especially on the opposing arch to avoid thinning out the bonding splint.

Figure 42.6 **(I)** Gingival contouring can be done using an eight-blade carbide finishing bur (ET4-Brasseler, USA).

Figure 42.6 **(J)** Final finishing is done by using impregnated polishing points (Illustra, Brasseler, USA).

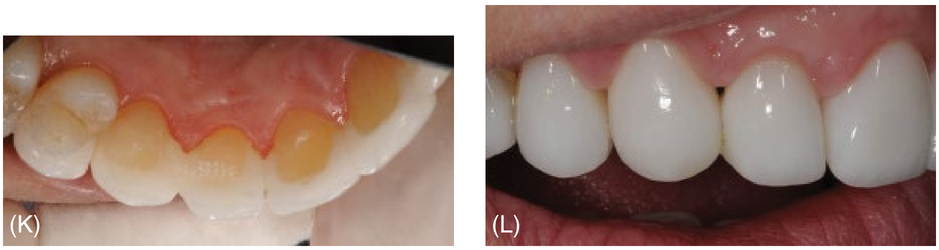

Figure 42.6 **(K, L)** The occlusal view shows the bonded splint in place maintaining space closure.

When temporary splinting is performed with composite resin, several factors must be considered. Fractures can occur unless an adequate thickness of resin is placed both labially and lingually. Since proper gingival embrasures must be maintained, it is important to trim and reopen these areas when finishing resin splints.

The A-splint for provisional immobilization

The A-splint provides all of the benefits of provisional immobilization of teeth not deformed by caries without requiring the subsequent restoration of these teeth with full-coverage techniques. The use of the A-splint does not preclude full-coverage reconstruction when indicated. Acrylic splints have been advocated for use as a transitional fixed appliance until a more permanent restoration or surgery is completed.

When using full-coverage acrylic splints, the most common error is the failure to create an environment conducive to health and to maintain this condition for a reasonable time. The A-splint is an alternative to full coverage that can aid in establishing and maintaining health and esthetics. It is simple, reliable, esthetic, and economic. Most importantly, the A-splint can be used in those patients for whom full-coverage fixed splints may not be indicated.[3]

An A-splint can be used in cases that require the following:

1. Immediate immobilization of seriously mobile teeth.
2. Total stability of teeth and contiguous periodontium undergoing periodontal therapy.
3. Stabilized arch integrity following treatment for elimination of crowding or diastema.
4. Vertical stabilization to help prevent extrusion of unopposed teeth.
5. Stabilization and retention of functionally repositioned, periodontally treated teeth.

The advantages of using an A-splint are:

1. The technique requires minimum tooth preparation and no impressions or models.
2. The operative procedure is direct and may be completed in one visit.
3. "Hairline" proximal anterior diastemas are eliminated.
4. Acrylic denture teeth may be added to the splint to replace missing anterior teeth.
5. Optimum accessibility helps the patient maintain good oral hygiene.
6. Adequate accessibility and security of total immobilization during periodontal procedures is provided without impinging on the interproximal tissues.
7. Total provisional immobilization of teeth with minimal clinical hazard is provided for at least 1 year; but owing to their temporary nature, these splints should be replaced or repaired every 18 months to 2 years.
8. An entire segment or any part of a segment may be secured at one sitting.

The technique for using the A-splint is as follows:

1. Approaching from the lingual aspect, cut a horizontal channel at the level of the contact points with a small inverted cone diamond. The channel should extend mesiodistally through, but not beyond, the proximal marginal ridges of the two approximating teeth. Undercut the preparations in order to provide adequate retention for the splint.
2. Isolate the teeth and insert base for pulp protection.
3. Etch the preparations and a 1 mm extension on the enamel margins with 50% phosphoric acid.
4. The wire to be used can be hard-drawn, deeply knurled, or serrated, dead, gold, round wire in a gauge equal in thickness to the preparation, or braided or serrated stainless steel ligature wire. The wire is cut to lengths matching the channels created.
5. If using acrylic, the pieces or wire are immersed in a self-curing acrylic monomer. Monomer is carefully painted into the undercuts of the channels with a sable brush.
6. The channel is half filled with beads of polymer powder. It is critical to avoid trapping air bubbles.
7. Seat the prepared wire into the channel so that it rests below the cavosurface margin.
8. Overfill the channel by adding monomer and powder in small additions.
9. As soon as the filling material loses its glisten, coat it with a lubricant to prevent the monomer from evaporating prematurely.
10. An adequate acrylic mask should be provided labially at the proximal contact point levels (when indicated) to assure good esthetics in the final restoration. Next, finish the restoration and polish.

Clinical case 42.7: Splint for posttreatment stabilization

Problem

A female patient, aged 35, was referred by the orthodontist for posttreatment anterior stabilization. For economic reasons, the patient wanted an attractive treatment splint to avoid crowning.

Treatment

The A-splint was chosen for its esthetic and functional advantages. Splinting was to be accomplished from maxillary cuspid to cuspid. First, the lingual surfaces of the teeth were polished with prophylaxis paste to remove the stain. Mesial and distal channels were prepared, and bases were inserted where necessary to protect the pulps, as outlined in the technique. Quick-curing acrylic was placed according to directions, and the section of serrated steel wire that had been cut along the diameter of the channels was inserted. Acrylic was added around the serrated steel wire. Anterior splinting was accomplished by doing first one side and then the other, and then finally connecting both sides with the serrated steel wire in the center.

Result

An esthetic type of splinting has been shown through the use of the A-splint (Figure 42.7A–E). The radiograph in Figure 42.7E show the results 5 years later. Note in Figure 42.7D and F–H the patient has also inserted her artificial interdental tissue appliance.

Figure 42.7 **(A)** This 35-year-old female was referred by the orthodontist for post-treatment anterior stabilization to avoid crowning her teeth.

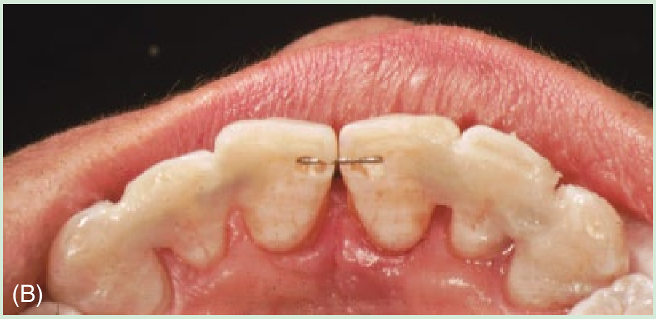

Figure 42.7 **(B, C)** Approaching from the lingual aspect, a horizontal channel at the level of the contact points was cut using a small inverted cone. A-splinting was accomplished from maxillary cuspid to cuspid to achieve a functional treatment.

Figure 42.7 **(D)** After splinting, no evidence of the metal reinforcement can be seen.

Figure 42.7 **(E)** Radiograph showing result of splinting 5 years later.

Figure 42.7 **(F–H)** However, the patient objected to the interdental spaces, so an artificial acrylic interdental tissue appliance was fabricated to help the patient achieve a more esthetic smile.

The following is an alternate technique:

1. After etching, coat the tooth with a bonding agent and polymerize with ultraviolet light for 30 s or use a self-etching bonding agent.
2. Place 1.5 mm of material in the floor of the channel in a preselected shade of composite resin.
3. Place the prepared wire into the channel so that it rests below the cavosurface margin. Then polymerize the material in the same manner as above for 1 min.
4. Slightly overfill the channel with additional material and polymerize again.

After the resin sets, flash is removed, and contours are restored. Special attention should be directed to the embrasure areas to assure accessibility for cleaning. Finish and polish as indicated for the particular material. Clinical case 42.1 illustrates the esthetic use of the A-splint.

Temporary restorations

When doing extensive 8–14 unit temporary restorations it is important to preserve the margins obtained during the impression stage, otherwise the tissue can collapse and cover the margin before you can finalize the temporary restorations. Thus, Goldstein created "The Temporary Temporary," or an immediate interim temporary restoration. To do this, first make a stone model from the original wax-up, and then make a vacuform matrix of the wax-up. Next, trim the vacuform matrix carefully, with 1 or 2 mm resting on the gingival tissue, which is necessary to obtain a good seal and to help properly seat the matrix. This step is especially helpful if the teeth have been built-up with wax, and thus not permitting a tooth-borne stop for the placement of the matrix. This matrix can also be valuable earlier as a try-in over the prepared teeth to make certain there is sufficient clearance all around.

After determining the successful fit of the matrix, use the automixing syringe to inject C-silicone material (Fit Checker, GC) into the teeth (Figure 42.8A and B), and then carefully and accurately seat the matrix over the teeth (Figure 42.8C). Wipe off the excess material and allow it to harden. It is important to not remove the interim temporary until it is time to seat the final provisional restoration(s) so it will stay in place.

With this technique, the patient not only has protection from sensitivity, but also is not toothless. Another advantage of creating a "temporary–temporary" restoration is allowing the patient to eat lunch consisting of either a soup or smoothie for nourishment while the final temporary restoration is being constructed in the laboratory. Do not underestimate the value of using a tooth-colored material, because this will be the first time the patient can visualize the new restoration (Figure 42.8D and E). The material we have found to esthetically work best for the insertion is a white vinyl polysiloxane (Fit Checker, GC America) although other manufacturers' vinyl polysiloxane material will do. The reason for preferring the white material is because it also permits the patient to see themselves with a much whiter tooth color than the final temporary shade will be. This is important because a patient who had very dark teeth may initially feel uncomfortable when they see such a bright white shade. So, using a very white shade in the interim provisional restoration helps mentally prepare the patient for the final light temporary shade. It is important to note that Fit Checker sets rapidly, so load and seat the matrix as quickly as possible. See also how accurate the margins look after removing the splint (Figure 42.8E).

A secondary function

There is another potentially valuable use for the interim temporary restoration, so be sure to save it after removal. At the try-in appointment, if there will be delay in making changes, you can place the interim temporary to maintain the gingival tissue. At the final seating of full-arch crowns or fixed partial dentures, if using a resin-modified glass ionomer cement, it is best to cement the crowns in quadrants because of the extremely rapid set time of these types of cements. The main concern with this technique is the necessity of keeping the resin-modified glass ionomer cement off the adjacent abutments, otherwise it may become difficult to fit the restorations in the adjacent segment. This step is where the interim provisional restoration has a secondary use. Cut off the segment being cemented, and place the adjacent part of the interim temporary back in place. This will protect the margin and axial walls of the remaining teeth, reduce sensitivity, and maintain the next segment so it is ready to be cemented.

Interim temporary methods construction

By far the most detailed direct method of constructing a temporary restoration that can accurately duplicate the incisal embrasures, interdental anatomy, and surface created in the wax-up is by using a Siltek® matrix. Make sure you scallop the labial edges just beyond the gingival margins to allow for easier removal. Fill the teeth to be restored with the approximate shade of composite resin and press the matrix accurately to place and wait until the matrix material sets before removal (Figure 42.9A–I).

Indirect Siltek method for implants

The Siltek matrix can also be utilized in construction of an indirect temporary restoration. This can be especially helpful in fabrication of implant temporaries (Figure 42.10A–G). When matching temporaries to adjacent natural teeth it is always best to do this indirectly (Figure 42.10G).

(A)

(B)

Figure 42.8 **(A, B)** Creating the "temporary-temporary" restoration. After determining the successful fit of the matrix, use the automixing syringe to inject silicone material into the vacuformed matrix.

Figure 42.8 **(C)** Seat the matrix over the teeth and wipe off the excess material and allow hardening.

Figure 42.8 **(D)** It is important for the patient to wear the interim temporary to avoid sensitivity of teeth. Also, by using a tooth-colored material, the patient can visualize the new restorations for the first time.

Figure 42.8 **(E)** Note how accurate the margins look after removing the matrix.

Figure 42.9 **(A)** A full-arch temporary splint was to be fabricated after making multiple polyvinyl siloxane impressions of the arch.

Figure 42.9 **(B)** A Siltek matrix was fabricated using the wax-up of the diagnostic models.

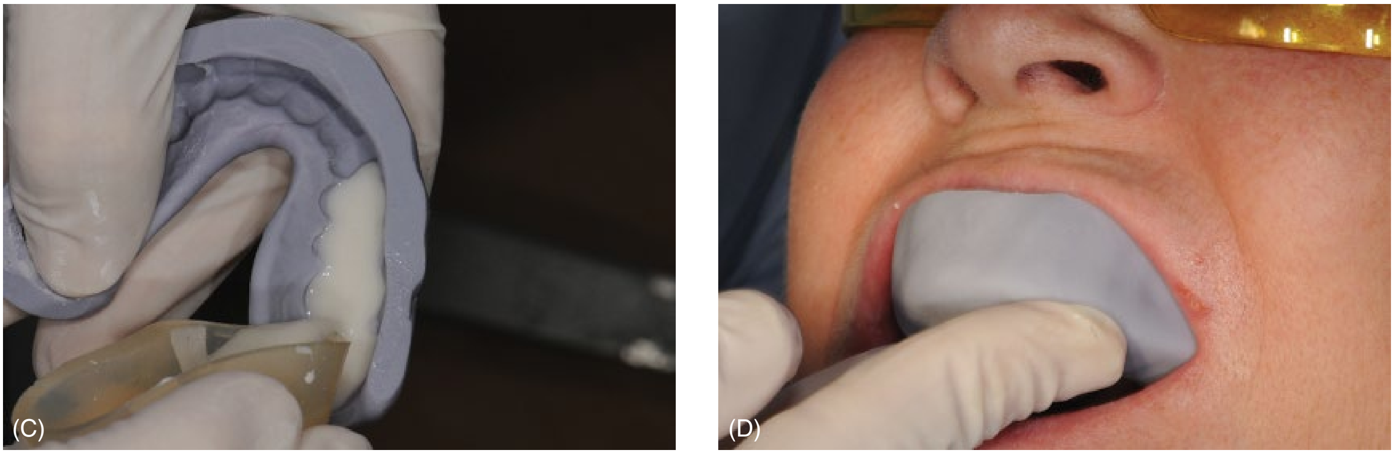

Figure 42.9 **(C, D)** Acrylic was mixed to a flowable consistency and poured into the matrix and immediately placed into the mouth for the upper right side of the preparation.

Figure 42.9 **(E)** Note the marginal accuracy as the temporary is made in separate sections.

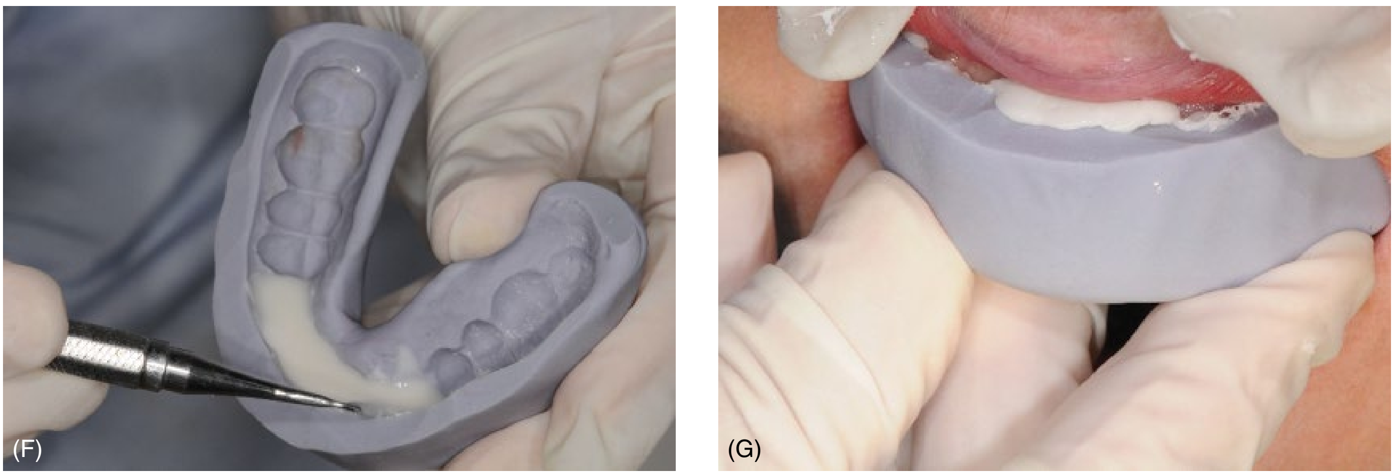

Figure 42.9 **(F, G)** Finally, the anterior section of the temporary was fabricated.

Figure 42.9 **(H, I)** Final result of the temporary can be seen. Note that although the gingival heights were not the same throughout the arch, this was not an esthetic concern for the patient because of her medium lip line.

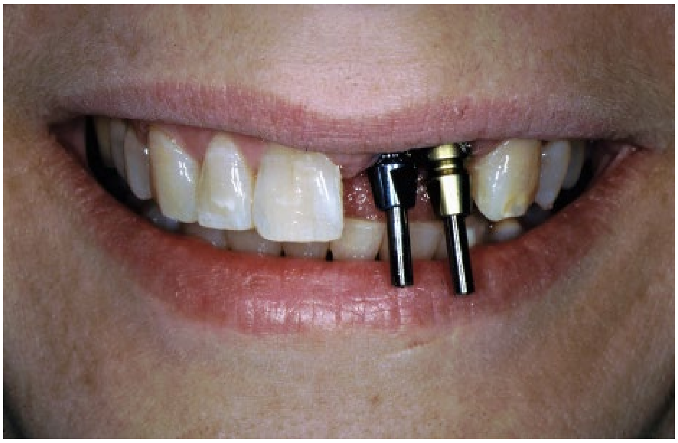

Figure 42.10 **(A)** After the impression copings were emplaced and fit was confirmed radiographically, an impression was taken of the two implant restorations #9 and #10.

Figure 42.10 **(B)** Plastic sleeves were positioned on the poured model to reshape before wax-up of the casting.

Figure 42.10 **(C)** Custom abutments were made with gold, metal, and subgingival porcelain margin.

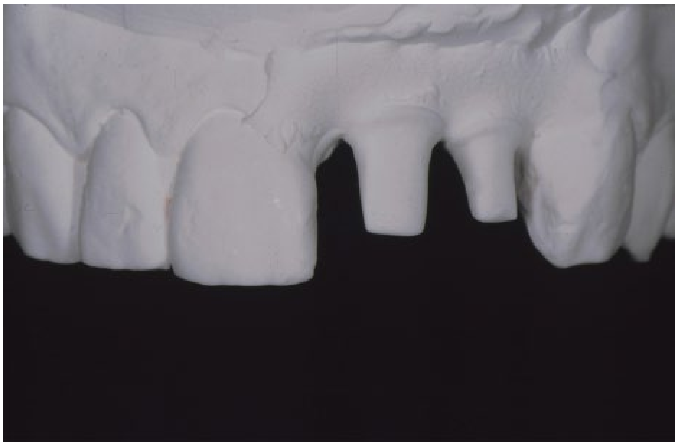

Figure 42.10 **(D)** Duplicate model of the implant abutments in place.

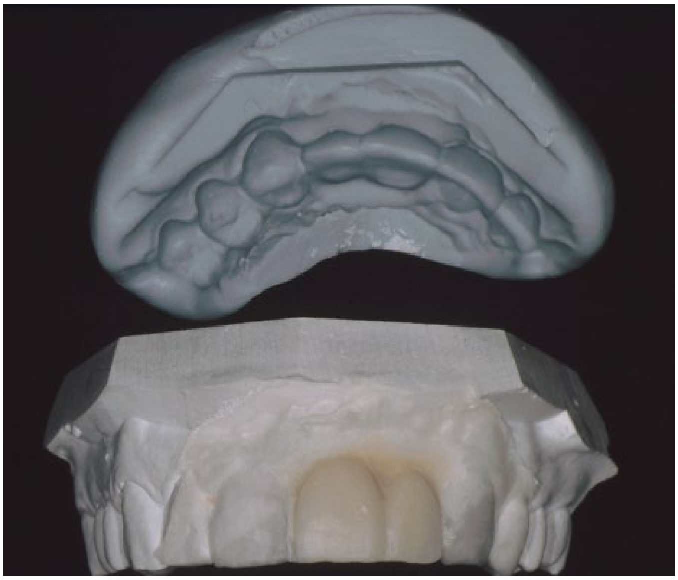

Figure 42.10 (E) The dentin acrylic was applied with silicone index with full contour.

Figure 42.10 (F) The temporaries were tried in on the actual custom abutments to make sure the fit was accurate.

Figure 42.10 (G) The temporary was cemented intraorally. Note the special effects that were incorporated into the temporary for esthetic purposes.

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Chapter 43 The Esthetic Try-In

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The try-in appointment makes the difference between average and excellent esthetic results. Esthetic objectives should be determined long before this appointment so as many as possible can be incorporated into the restoration in the laboratory. The remainder are added during the try-in appointment. The main reason for spending so much time during the temporary phase is to avoid major changes during this final part of the treatment. Having to make major changes at the ceramic try-in stage is time consuming, costly, and counterproductive. However, there is no doubt there will be times when, despite everything you have done to satisfy their esthetic demands, your patient may suddenly insert a set of new ones at the esthetic try-in appointment. Most times, it will occur with patients who have a difficult time making up their mind about what they really like.

The best way to avoid having a frustrating time at the try-in is not to eliminate any step in the systematic process of esthetically pleasing your patient:

- Step 1: Diagnosis. Use esthetic imaging to visually show the patients how their new smile can look both close up and full face.
- Step 2: Waxing on models and/or composite resin to "mock up" in the mouth when possible. A direct mock-up technique serves as an effective communication tool between you, the patient, and the lab technician. A limitation can be a patient with a maxillary protrusion.
- Step 3: Trial smile.
- Step 4: Making sure your temporary restorations incorporate all the changes you and your patient anticipate in tooth shape, size, color, and arch alignment.
- Step 5: Have your patients "sign off" in the folder after they are satisfied with their new "temporary" smile and then again after the final try-in is accepted.

Patient communication and good records that include shade and esthetic evaluation information sheets all help to attain this objective.

Patient involvement is an essential part of the esthetic treatment process. In a study of 40 denture patients by Hirsch et al.,[1] the crucial variable was patient involvement, rather than the

Ronald E. Goldstein's Esthetics in Dentistry, Third Edition. Edited by Ronald E. Goldstein, Stephen J. Chu, Ernesto A. Lee, and Christian F.J. Stappert.

esthetic quality of the denture. The authors found that patients respond more favorably to dentures when they are involved in the selection than when the dentist acts as the authoritarian.

Initial visualization

It is vital that the patient be able to visualize as closely as possible the restoration as it will appear in the final form. This is especially true if you are trying-in ceramic restorations.

Stable occlusal relationship

Regardless of which articulator is used, an occlusion balanced in all movements must be established before the esthetic try-in. This will keep further refinement of the occlusion to a minimum. The closer to perfection the occlusion can be, the sooner you can get to what the patient may be most concerned about: the final esthetics. Remember, the patient will usually begin to judge your treatment based on how the restoration feels to the tongue, the tissues, and the bite. The closer you can arrive at a perfect occlusion the more confidence the patient may have in your ability to satisfy their esthetic requirement.

Adjuncts in therapy and esthetic determination

Try-in with additional viewpoints

Depending on the patient's need, consultation with another person at the try-in appointment is always advisable and often necessary. This is especially important for patients who have difficulty making decisions. Failure to recognize your patient's need for an extra pair of eyes by the person they trust most can result in later problems.

Even if your patient signs the approval form, the disapproval comments by a trusted family member can result in a patient's dissatisfaction with the esthetics. However, sometimes it is unavoidable. Some years ago an elderly woman came in for a new maxillary denture by one of my (Goldstein) associates. However, I consulted on the case because esthetics was of high importance to this lady. Each appointment she was accompanied by her daughter who helped with the esthetic decisions. At the final try-in, several hours were spent fine-tuning all the esthetic changes the patient requested and the denture was processed. Both mother and daughter were extremely pleased, especially since the new tooth arrangement made the elderly grandmother look about 15 years younger. Everything was fine until she went back to her home, which was about 1500 miles from Atlanta. When she got off the plane her son-in-law said "What did you do to yourself?" His negative comments were so hurtful that she eventually sent the dentures back and had another office duplicate the older version of her tooth arrangement to please her son-in-law. Regardless of the reasons for his negative and degrading comments, the important lesson in this case is to make sure you have the right person with your patient to help them make a decision everyone can live with.

I had another patient who had such difficulty making a final esthetic decision that I ended the try-in session and requested she come back with her two daughters whose opinions she valued. Most of the time, the extra people give your patient the confidence that the right esthetic decision is being made.

Trial smile

The purpose of the trial smile is to let the patient live with your intended esthetic arrangements and shade. This can help in so many ways since your patient can have sufficient time to let many friends and relatives hopefully approve or make constructive comments so your esthetic try-in will be a much easier and successful appointment.

Young patients usually require a parent's advice and reassurance. When others accompany the patient, insert the restoration temporarily to allow time for critical evaluation and possible changes. Never rush your patient's decision making. Another person's view can be most helpful, because esthetics is an individual determination.[2] The appearance of the teeth is influenced by individual preferences and cultures; therefore, the opinions of these friends may be quite valid, and by sharing in esthetic considerations they also will share the responsibility for the esthetic result.[3] Explain to the patient that these other opinions assist in achieving the very best result. It is also advisable to have this friend or relative present during shade and shape determination to help further define the patient's wishes and esthetic expectations. Remember, this "friend" or relative will probably be the very first person who your patient will go to for esthetic approval, so it is crucial to get that approval before final cementation when only minimal changes may be able to occur.

It is a mistake to assume that because your patient says they make their own decisions that others' opinions do not matter. They almost always do! One of the best types of trial smiles for patients who do have problems making esthetic decisions is the "snap on smile" (Figure 43.1A–D).

Technique for patient direct viewing of restorations

After insertion and viewing in the sitting or reclining position (Figure 43.2A and B), ask the patient to stand and view the restoration in a full- or half-length mirror (Figure 43.2C). Patients will tend to stand further away from a large mirror at first, which is important for them to see the restoration in proper perspective. Observe the patient standing so that you can see how the teeth appear to others when the patient is speaking (Figure 43.2D). Teeth that are flared out labially may appear to be shorter than they actually are—especially in a tall individual. Conversely, a short person with flared-out teeth may appear as if their teeth are too long. Therefore, it is important to correct poor tooth position during the tooth preparation stage. You should also realize that if gold occlusal surfaces are to be used they would also be more visible on the lower bicuspids and molars of short people, whereas in tall persons the upper arch will be more visible. It is much wiser to have a discussion of all-ceramic or porcelain versus gold occlusals at the planning stage rather than have an unhappy patient after crowns are inserted.

Figure 43.1 **(A)** This lady felt her smile was not prominent enough for her face and wanted to improve it if possible with porcelain veneers. However, she wanted to make sure she would like the final result before committing to treatment.

Figure 43.1 **(B)** An extended-wear trial smile appliance (Snap-On Smile, DenMat) was made to allow her to wear it so others could also help her in evaluating what the new smile could look like.

Figure 43.1 **(C)** The appliance with cutouts to fit over the existing teeth.

Figure 43.1 **(D)** This image shows how precise the appliance fits over the teeth so the patient can securely keep it in place and even eat with it.

Figure 43.2 **(A)** The most frequent view that dentists use to evaluate patient restorations is when the patient is reclined in the chair.

Figure 43.2 **(B)** Additional help is achieved by having input from your assistant, who can see the restoration from a different view.

Figure 43.2 **(C)** It is best for the patients to always view the restoration in a large fixed mirror while standing, so they can observe the smile as it will appear to others.

Figure 43.2 **(D)** You and your assistant should also observe the patient's smile in a standing position to see it as others will view it.

Viewing at different angles. A full-length mirror allows the patient to be viewed at different angles and positions. Observe the patient in front of and also in the mirror. Viewing the patient only in the dental chair may present a more unnatural view than would normally be observed. The size and position of the mirror can have a major effect at this stage. A small hand mirror is ill-advised, since it does not allow a view of the restoration in relation to the entire face (Figure 43.2E). While the patient is in the dental chair, use a large, clean mirror rather than a small close-up mirror. Judging a new smile should always be done in proper perspective. First impressions are so important for patient acceptance, as well as proper orientation. We want patients to visualize themselves as others will see them, and few, if any, will isolate your patient's smile as most patients do by holding a hand mirror so close that only the lips and teeth show. So ask your patient to hold the mirror at arm's length to attain the proper perspective.

Figure 43.2 **(E)** It is ill-advised to have the patients view their smile in a small hand mirror as this does not allow a view of the restoration in relation to the entire face.

Figure 43.3 **(A, B)** Warn the patient about pulling the lip or viewing the restoration in an unnatural or strained position. **(C)** The proper method is to have the patient smile as wide as possible, but naturally.

Viewing esthetic improvement. With the full-or half-length mirror, the entire face may be observed and the role the new restoration plays in any facial improvement can easily be seen. At this point, most patients get too close to the mirror; therefore, warn them beforehand that extreme scrutiny is generally used only by the dentist and the patient and to hold the mirror at arm's length to get the view seen by others. They may be judging an effect that will never be noticed by anyone else. Remind the patient that most people observe them at a distance of approximately 1 m or more. At shorter distances the mouth is less noticeable, because eye-to-eye contact is usually maintained.

Avoid viewing with unnatural lip positions. Pulling the lip away or holding it in an unnatural or strained position merely to expose the cervical portion of the tooth allows improper and unnatural lighting effects (Figure 43.3A and B) that give an unrealistic view of the esthetic effect. Warn the patient of this before you allow them to see the restoration. The proper method is to tell the patient to smile as wide as possible, but naturally (Figure 43.3C). Explain that the incisal portion of a crown can appear drastically different with and without lip shadowing and may also vary with the position of the patient's head as well as the lighting condition. Using different light sources will influence the analysis of the optical behavior of natural and artificial dentition.[4] Viewing from a direct-angle illumination, such as a unit light, will create a different effect than an overhead light source. Allow the patient to view the restoration with frontal, overhead, and side lighting. Natural light should also be used to compare the shade with artificial light, even if your artificial lighting is "color corrected."

Indirect viewing

There are two easy methods for allowing the patient to see themselves as others see them (since a mirror view reverses the patient's image): still digital photography and digital video.

Still digital photography

For most patients, seeing a two-dimensional photograph of their smile will be extremely helpful in evaluating a new smile (Figure 43.4A). Since looking in the mirror becomes a three-dimensional view, outline form is more difficult to discern. Instead, a digital photograph loaded into a chairside monitor or even a monitor in another room allows both you and your patient to better see silhouette form (Figure 43.4B). You will get an idea of the amount of incisal showing and gingival display, both features that influence the esthetics and design of the new smile. You should also take multiple views so your patient can see lateral and profile smiling views. Both full-face and close-up views should be taken to let your patient feel comfortable with their new look. Conversely, if there are potential changes your patient wants to be made, now is the best time to make them.

Another advantage of immediate digital photography is the ability of making your patient's desired potential changes in the computer image first rather than altering the porcelain. For instance, if your patient feels that the teeth may be too long it is a lot easier shortening the imaged teeth first to make certain the patient really does like the shorter version better. We have found using this technique has saved valuable time and costly laboratory remakes. Plus, we utilize these views to help us and our ceramist obtain the best esthetic result. Generally, one should retake new digital photos after each correction so that the patient will feel that, together, esthetic success has been achieved.

Digital video

Digital video can be extremely helpful to patients who are public speakers or television, stage, or movie performers (Figure 43.5). This is really the best way to show them not only how they will look when talking or smiling but also how they sound when speaking or even singing. Continue to use digital video after each correction, since the visual result can change. This way your patient will feel much more confident with their new look.

A good digital video camera need not be expensive and can be played immediately by just connecting it to your monitor. However, both still photograph and video viewing can take considerable extra time, and you need to consider this before you calculate your fee for treatment. Patients must know that this is part of the extra esthetic treatment that no insurance plan could possibly cover!

Indications for additional appointment time

If there is lingering doubt in the patient's mind regarding appearance, a second try-in appointment should be arranged. Sometimes it takes one or more additional appointments at intervals that allow the patient to discuss the new appearance and hear a critique from members of the family. Multiple

Figure 43.4 **(A)** Use a good digital camera to record your patient's close-up and full-face smile so that you both can observe it in two dimensions.

Figure 43.4 **(B)** Seeing the patient's smile on your chairside monitor makes it much easier for you and your patient to see the shapes of the teeth in silhouette form.

appointments means additional time, and providing this extra service is necessarily more costly; nevertheless, if you desire to please your patient, you must be willing to make the necessary time available. Remember, not all patients are alike. Some will need two or three times the try-in time before they are willing to sign off on the first try-in. Any dentist interested in obtaining superior esthetic results must allow enough extra time to fit restorations, position teeth, properly balance the occlusion, and so on. Sufficient time should also be available to carve and reshape the restoration to suit the patient's personality and esthetic needs. This may require several appointments, remaking the restorations, or possibly altering the tooth preparation if desired results are not forthcoming, but the solution of a specific esthetic problem is a personal challenge to be met. Obviously, if you can predict the amount of extra time that your patient will require, you can and should adjust your fee appropriately.

Communication for a better esthetic result

Communication is an essential element of treatment. Your expectations should be clarified early to obtain approval at the try-in appointment by using written reports, letters, and evaluation charts. Superior esthetic laboratory service also depends upon continuous, accurate communication among the dentist, patient, and technician. Through effective communication, the patient gains confidence in the dental team and better understands the proposed restorative treatment. When a patient presents with challenging esthetic problems it is always best to arrange a joint consultation that should include your ceramist. Communication between ceramist and patient can be an important step in determining many factors, such as type of restoration, color, and esthetic desires. Hearing the patient's concerns first hand can be invaluable, especially when the patient has a difficult time communicating what they want.

If an "in person" consultation is not possible, consider e-mailing your ceramist sufficient digital pictures, or even an interview and clinical esthetic exam video, to let them see firsthand what problems will need to be solved, and to better help you help your patient by joint communication using Skype (Figure 43.6). The most successful dental esthetics comes from a thorough analysis and accurate interpretation of the sex, personality, and age considerations of each patient. Better esthetic control of factors at the try-in appointment can be gained by careful use of an esthetic checklist to be utilized after fit and occlusion have been established. The checklist in Box 43.1 has been elaborated for a patient from a two-page spread in *Change Your Smile*.[5] It is so important for your patient to help esthetically judge their new restoration from every factor during the try-in so that any remaining problems or compromises can be explained and dealt with at this visit.

Written statement of approval

It is a good idea to have the patient sign off at the try-in stage before proceeding to the final glaze. However, patients should always sign a written statement of approval when they are satisfied with their appearance at the try-in. Emphasis should be placed on concern for satisfaction, and patients should never be pressured or hurried. Continually emphasize that treatment will not progress until everyone involved is satisfied with the appearance of the restoration. When this is accomplished, ask the patient to sign a statement of approval, which goes into the chart,

Figure 43.5 Digital video is an economic and helpful way for patients who are concerned about how they will sound and look in public.

Figure 43.6 Consultation with your ceramist is extremely important in patients with esthetic problems. If it is not convenient for an in-office joint consultation, try using e-mail or Skype to accomplish optimal communication.

> **Box 43.1 Checklist at try-in appointment.**
>
> Check approval
>
> - Shade
> - Color
> - Length of teeth
> - Gum embrasure
> - Incisal embrasure
> - Midline—preferably in line with the midline of the face
> - Shape
> - Contour
> - Texture
> - Adjacent teeth (contour)
> - Arrangement

and have your dental assistant, as well as any observer the patient has called in, also witness the signature. It is not uncommon for patients who are difficult to please to later change their minds about their esthetic desires, especially after having the restoration viewed by a number of friends and family. Having a written statement of approval does not mean that the restoration cannot be changed. Rather it emphasizes that both patient and dentist approved the restoration and any changes made later would be the financial responsibility of the patient. Prevention—the best insurance against serious postinsertion problems—results only through adequate patient–dentist communication. Such dialogue results in realistic expectations, allowing not only to understand patients' desires and expectations, but also to understand the anatomical and technical limitations inherent with their restorations, and leading to ultimate patient satisfaction[2,6] (Figure 43.7).

Try-in principles for fixed restorations

Initial evaluation of delivered case prior to chairside approval

When the completed prosthesis arrives from the laboratory (before the patient's appointment), examine it for any obvious problems that could be corrected prior to attempting to place it in the mouth. It is always worth evaluating the fit of the crown on the cast before trying it in the patient. In this way, problems involving shade variations, marginal fit, contacts, and articulation can be anticipated prior to chairside approval. This final version should match the approved try-in restoration as close as possible.

Shade variation. Verify the shade to establish whether variations of hue, chroma, value, characterization, and translucency are present in the restoration. If a porcelain restoration is glazed, compare the shade guide (which may have been included with the case) with the actual restoration. Even though your own individual shade guide and complete descriptions were enclosed, the color may nevertheless be mismatched. Lighting in the laboratory may well be different than the lighting in your operation. If the crown has not yet been glazed, matching color with the shade guide will indicate how accurate the laboratory has been. It is quite helpful to have a computerized shade verification (list them!! VITA EasyShade Shade-Selection Device; SpectroShade; ShadeScan; and ClearMatch) as well. Not only will the computerized shade procedure help you determine the correct shade, when matching existing teeth is important, but it will also provide a color mapping to guide your ceramist through the restorative process.

Areas of potential overextensions. Although it is not advisable to work with any crown or dies prior to seeing them in the mouth, it is important to correct any obvious marginal areas that might be overextended, adjusting those areas from the axial surface, not from underneath.

Improper contacts. All too often a dentist will attempt to seat a crown and in the process destroy contacts and deplete anterior surfaces of the crown when removal of a slight marginal overextension would have allowed the crown to seat properly.

Prior to a patient's arrival at the office it is important to note contour, contacts, and embrasure form, and especially the presence of occlusal discrepancies. Observe esthetic qualities such as translucency of porcelain, shade, and consistency to check the natural appearance of your restoration. Compare the original shade with the porcelain. Do not hesitate to send the case back to the laboratory for any needed correction before the patient's appointment.

Chairside appointment prior to insertion

Confirm the try-in appointment with the patient by telephone. Be sure to let your patient know it could take a half or entire day for their appointment. At the same time, determine the possibility of any problem.

The patient may disclose a change in oral condition, such as points of irritation following surgical techniques, or a pulpitis following abutment preparation. Roberts[7] warns that to cause any further irritation to an already affected pulp (by drying the teeth or subjecting them to the trauma of removing the provisional restoration) may only do more harm. Therefore, the appointment may have to be postponed. However, your patient's sensitivity could be caused by a washout of the temporary cement, so postponing the visit may not correct the problem. Examine the patient to see whether the temporary restoration is loose or if there is a cement washout.

The use of local anesthesia or an analgesic may be indicated when placing a laminate crown or fixed partial denture on a vital tooth. When removing a temporary restoration, isolate and check the tooth carefully to insure that no temporary cement remains. Use coarse pumice on abutment teeth followed with chlorhexidine mouthwash, which helps to reduce the amount of bacteria and inflammation, as well as swelling of gums in the area.[8] Cleaning should include both the supragingival and subgingival areas. Examine the pontic area and gingival margins for inflammation that could cause contours different from those present at the time the impression was taken.

gg&s

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I approve of the color, shade, shape and size of the crowns that have been fabricated for my teeth and wish to have them final glazed. I approve of the restorations in every way. I have discussed this with Dr. Goldstein and his staff and have had all my questions answered.

____

Patient's name printed

____________________________ _____________

Patient's signature Date

____________________________ _____________

Witness Date

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Figure 43.7 It is a good idea to have the patient sign a consent form before proceeding to the final glaze. This image presents a good example of an informed consent form at this stage.

Principles for the esthetic try-in

- *Fitting the crown to the tooth* As stated earlier, studies show that if patients are satisfied with the fit of a denture, they will usually be satisfied with its esthetic effect and their ability to chew and speak.[9] This can also be true with fixed restorations, although the patient motivated primarily by esthetics may react just the opposite. A crown can have all the qualities of functional perfection, but if it does not esthetically match the adjacent or complementing tooth then no amount of explanation will satisfy this type of patient. Always remember, fitting the crown to the tooth is the most important functional step of the try-in procedure and must be done prior to any esthetic evaluation.
- *Ceramometal crowns* All esthetic crowns are tried in before final polish or glaze. With careful examination of the casting it may be possible to determine areas of binding. Roberts suggests using graphite or lipstick on the internal surface to make these areas easier to observe.[7] Sandblasted or dull gold surfaces will also reveal binding areas on the internal surface of metal crowns. Fit Checker (GC) or aerosol sprays (Occlude-Pascal) are two products that can be helpful to reveal binding areas and any irregularities of fit in ceramometal crowns. A third alternative to discover a tight area on the inside of a crown is to use a colored paste of equal parts lightly working the inside of the crown. Put it into place and the material sets quickly. After withdrawing the crown, any binding spot is easily revealed. An example of this can be seen in Figure 43.8A–G on an all-ceramic splint. Frequently, a ceramometal crown will fit too tightly due to the rate of contraction–expansion and ratio of the porcelain and metal. If this happens, be careful of relieving too much of the inner core of metal. Thin spots can be created which might allow internal stress, metal flexing, and perhaps eventual porcelain fracture. For this reason, a uniform metal thickness is very important to prevent any failure in the metal–ceramic bond. A minimum metal thickness of 0.3–0.5 mm is allowable for possible shrinkage or the possibility of some relief without weakening the metal substructure. However, a better technique is to adjust the tooth preparation rather than the metal to help properly seat the crown. One significant problem, and a potentially major one, is not being able to remove a crown at try-in. A simple solution is to fit a Tofflemire band slightly on the crown (Figure 43.8 F) and then use a reverse hammer to help dislodge the "stuck" crown by tapping vertically as close to the band as possible (Figure 43.8G). Try to balance the crown by pressing with your finger on the lingual surface as you tap.
- *All-ceramic crowns* Since all-ceramic crowns have a passive fit, the try-in of these types of restorations creates different problems. A single crown is easiest to fit since existing contacts are present and the new crown just has to be held in place while margins and contacts are checked. Then the occlusion can be evaluated using microthin articulating paper and 5/10,000ths of an inch thick stock strips (Artus). If the crown has no ability to stay in place for the occlusal check, try temporarily cementing it with a product like fit checker (GC) (Figure 43.9). One reason for making multiple impressions is to be able to verify fits with duplicate models. This can be especially helpful when trying to determine whether a slight ledge or overhang is present. If you determine the presence of a ledge or slight void in the margin, the duplicate model can be used to help repair the defect without taking another impression.

In certain difficult cases the laboratory may have a problem in seating an extensive bridge or fixed splint. Rather than having the patient return to reprepare a tooth or teeth and then take new impressions, consider the following technique (Figure 43.10A–D):

1. Have the technician carefully mark undercut areas plus where the abutment teeth may need slight reduction. Then the technician reduces the tooth on the model sufficient to how the bridge draws.
2. The technician then makes a plastic or metal coping of the tooth or teeth needing further reduction.
3. Next, the technician trims through the coping incrementally until they see the bridge will draw. Then the bridge is constructed.
4. Before trying in the restorations, fit the coping precisely to the abutment tooth and make the exact same cut as the technician did.
5. Now fit your restoration as normal.

Figure 43.8 **(A)** Although this four-unit all-ceramic fixed splint fit perfectly on the model, there was a slight discrepancy during the try-in. **(B, C)** A green indicating spray (Occlude-Pascal) was used on the inside of the splint to help define any binding area in the intaglio surfaces of the crowns.

Figure 43.8 **(D)** When seating the splint firmly, try to verify which tooth/teeth have marginal discrepancies.

Figure 43.8 **(E)** Observing where the spray has been removed will also show you the areas on the tooth that can be adjusted for perfect fit and draw.

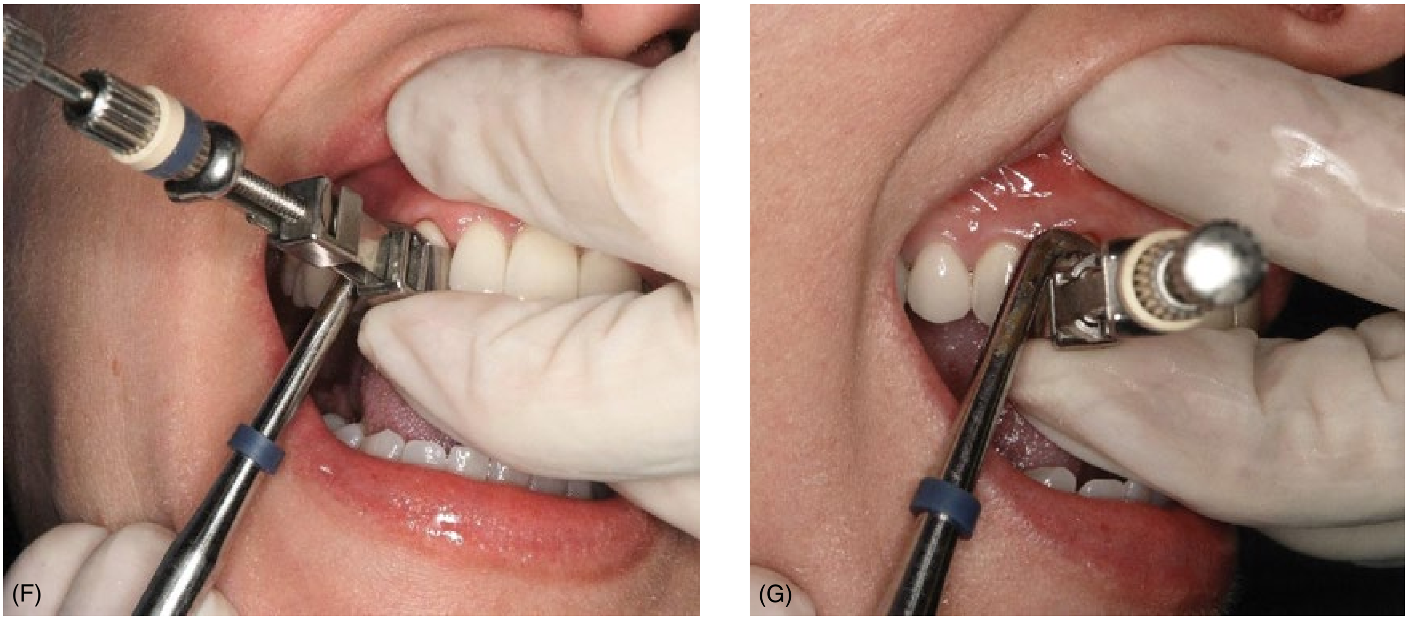

Figure 43.8 **(F, G)** At times, a crown can get stuck on the tooth during the try-in appointment. First fit a thin Tofflemire matrix band to the tooth. Then, use a reverse hammer with vertical taps to remove the crown.

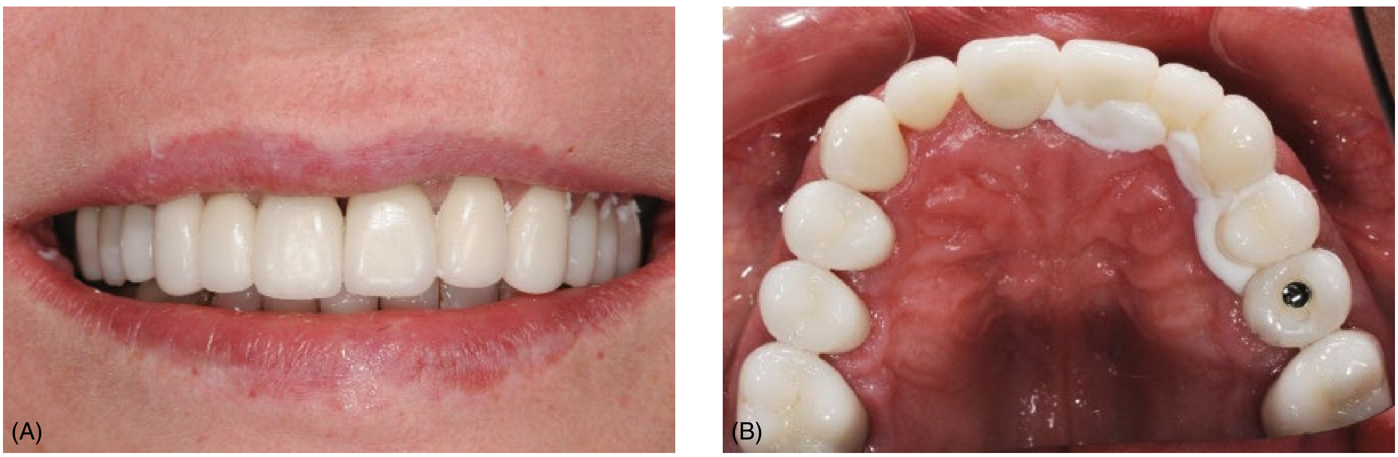

Figure 43.9 **(A, B)** If the crowns have little or no ability to stay in place, try temporarily placing them with a product like Fit-Checker (GC).

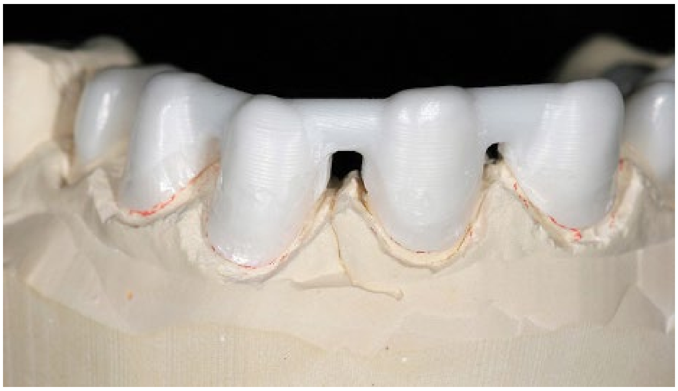

Figure 43.10 **(A)** This five-unit fixed all-ceramic bridge did not have a perfect draw. Rather than have the patient return to reprepare the teeth and take new impressions, the dentist decided to have the technician make the small changes on the prepared teeth on the model.

Figure 43.10 **(B, C)** The technician then made a coping which revealed exactly where the tooth needed to be reduced.

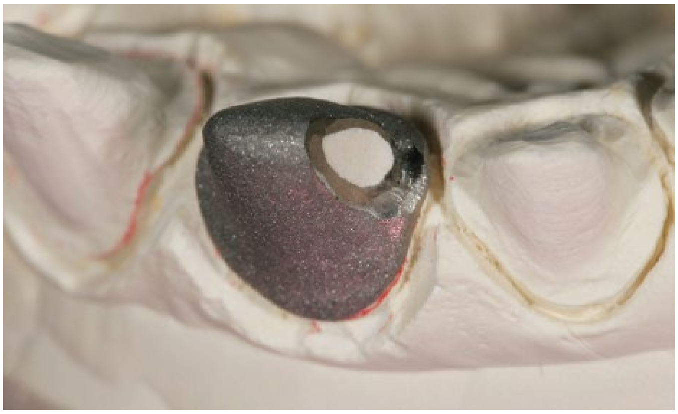

Figure 43.10 **(D)** When this coping is tried in the patient's mouth, the dentist will have an exact reduction guide for the necessary alteration on the prepared tooth.

When using a full shoulder margin, make sure no ledge exists by running the explorer both apically and incisally. If you find a ledge, try the crown on a duplicate model to see whether you can see where the void occurs. If so, the technician will be able to repair the defective margin. If you do not have an extra model, retract the gingival tissue and take a polyvinyl siloxane impression to show the technician the difference. A similar technique can be used if the patient's gingiva has receded since taking the final impression and is exposing the root. You can start the crown to make sure it fits perfectly. If so, then use a tissue-protective end cutting bur to reprepare a new labial margin subgingivally and then retract the tissue gently and seat the crown and take a new polyvinyl siloxane impression to show the ceramist where to add (Figure 43.11A–F).

Ideally, take three impressions so you will have adequate untouched models to verify your fit as well as to make sure your technician did not trim too much of your margin away.

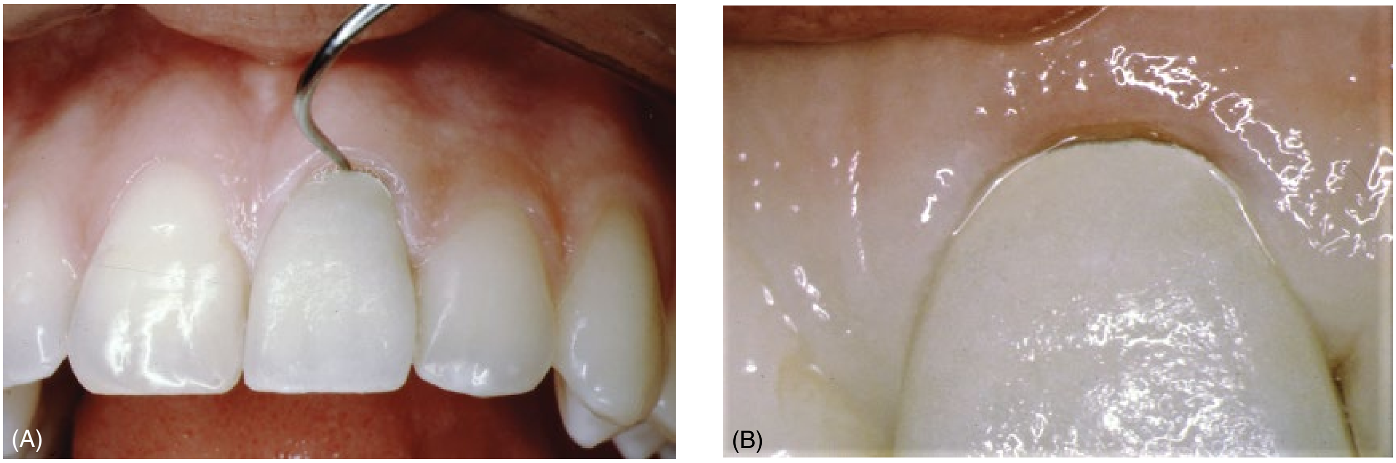

Figure 43.11 **(A, B)** At try-in, one of the all-ceramic crowns now has an exposed supragingival margin on a patient with a high lip line.

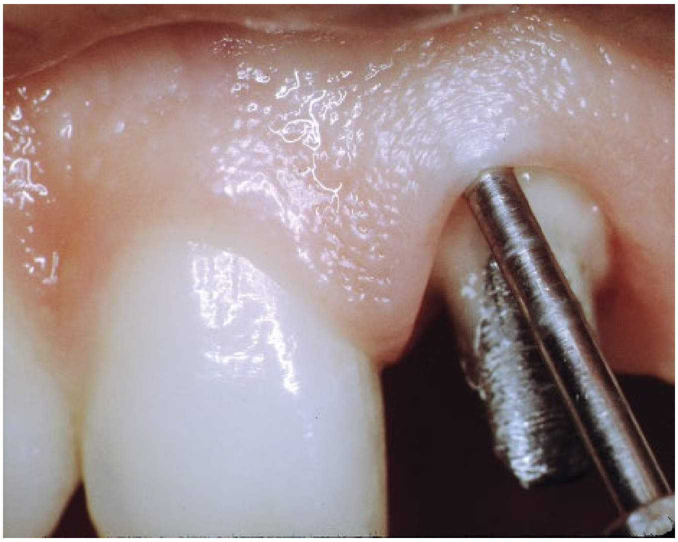

Figure 43.11 **(C)** Instead of repreparing the tooth and making a new crown, a tissue-protected end cutting bur was used to prepare the labial margin subgingivally, while avoiding making any alterations to the labioaxial wall of the prepared tooth.

Figure 43.11 **(D)** At this point, a polyvinyl siloxane impression should be made of the newly prepared area with the crown in place. However, in this particular case, a soft compound was used to make the individual tooth impression.

Figure 43.11 **(E)** Once the crown is removed, it is easy for the technician to see exactly where the shoulder margin is. A new die is made to make the necessary porcelain addition.

Figure 43.11 **(F)** The final crown now shows a proper subgingival margin for the necessary esthetics and function.

- *Contact* Too much contact can be inadvertently removed because of incorrect position of the teeth and the path of insertion, which can be heavy upon insertion and yet seemingly fit right into place. Therefore, it is important that potential gingival impingement areas, contacts, and marginal discrepancies be checked simultaneously to properly evaluate which condition is preventing the crown from seating. There are easy ways to evaluate where your tight contact first touches. One way is to use ultrathin articulating paper and have your assistant hold it in the contact area while you seat and hold the crown in place. Then the assistant pulls the articulating paper out, leaving a colored mark in the offending contact area to be slightly reduced. Then repeat the process until your crown goes to place with the tightness you and your patient desire. Your main problem is to first decide whether the mesial or distal or both contacts need reducing. Therefore, only do one side at a time if both are tight. When the marginal fit is bad, reexamine the preparation and correct if necessary, and then take a new impression or use a duplicate die to help repair the defect. Before the marginal fit can be checked, the crown must be completely seated.[10] The contact areas may be checked visually, but it is best to evaluate by passing dental floss, not tape, through the mesial and distal contacts. The tightness of the contacts can be tested with dental floss and should offer some resistance but not make its passage too difficult. Have your assistant place their thumb on the two crowns to hold them in place once you have positioned the floss. When necessary, ease the contact after carefully assessing the area of initial contact. When the crown is thought to be completely seated and the margins are adjusted as necessary, a digital X-ray is taken to verify the fit (Figure 43.12). Open contacts occur less frequently and may be modified by returning the crown to the laboratory for addition of porcelain.

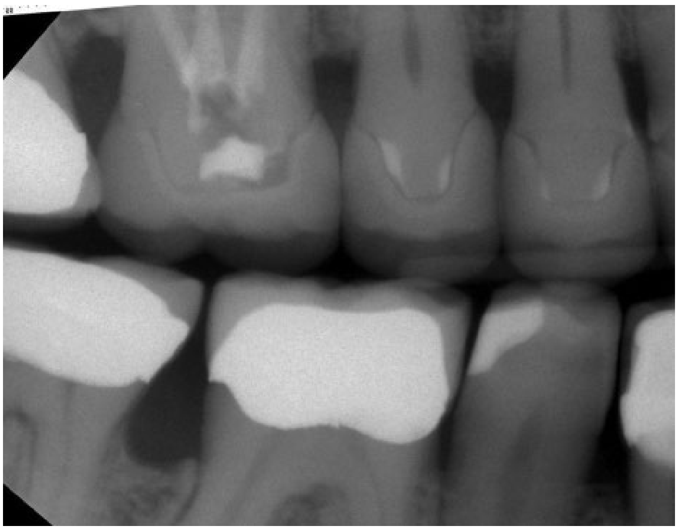

Figure 43.12 After the restorations are seated and adjusted for proper contact, margins are checked and verified by clinical examination. Next, a digital X-ray is made to confirm the interproximal marginal fit.

- *Alignment* In trying-in a ceramometal splint, check alignment of the retainers, because even if the individual units seat properly, the fixed appliance may not, due to incorrect relationships. In such a case, the simplest procedure, unless the misalignment is slight, is to section the various components, reseat in the mouth, and, if they fit properly, finish the try-in by obtaining the proper occlusal contour, and then stain and glaze the porcelain as necessary. Then place the components into the mouth. Next, lute with acrylic (Duralay), take a plaster localizing impression, and, after pouring in soldering investment, resolder.
- *Tissue contact* When esthetics dictate, the pontic should exert only very light pressure. If it causes severe blanching, it must be eased to prevent gingival proliferation around the pontic. If it fails to touch the mucosa by more than 0.1 mm, an addition may be required. If the patient has a high lip line, make sure the tissue fits into the pontic area with a natural appearance. There are instances where the ovate pontic may be indicated for a more realistic look.[11]
- *Marginal fit* With the latest impression and casting procedures, there should be little need for major modification in this area. However, where possible, accessible margins may be finished with sandpaper discs or stones. Finally, impregnated cups, points, and wheels are employed. If you are using a gold feather edge, metal margin, it should be burnished before cementation.[10] An accurate marginal fit will have long-term benefits; meanwhile, an ill-fitting margin will compromise gingival health by plaque retention, recurrent decay, and cement dissolution.
- *Reevaluate shade* At this point, merely determine that the shade will be accurate enough to be used. This reevaluation of shade may require removal of the veneer porcelain if the shade is too far off. Slight discrepancies should be correctable by staining and glazing. In situations where shades are slightly lighter, they may be darkened by addition of stain and refiring. If the shade variation is too great to correct by staining, or reveneering, check any other basic flaws, such as occlusion and midline, and have the laboratory remake it. The crowns should be glazed once you and your patient are happy with the final appearance.
- *Check midline relationship on multiple anterior units* This should be established before any major recontouring of teeth is started. The midline should be vertical and, if possible, coincide with the midline of the face (Figure 43.13). However, much more important is for the two front teeth (central incisors) to be the same size or appear proportionate to each other and to the face. Therefore, it may be necessary for the dentist to move it to the right or left. Nevertheless, it should be vertical and parallel to the midline of the face or perpendicular to the eyes. If the midline is off, mark the correct line with a sharp black pencil so the laboratory can add new porcelain and/or reveneer.
- *Position in the arch* Now is the time to check tooth position in the arch and make any adjustment necessary by reshaping the crown.

Figure 43.13 Using a colored dental floss makes it easy to see where the midline is in relation to the rest of the face. For this particular patient, the midline of the teeth was positioned to the midline of the face, even though her nose is slightly deviated to the right.

- *Adjust occlusion* No matter which articulator is used, the mouth must be the true test in the final analysis. Adjust if possible, but remount if there is a major occlusal discrepancy.For the final occlusal adjustment use the following procedure:

  1. If ceramic crowns, use microthin articulating paper that has been coated with Vaseline or other lubricant that will make the marks easier to read.
  2. Check centric contact with thin articulating tape (Artus 0.0005″ (0.0127 mm) thickness).
  3. Use occlusal indicator wax to double check for prematurities.
  4. Judge by touch and by articulating paper whether the occlusion is too heavy on any particular tooth.

- *Establish proper gingival embrasures* Shaping the gingival embrasure is the second most important step of the try-in appointment. Unless this procedure is properly accomplished, functional principles will be violated that preclude an esthetic result. It is important to emphasize that many times tissue blanching is normal, so have the patient bite on a cotton roll and allow up to 5 min for the crowns to settle into position. Then verify and correct the cause of any continuous blanching. That pressure on the gingival tissue may cause remodeling of a specific area, and may lead to unwanted tissue changes. There are two methods of determining correct gingival form.
  - *Indirect method* There are several ways of determining this contour. Because a full impression obtained with retraction cord does not give the true representation of gingival tissue, a second polyether or polyvinyl siloxane impression can be made after the tissue has had time to return to a rest position. Because the tissue is not retracted, the chances are the margins will not be perfect. Therefore, using the dies from the master impression, pour the second impression with these same dies seated into the impression material. Now the dies and crowns can be interchanged and an accurate measurement of proper gingival contour can be made on the second model. It also provides an esthetic determination of where the labiogingival–ceramometal junction should be. According to Pincus (see Appendix D), this model can also be poured in soft acrylic to offer a more natural feeling and appearance.[11] Another method is to take an accurate study model and measure the distance *c* from the incisal edge *a* to the height of the interdental tissue *b*. The distance from the crest of the mesial interdental tissue to the distal interdental tissue can also be recorded and duplicated in the crown shape. B1, B2, C, E, and A/D are duplicable measurement that can more accurately be used in forming and contouring the porcelain.
  - *Direct method* Obviously, if only a small amount needs adjusting, try to do it direct in the mouth. A second method of obtaining proper gingival embrasures is to have the laboratory build the crown as accurately as possible for the try-in appointment. After the crown is fully seated with margins and contact corrected, a sharp black pencil is used to scribe the cervical portion of the crown at the gingival. In cases where the crowns are overbuilt and cause tissue pressure, use a cotton roll with the patient biting firmly. Next, remove the crowns and observe the gingival markings on the model. Reduce the part below the contoured line as necessary to duplicate natural tooth anatomy in the proximal surfaces. Continue trying the crown in until correct contours are established and then glaze.
- *Obtain correct incisal embrasure* Use an ET3 diamond (Brasseler USA) to open the incisal enclosure to make it appear (Figure 43.14A and B) as natural as possible. The incisal embrasure should display a natural, progressive increase in size and depth from central incisors to bicuspids, as we proceed from central incisors to bicuspids moving the contact point further toward the gum.
- *Maxillary incisors* The incisal embrasure between central incisors is usually placed approximately 1 mm lower than the one between the lateral and central. This embrasure can be several millimeters deep, depending on the desired illusion.

Figure 43.14 **(A)** When a small adjustment needs to be made to open the gingival embrasure, it can be done directly or indirectly. Here, it is being done directly in the mouth with a DET3EF 15 μm diamond (Brasseler USA).

Figure 43.14 **(B)** A DET3EF 15 μm diamond (Brasseler USA) is used to open the incisal embrasure to make the restoration as natural as possible.

The most important but frequently neglected incisal embrasure is the one between the maxillary lateral and cuspid. This is the longest one because of the change in shape between the lateral and cuspid. The embrasure can be as high as one-half the incisogingival length of the lateral incisor. Reduce the cuspid from the linguoincisal aspect to avoid a bulky look. Always try to duplicate natural teeth when carving incisal embrasures.

- *Mandibular incisors* Although the embrasures between the mandibular incisors are not as prominent as those on the maxillary teeth, it is equally important to create a feeling of naturalness through incisal separation. The length of the incisal embrasure between the centrals and laterals usually varies between 0.25 and 0.5 mm. The mandibular lateral-cuspid embrasure can vary between 1 and 3 mm. For a more esthetic, natural arrangement, the position of these embrasures can be altered by using a very thin polishing diamond DOSF ET3 (Brasseler USA). Another instrument that can be easily used to shape incisal embrasures intraorally is the ET3 diamond (Brasseler USA) (Figure 43.14B).
- *Posterior teeth* Do not neglect posterior embrasures. Distal to the cuspid and to the bicuspids are the most important areas. Generally, if the bicuspids are properly carved, the embrasures take care of themselves. The bicuspids should complement the cuspid shape and the amount of space between the teeth.
- *Form proper length and position of contact areas* Reexamine both labiogingivally and inciso- or occlusogingivally to make sure anatomy is correct. Add or subtract as necessary.
- *Incisal length* Judge proper incisal length with the patient standing and sitting. In the case of multiple anterior units, establish correct incisal length variation from tooth to tooth. At times, slightly overlapping laterals or prominent labioincisal line angles can be utilized to obtain an effective natural look. Sculpt the teeth not only from the gingival side, but also the incisal, to create a more esthetic and natural illusion. Rotation of abutments and retainers may be employed as well. Observe patients speaking and smiling. Have them count or speak words that require high lip line, smiling, laughing, and rest positions. Whenever possible, use the temporary restoration to add length when your patient feels the teeth may be too short (Figure 43.15A–D).
- *Labial and lingual contours* With particular attention to correct speech patterns and lip support, carve labial and lingual contours. Use adjacent teeth as the model for lingual anatomy.

Shaping

Since the try-in of the final restoration is basically a duplicate of the temporary restoration, there should be no need for major changes. However, final shaping or contouring the restoration is really what the try-in appointment is all about. The shaping of incisal embrasures, proximal contacts, and gingival outline will establish the silhouette of the tooth while line angles and contours will establish the face of the tooth. No matter if the ceramist has carved an attractive restoration; even a minute alteration can many times help to personalize it.

After the restorations are properly fitted, examine the smile and note the effect the teeth have on the lips and facial expression. The personality of the patient should be stressed at this point. Know what type of image the patient wishes to project and incorporate this into the shapes of teeth. Sex appeal, naturalness, and aging should be considered at this time. Naturally, if the treatment requires matching adjacent teeth, little personality change can be accomplished. However, if all or most of the maxillary teeth are being crowned, a different approach should be taken. The choice of whether to change previous shapes of teeth should already have been made, so that the technician could begin with a close approximation of what is desired. If the shapes are to be improved, note the changes to be made in the laboratory. The final changes should be either carved or stained into the

Figure 43.15 **(A)** This patient felt she needed to show more tooth structure when she smiled.

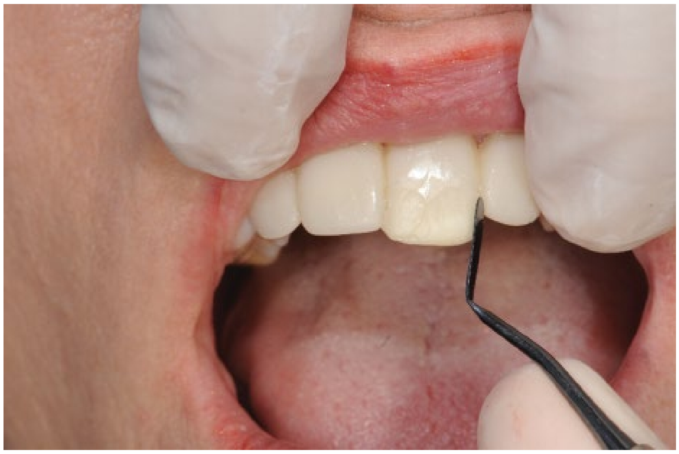

Figure 43.15 **(B)** Additional incisal length was added to her temporaries on one side of her arch using composite resin.

Figure 43.15 **(C)** After observing the patient during speaking and smiling, it was decided by both the doctor and the patient to add more incisal length to her final anterior restorations.

Figure 43.15 **(D)** The patient was very happy with the final results at try-in.

restoration at this time. Figure 43.16A–G shows how much can be accomplished during the try-in appointment. Figure 43.16B shows the frontal view of the porcelain crowns after fitting but before final shaping. The teeth are then marked (Figure 43.16C–E) and contoured to create a more feminine appearance.[11] A method of communication between dentist and laboratory technician can be instituted by markings. One way is to use straight or curved diagonal marks for areas to be carved. Solid black areas should be used to indicate complete reduction. This can also aid you in remembering where and how much to carve after removing the case from the mouth. Use an alcohol marker (Masel) or black pencil to mark the labial surface where shaping should be performed. Remove the crowns and proceed with contouring as indicated by the black marks.

Shaping and contouring anterior crowns takes the most time at the try-in appointment. After contouring as much as you think is needed, stop and take a break. Come back after several minutes, and the chances are that a slight alteration will greatly improve the appearance. One of the most important views is the occlusal view of the labial surfaces. This is best done by using a large front surface mirror and rotating it back and forth, which should allow you to easily view your crown or crowns and to compare them with adjacent teeth (Figure 43.17). The rotation of the mirror also makes it possible for you to observe each part of the labial surface, the gingival body, and incisal edges. This task can make the difference in contouring perfection. Allow the patient to view the restoration without you several times, and each time let the patient take approximately 5 min to look, either alone or with the dental assistant. This enables the patient to participate in determining the shape of their restorations without making split-second judgments of whether or not it is correct. Patients as well as dental assistants will frequently make excellent suggestions about width, length, or shape of teeth as seen from their own viewpoint. These judgments should always be considered and if possible incorporated into the shape of the teeth.

If the patient suggests an alteration that seems contrary to their best esthetic interests, it is far better to say, “Maybe just a slight bit,” than to say “No, you are wrong about that.” Disk the

Figure 43.16 **(A)** This 42-year-old female was dissatisfied with her canted arch, high lip line, and discolored teeth.

Figure 43.16 **(B)** After crown lengthening, the final crowns were constructed. At the try-in appointment, it was determined that, although the arch alignment was improved, the crowns were too long and out of proportion for her face.

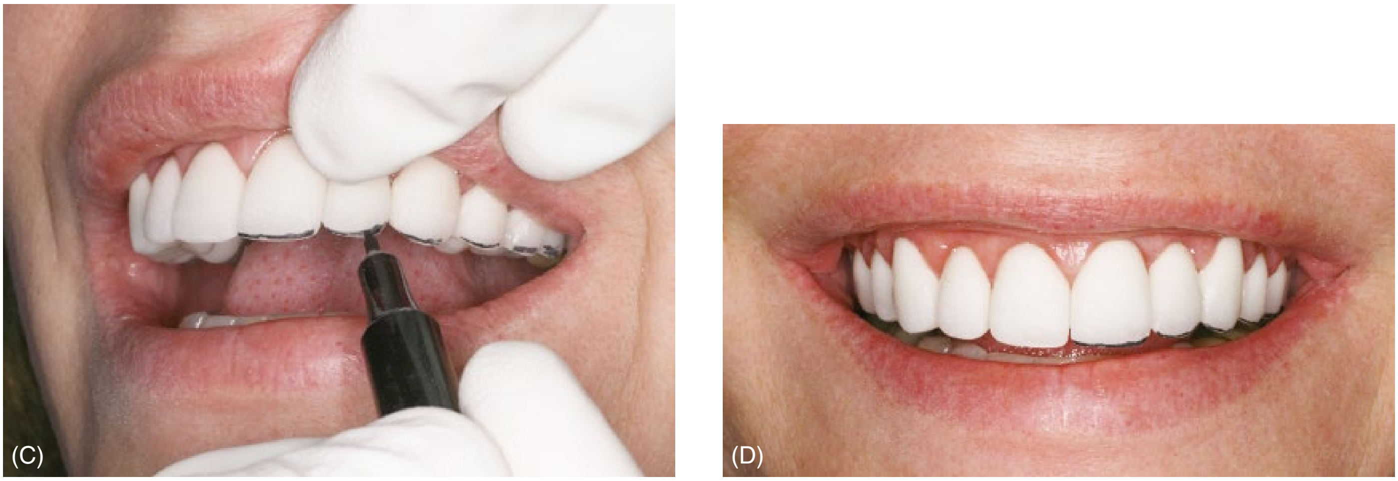

Figure 43.16 **(C, D)** The proposed amount to be reduced was marked with a black alcohol pen.

Figure 43.16 **(E)** The incisal line also showed where the crowns could be reduced a bit labially to make the teeth appear more in line, delicate, and feminine.

Figure 43.16 **(F)** The final maxillary crowns plus mandibular porcelain veneers and crowns are shown. Note, the bright shade of the teeth was chosen by the patient.

crown very slightly, and then say, "Yes, it does seem better now." The patient will feel it is actually better, because they have participated in the judgment, and they should be much more pleased with the overall esthetic result. This is especially true of determining the length of crowns. Patients whose teeth are worn due to bruxism or attrition are resistant to longer teeth because of the different feeling and perception of what is esthetic. Frequently, the patient who wants teeth to be even and straight across has a faulty concept of what is esthetically best. Explanation and communication are necessary,[11] but what is most important is to let the patient wear the "new length" in the temporaries long enough to get used to it.

Figure 43.16 **(G)** The patient was extremely pleased with her final result.

Incisogingival and mesiodistal direction

Establish proper facial contours. In the case of a bonded bridge or one employing pontics, the overall form is first adjusted where necessary, as with a full porcelain crown.

Contours for characterization, light reflection, and proper texture

Characterization

The final phase of contouring includes shaping various artifacts or other forms of wear that add naturalness to the restoration (see Chapter 31).

Light reflection

Observe how the light reflects off the teeth and ask yourself if the line angles are symmetrical. If not, adjust by either contouring or adding porcelain.

Texture

Texture varies according to the adjacent teeth and patient desires. If they are glossy and smooth, copy this surface in the new crowns. Basic texture should be placed into the crowns at the laboratory by referring to close-up digital pictures, stone models, and photographs of the adjacent teeth. After shaping is completed, major grooves in the labial surface of the corresponding natural tooth are marked with a black pencil (Figure 43.18A) since the basic grooves are much easier to see when marked. Next, mark the adjacent crown in the intended matching area. Remove the crown and lightly place textured cuts with a white or porcelain stone. The glazed result is seen in Figure 43.18B.

Reevaluating the case

At this point both patient and dentist should reevaluate the restoration in terms of shade, considering the gingival, body, and incisal portions of the teeth. Restaining and glazing should be kept minimal.

Figure 43.17 The facial alignment of the restorations should also be examined by using a large front surface mirror while rotating it back and forth.

Figure 43.18 **(A)** Tooth texture varies according to the adjacent teeth and patient desires. Marking the main groove lines in the adjacent teeth makes it easier to duplicate in the final crown at try-in.

Figure 43.18 **(B)** The final glazed result.

Unglazed restorations

Only on rare circumstances should the dentist allow the patient to wear any restoration out of the office before they have been glazed. Unglazed porcelain will readily pick up contamination over a short time and can cause discrepancies in the shade with the final glaze.

Polishing

Gold margins are polished where applicable. The polishing procedure will not only enhance the restoration by smoothing away any surface roughness, producing a smooth light-reflecting luster, but also will affect the biocompatibility of the restoration with tissues, its longevity, and long-term esthetic results.

Cementation

Cement the case temporarily or finally. If temporarily, have the patient return for final cementation (see Chapter 44). In some situations the only option may be to cement final restorations temporarily. In these cases, the restoration should be fitted temporarily for several days to allow the patient to assess the esthetic and functional results more accurately. However, if the crowns are all-ceramic it may not be feasible to cement temporarily unless the patient will agree to a strict soft diet so that no chewing will take place. The all-ceramic needs the support of a final cement to support the forces of mastication.

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Chapter 44 Cementation of Restorations

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Chapter Outline

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Cementation is the final step in providing an indirect esthetic restoration. Like so many procedures in dentistry, attention to detail is essential, and inappropriate choice of material or its manipulation can ruin an otherwise outstanding patient treatment. A wide range of luting agents is now available, and the dentist should choose a material carefully and ensure that the office staff is thoroughly familiar with the recommended manipulation procedures. The choice of luting agent depends first on whether a conventional casting or an adhesively bonded restoration—such as a ceramic veneer or resin-retained partial fixed dental prosthesis—is to be cemented. Traditional dental cements can be used for conventional castings, but not where adhesion is needed. Adhesive resins are necessary for adhesively bonded restorations, but they can also be used for conventional castings; however, they may prove to be more difficult to use.

Dental cements

In the past, the luting agents used for cast restorations have been dental cements, such as zinc phosphate or glass ionomer. These consist of an acid (liquid) that is mixed with a metal oxide base (powder) to form a salt and water. The set material consists of unreacted powder particles "glued" together by the reaction products. However, cements are susceptible to acid attack and, therefore are, to some extent, soluble in oral fluids.[1,2] Nevertheless, the materials have proved to give excellent clinical performance, presumably because the cement margin is protected from further physical disintegration even after some dissolution has occurred.[3,4]

Many dentists continue to use zinc phosphate cement for their metal–ceramic crowns. This traditional luting agent has

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adequate strength, and it is easy to use, with low film thickness, reasonable working time, and, because it is nonadhesive, excess material is relatively easily removed. No luting agent has a longer history of successful use, and we have no data to prove that restorations will survive longer with the newer materials.

Glass ionomer cement has the advantage of adhesion to enamel and dentin and exhibits good biocompatibility. It is slightly stronger than zinc phosphate, though the setting cement is particularly susceptible to early moisture contamination[5] and should be carefully protected. The set material releases fluoride[6,7] and has been promoted as having an anticariogenic effect. However, this has not been documented clinically.[8] Glass ionomer cement is somewhat translucent, which provides an esthetic advantage over zinc phosphate. The newer resin-modified glass ionomers are less susceptible to early moisture[9] and represent one of the most popular type of luting agent in North America in terms of annual sales volume. (The terminology of some of the newer glass ionomer–resin combinations is rather confusing. In this chapter, the term "resin-modified glass ionomer" has been used. Other terms used for luting agents and restorative materials with a combination of glass ionomer and resin chemistries include "compomer" (mostly composite with some glass ionomer chemistry), "hybrid ionomer" (now considered obsolete), and "resin-reinforced glass ionomer.") Current developments include encapsulated and paste–paste formulations for easier and more accurate manipulation. Resin-modified glass ionomers are questionable with ceramic restorations as they have been associated with fracture,[10,11] probably due to their water absorption and expansion.[12] However, when using an all-zirconia or zirconia-core crown in which the internal surface cannot be etched, a resin-modified glass ionomer cement can be helpful, especially due to the passive fit of the all-ceramic crown.

Resin luting agents

Unfilled resins have been used for cementation since the 1950s. These early products were not successful because of high polymerization shrinkage and poor biocompatibility, but had very low solubility and good esthetic qualities. Composite resin luting agents with greatly improved properties were developed for the resin-retained prostheses and are extensively used for the bonded-ceramic technique (Figure 44.1A–G). Resin cements are available with adhesive properties; that is, they are capable of bonding chemically to dentin. Typically, bonding is achieved with organophosphonates, such as 10-methacryloyloxydecamethylene phosphoric acid, hydroxyethyl methacrylate, or 4-methacrylethyl trimellitic anhydride.[13] These developments have popularized the use of resin cements for crowns and conventional fixed prostheses. However, resin luting agents tend to have greater film thickness[14] and are less biocompatible than cements such as glass ionomer, especially if they are not fully polymerized.

Resin luting agents are available in a wide range of formulations. These can be categorized on the basis of polymerization method (chemical polymerization, light polymerization, or dual polymerization) and the presence of dentin bonding mechanisms. Metal restorations require a chemically polymerized system, whereas a light- or dual-polymerized system is appropriate with translucent ceramics. Resins formulated for cementing conventional castings must have lower film thickness than materials designed for ceramics or orthodontic brackets. However, this may be achieved at the expense of filler particle content and will adversely affect other properties, such as polymerization shrinkage.

The manipulative techniques may be very different with different brands of resin cement. For example, one material (Panavia 21) sets very rapidly when air is excluded. The directions call for the material to be spatulated in a thin film. It will set rapidly if piled up on the mixing pad. Another material (C&B-Metabond, Parkell Inc.) is mixed in a ceramic well that must be chilled to prevent premature setting.

Postcementation sensitivity

Increased sensitivity to hot or cold stimulation is an occasional but perplexing unwanted consequence of a newly cemented restoration,[15] and its occurrence is probably underestimated by most dentists.[16] Although conventional glass ionomers have been most often reported to cause sensitivity,[17] there appears to be little pulpal response at the histological level,[18] particularly if the remaining dentin thickness exceeds 1 mm,[19] and the reports have not been supported by clinical trials.[20–22] Side effects such as posttreatment sensitivity that have been ascribed to lack of biocompatibility are probably due to desiccation or bacterial contamination[23] of the dentin rather than irritation by the cement per se. If, in practice, dentists find postcementation sensitivity to be a problem, then they should carefully evaluate their technique, particularly avoiding desiccation of the prepared dentin surface. Resin-modified glass ionomer materials and self-etching resin cements have been reported to exhibit less postcementation sensitivity,[24,25] which may be due to reduced marginal leakage[26] or their antimicrobial effects.[27] A desensitizing agent or antimicrobial may reduce sensitivity, though it may also adversely affect retention, at least with some luting cements.[28,29]

Preparation of the restoration and tooth surface for cementation

The performance of all luting agents is degraded if the material is contaminated with water, blood, or saliva. Therefore, the restoration and tooth must be carefully cleaned and dried after the try-in procedure, although excessive drying of the tooth must be avoided to prevent sensitivity. A metal casting is best prepared by airborne particle abrading the fitting surface with 50 μm alumina. This should be done carefully to avoid abrading the polished surfaces or margins. Abrasion has been shown to increase the in vitro retention of castings by 64%.[30] Alternative cleaning methods include steam cleaning, ultrasonics, and organic solvents. Also, make sure all porcelain shoulder margins are properly etched with hydrofluoric acid and silanated before cementation (Figure 44.2).

Figure 44.1 **(A)** This 17-year-old girl was unhappy with her discolored teeth which bleaching had not helped.

Figure 44.1 **(B)** It was decided to do porcelain veneers on the mandibular left lateral and central incisors to improve their color and form.

Figure 44.1 **(C)** The maxillary central and lateral incisors were prepared for porcelain veneers. However, there was a dark brown spot on the central, which would influence the final shade.

Figure 44.1 **(D, E)** Since a resin luting cement was to be used to bond the porcelain veneers into place, the dark brown area was slightly prepared and a white resin opaque was applied to help mask the stain. (Cosmedent).

Figure 44.1 **(F)** An extra-coarse diamond (AC2, Brasseler USA) was used to make sure the veneer still fit perfectly.

Figure 44.2 When using a metal-ceramic butt-joint restoration, it is important to always make sure the porcelain butt margin is etched and silanated before cementation.

Cementation procedure for metal–ceramic restorations

Resin-modified glass ionomer is used to illustrate the typical procedure, although, depending on the cement chosen, the steps may vary slightly. When using a resin-modified glass ionomer cement, avoid cementing too many crowns at the same time due to the fast set of material. Generally, a quadrant consisting of four posterior crowns or six anterior crowns can be accomplished, but only if you have two to three mixes of cement

Figure 44.1 **(G)** Resin luting cement was used to bond the four veneers into place. Note the shade blends without showing evidence of the dark stain on the upper right central.

virtually at the same time. As each crown is placed, the next one is quickly inserted until all the crowns are seated.

1. Immediately prior to cementation, inspect all preparation surfaces for cleanliness (Figure 44.3A). Remove any provisional luting agent with a pumice wash or hydrogen peroxide. Use an antimicrobial if desired, although research has not proved this step to be beneficial. The casting should be airborne-particle abraded, steam cleaned, or cleaned ultrasonically and washed with alcohol to remove any remaining polishing compound or die spacer. The prepared tooth should be isolated with cotton rolls, and a saliva evacuator is placed (Figure 44.3B–E).
2. Mix the luting agent as recommended by the manufacturer; check the consistency to make sure the product has been dispensed correctly.
3. Apply a thin coat of cement to the clean internal surface of the restoration. To extend working time, the cement should be applied to a cool restoration rather than to a warm tooth (Figure 44.3 F–I).
4. Check that the tooth is properly isolated and push the restoration into place. Final seating is achieved by rocking with an orangewood stick until all excess cement is seen to have escaped. It is important to seat the restoration firmly with a rocking, dynamic seating force. Using a static load may cause binding of the restoration and lead to incomplete seating.[31] Excessive force during seating should be avoided. A cotton roll can continue to hold the crowns in place once firmly seated (Figure 44.3 J).
5. After the casting is seated, check the margins with an explorer to verify that the restoration is indeed fully in place. Another technique to make certain the crowns are in proper occlusion is to have the patient quickly close onto shim stock that is 5/10,000″ thickness (Artus) until they are seated properly. Protect the setting cement from moisture by covering with varnish.
6. When fully set, remove excess cement with an explorer or scaler (Figure 44.3 K–L). Early removal of cement may lead to early moisture exposure at the margins with increased solubility. Dental floss with a small knot in it can be used to remove any irritating residual cement interproximally and

Figure 44.3 **(A)** Two complete metal-ceramic crowns will be cemented into place on the mandibular right first and second molars.

from the gingival sulcus (Figure 44.3 M). Occasionally cement gets trapped in the contact areas, making it impossible to get dental floss through. One good technique is to use a very thin saw to easily separate the contact and allow floss to get through. The sulcus should contain no cement. Many dentists take a radiograph to help identify residual cement. After the excess has been removed, the occlusion can be checked once more with Mylar shim stock.

7. Cements take at least 24 h to develop their final strength. Therefore, the patient should be cautioned to chew carefully for a day or two (Figure 44.3 N).

Figure 44.3 **(B–E)** After cleaning off any temporary cement, pumice the prepared teeth. Next, a mild acid conditioner (GC Fuji Plus Conditioner) is applied and thoroughly rinsed.

Figure 44.3 **(F, G)** The two metal-ceramic crowns are taken off of the die with finger position exactly as it should be placed in the mouth.

Figure 44.3 **(H, I)** The first molar crown is removed from the die with finger position exactly as it should be placed in the mouth.

Figure 44.3 **(J)** Once the crown is firmly seated into place as described in the text, repeat the same procedure for the second crown, then have the patient bite into centric with either an orange stick or cotton roll. Note, as this type of cement sets quickly, it is urgent that each crown be seated and verified one after the other as quickly as possible.

Figure 44.3 **(K, L)** Once the cement has reached its initial set, it is important to immediately begin to remove the excess cement with a combined chisel/scaler instrument (Novatech 12-CRNT12, Hu-Friedy).

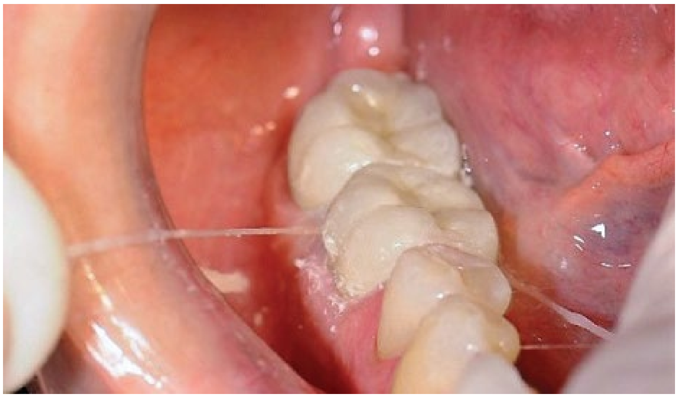

Figure 44.3 **(M)** Dental floss with a small knot can be used to remove any residual cement interproximally and from the gingival sulcus. At times, a very thin saw (ET Flex, Brasseler USA) can be used to separate a contact and allow the floss to go through.

Figure 44.3 **(N)** Final crowns cemented into place showing good tissue adaptation and no cement residue.

Cementation technique for all-ceramic crowns

Cementation for all-ceramic crowns is similar to procedures for ceramic veneer inlays and onlays. However, some of the newer luting agents are self-adhesive, not requiring a separate step etching during tooth preparation. Nevertheless, that option is up to the dentist to decide whether extra etching is necessary. The same can be said about the bonding resin placed inside the crown. One example of step-by-step cementation of an all-ceramic crown with self-adhesive cement can be seen in Figure 44.4A–J.

Cementation procedures for ceramic restorations

Depending on the ceramic system used, these restorations may rely on resin bonding for retention and strength. The cementation steps are critical to the success of the restoration, and careless handling of the resin luting agent may be a key factor in their prognosis. Bonding is achieved by (1) etching the fitting surface of the ceramic with hydrofluoric acid, (2) applying a silane coupling agent to the ceramic, (3) etching the enamel with phosphoric acid, (4) applying resin bonding agent to etched enamel and silane, and (5) seating the restoration with a resin luting agent.

Selection of resin luting agent

Composite resin luting agents are available in a range of formulations. For translucent ceramic veneers, a light-polymerized material can be used, but for inlays a chemical- or dual-polymerized material is preferred to ensure maximum polymerization of the resin in the less accessible proximal areas. Dual-polymerized resin has been found to give better marginal adaptation at the critical gingival margin area, possibly because voids incorporated during mixing reduce the harmful contraction stresses of the resin.[32]

The appearance of veneers can be modified to some extent by the shade of the luting agent. Color-matched try-in pastes are available for some products (e.g., NX3, Kerr Corporation) to facilitate selecting the best shade.

Figure 44.4 **(A)** Cementation for this all-ceramic crown begins with etching the internal surface of the crown with 9.5% hydrofluoric acid (Porcelain Etchant, Bisco Inc.) for 90 s.

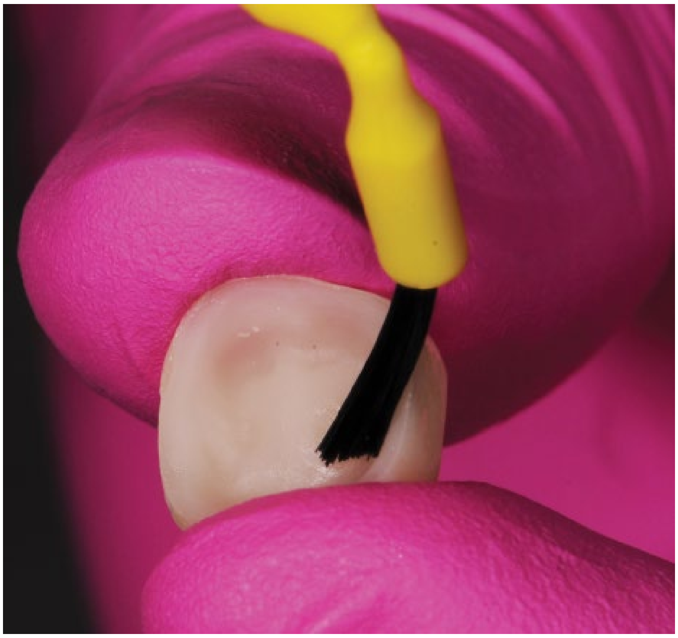

Figure 44.4 **(B)** Next, apply two thin coats of silane to the etched internal surface and air dry.

Figure 44.4 **(C)** Coating the inside of the crown with bonding resin could be an option according to some manufacturer's instructions.

Figure 44.4 **(D)** Although not necessary with self-adhesive resin cements, the prepared tooth can be etched with 35% phosphoric acid for 20 s and rinsed thoroughly.

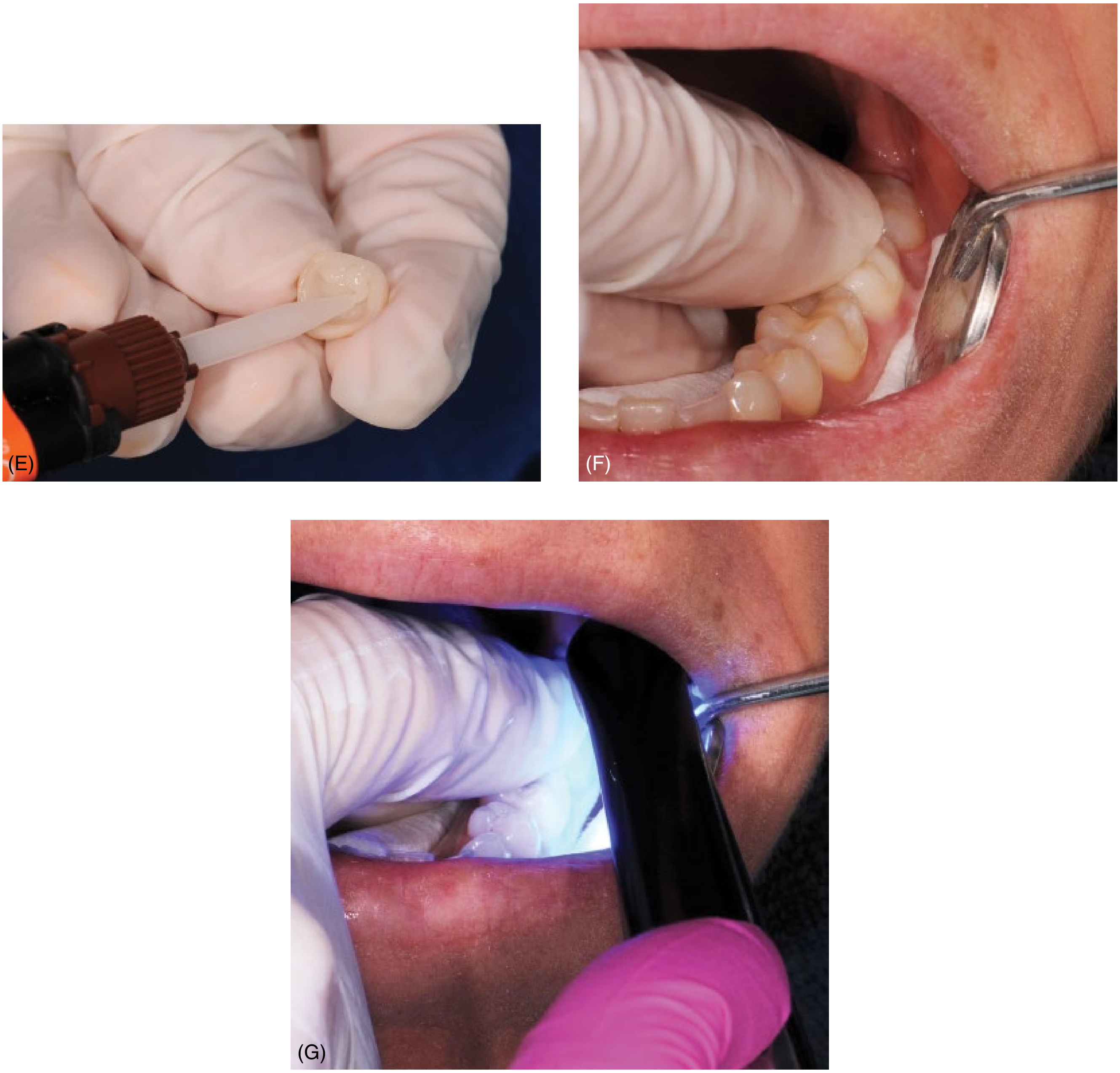

Figure 44.4 **(E–G)** The cement is loaded into the crown by lining the internal surfaces and immediately put into place and tack cure for 2–4 s.

Figure 44.4 **(H)** Remove excess cement, and repolymerize all surfaces for 20 s.

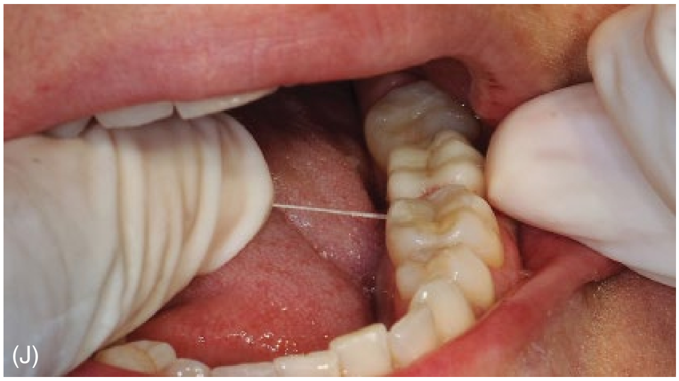

Figure 44.4 **(I, J)** If excess cement is in the contact area making it impossible to get floss through, use a very thin saw instrument (ET Flex, Brasseler USA) to clear the contact area.

Cementation procedure for ceramic veneers and inlays

1. Clean the teeth with pumice and water. Isolate them with a rubber dam or displacement cord. Remember, a luting agent containing zinc oxide–eugenol (ZOE) is best avoided for cementing provisional restorations prior to resin bonding. Eugenol inhibits the polymerization of the resin. If a ZOE-containing product has been used, cleansing with pumice will not remove it completely.[33] Etching with 37% phosphoric acid after cleaning with pumice may be the best means of ZOE removal.[34]
2. Evaluate the fit and esthetics of the restorations with glycerin or a try-in paste. Sometimes multiple restorations can only be inserted in one sequence, so note this order.
3. Clean the restorations thoroughly in water or acetone with ultrasonic agitation. Dry them and support in soft wax with the fitting surface uppermost.
4. Apply a 1 mm coat of the etching gel (Ceram-Etch Gel (9.5% hydrofluoric acid), Gresco Products Inc., Stafford, Texas (or the ceramic manufacturer's recommended product)) to the fitting surface only. The etching time will depend on the ceramic material. Feldspathic porcelain is typically etched for 5 min.
5. Very carefully rinse away the gel under running water. The gel is very caustic; it should not be allowed to contact skin or eyes. Continue to rinse until all the gel color has been removed.
6. Dry the ceramic with oil-free air. If there is doubt about the unit air, a hair drier is recommended to ensure that the ceramic is not contaminated.
7. Apply the silane according to the manufacturer's recommendations. Some manufacturers recommend a heat-polymerized silane coupling agent for increased bond strength, rather than a chemically activated silane. Heat curing is normally done by the laboratory, and care must be taken to clean the fitting surface thoroughly with alcohol before cementation.
8. Acid etch the enamel; 37% phosphoric acid is generally used, applied for 20s. Rinse thoroughly and dry.
9. Apply a thin layer of bonding resin to the preparation. Brush, rather than air thin, the bonding resin, as air thinning might inhibit polymerization.[35] Do not polymerize this layer before cementing, as it might interfere with complete seating.
10. For veneers, place a Mylar matrix strip at the mesial and distal surfaces of the prepared tooth.
11. Apply resin luting agent to the restoration, being especially careful to avoid trapping air.
12. Position the restoration gently, removing excess luting agent with an instrument or brush.
13. Hold the restoration in place while light curing the resin. Do not press on the center of veneers; they may flex and break.
14. Use dental tape to remove resin flash from the interproximal margins of inlays and onlays before curing these areas.
15. Do not underpolymerize the resin cement. Allow at least 40 s for each area.
16. Remove resin flash with a scalpel, sharp curette, or an ET 15 μm diamond (Brasseler USA).
17. Finish accessible margins and occlusion with fine diamonds, using water spray. Use finishing strips for the interproximal margins.
18. Polish adjusted areas with rubber wheels or points and then with diamond polishing paste.

Summary

Proper moisture control is essential for the cementation step. The restoration must be carefully prepared for cementation, including the removal of all polishing compounds.

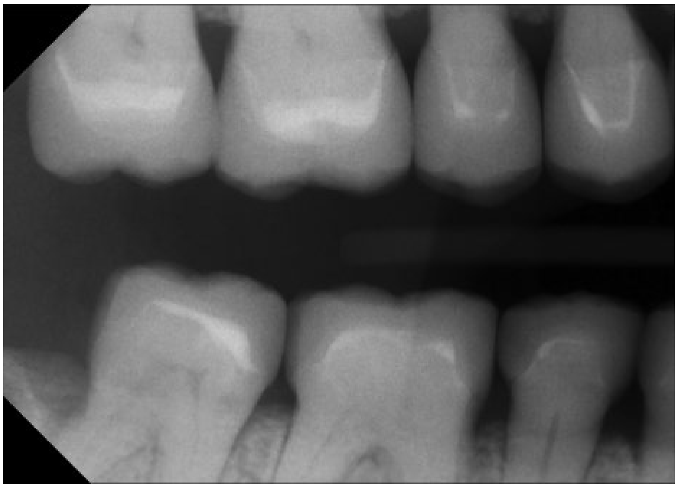

Figure 44.5 **(A)** Following cementation, a postoperative radiograph should be taken to verify that all cement has been removed.

Figure 44.5 **(B)** This is a perfect example showing why a postoperative radiograph is necessary. Note the presence of extra cement at the distal of the first premolar.

Airborne-particle abrading the fitting surface of metal ceramic restorations is recommended. The luting agent of choice is mixed according to manufacturer's recommendations, and the restoration is seated using a rocking action. The cement must be protected from moisture during its initial set. Removal of excess cement from the gingival sulcus is critical for continued periodontal health. A digital radiograph is the last way to make certain that no cement remains (Figure 44.5A and B).

Additional steps are necessary for adhesively bonded restorations. These steps must be carefully sequenced according to manufacturer's directions.

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PART 9
TECHNICAL ADVANCES AND PROPER MAINTENANCE OF ESTHETIC RESTORATIONS

Chapter 45 Esthetic Principles in Constructing Ceramic Restorations

Robert D. Walter, DDS, MSD

Chapter Outline

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The principles to restore the positions, proportions, and contours of teeth along with future plans for maintenance should be sequenced in a treatment plan prior to the selection of a restorative material. When the suggested sequence is followed, the principles for the selection of the appropriate dental ceramic deliver subtle nuances that elevate esthetic dentistry to new and greater levels. Ceramic restorations have many esthetic, functional, conservative, and biocompatibility benefits to deliver new opportunities for challenging clinical situations and to manage maintenance issues. Hence, ceramic restorations have become very popular. With their popularity, the contemporary dental patient and dentists have come to expect or demand the state of the art in dental esthetics. Regardless, treatment plans should never be designed around a primary objective to deliver a specific type of dental material or technique.[1] Success of all-ceramic restorations does not come from only one material, but from the clinician's understanding of patients' needs and a working knowledge of how to match the appropriate materials, fabrication techniques of the restorations with a material's specific handling considerations, and clinical handling including delivery procedures.[2] Since all dental therapy will inevitably fail with time, strategies for maintenance should try to minimize catastrophic failure. To make a treatment plan of this caliber, it has to be studied for its weakness. The weakest links to consider are typically the restorative interfaces. Once the restorative interfaces are defined within the treatment plan, then the appropriate dental materials can be selected with the foresight of maintenance so contingencies can be implemented to facilitate the long-term management of the all-ceramic restoration. Four restorative interfaces have been considered in this chapter for the implant and tooth-borne restorations:

- abutment–implant platform interface
- implant abutment–soft tissue interface
- tooth or implant abutment–restoration interface
- occlusal surface–opposing dentition interface.

Ronald E. Goldstein's Esthetics in Dentistry, Third Edition. Edited by Ronald E. Goldstein, Stephen J. Chu, Ernesto A. Lee, and Christian F.J. Stappert.

Each interface of the restoration has a different inherent function. With collaborative analyses of all the interfaces involved for a planned restoration, one interface may be determined to be the limiting factor for long-term maintenance success. The ceramic material should be evaluated for its mechanical and optical properties as well as for its biocompatibility so that the most suitable ceramic material can be recruited for the specific restorative interface and to address the weakest link.

Abutment–implant platform interface

The ceramic restoration–implant platform interface has an interesting relationship between two dissimilar dental materials. Presently, ceramic implant abutments are dominantly made of zirconium dioxide, also known as zirconia. The zirconia abutment has three general design categories to address the connection between the ceramic abutment and titanium implant platform. One category of ceramic abutments has a titanium insert within the abutment. Dependent on which manufacturer, the ceramic abutment and titanium insert may be bonded together or coupled with a friction grip connection. The titanium insert typically acts as an antirotation component of the abutment with the implant. Ceramic abutments within this category have a percentage of ceramic still in contact with the implant platform and the prosthetic screw head (Figure 45.1). The second category of ceramic abutments has a complete metal contact with the implant; more vertical space is required for the abutment emergence profile because of the added material thickness. Figure 45.2A and B shows a custom two-piece abutment that was cemented together. The abutment–implant platform interface had 100% titanium contact with the dental implant. A subcategory within the ceramic and complete titanium interface uses a titanium transitional/transmucosal abutment to correct off-angle implants so that a screw-retained zirconia bridge may be delivered.

The third category supports the fabrication of ceramic abutments completely out of one piece of zirconia. A one-piece or monolithic ceramic abutment puts 100% of the ceramic–titanium junction at the implant platform and all internal connections. With this design the prosthetic screw head engages the abutment and the screw threads engage the titanium alloy threads of the implant. Unlike the two-piece ceramic abutments with 100% metal contact, the monolithic zirconia abutment requires less vertical space to develop the emergence profile without concerns of metal display (Figure 45.3). Research has shown single-tooth zirconia implant abutments to have the same survival, technical, and biological outcomes as single-tooth titanium implant abutments for the replacement of single anterior and posterior teeth.[3–7] However, because of the interesting dynamic relationship between the ceramic and titanium interface coupled with the prosthetic screw found in the three design categories, it is important to understand the material properties of wear and to be certain that the manufacturers' recommended preload is achieved to minimize future screw loosening.[8]

Figure 45.1 Hybrid zirconia and titanium implant abutment. Both zirconia and titanium contact with implant platform.

Abutment–soft tissue interface

With the continuation of improvements in survival and success of dental implants through osseointegration, the attention turned to the esthetics of the peri-implant soft tissues.[9–11] Animal studies revealed that gingiva did not attach to cast gold alloy abutments but did attach to titanium, densely sintered high-purity alumina, and zirconia abutments.[12,13] With zirconia and titanium, the criteria of clinical markers for implant success and failure continue to evolve. In part, the evolution was due to titanium and zirconia's high biocompatibility, and today these two materials are considered as the standard.[3,14] Zirconia implant abutments improve local factors of peri-implant tissue health through increasing tissue attachment, reducing pocket probing depths, and having minimal bacterial colonization and adhesion.[15–17] These local factors are signs of peri-implant tissues health improvement, but the esthetics of the implant restoration–tissue interface are also addressed with the available ceramic materials today.

Peri-implant soft tissues are different in color than the gingiva of natural teeth (Figure 45.4A).[3,18,19] Clinical observations have reported a graying in the tissues of concern when they are coupled with implant-supported restoration retained by metal abutments.[20] ΔE was recommended by the International Commission on Illumination as a metric to describe perceived noticeable difference in color, where the symbol Δ represents difference and E stands for the German word "Empfindung," which means sensation.[21] The color difference ΔE of the peri-implant tissues are significantly affected by the selection of implant abutment whether it is fabricated from titanium alloy or ceramic.[18,19] To improve the color of peri-implant tissues in the anterior, ceramic implant abutments are recommended along with connective tissue grafts if the labial tissue thickness is less than 2 mm.[19,22,23]

However, not all dental patients are the same. To address specific patient needs, the interaction of two conditions needs to be collectively considered when selecting an abutment material. When a dental implant replaces an anterior tooth, two things have to be considered for the selection of the abutment material.

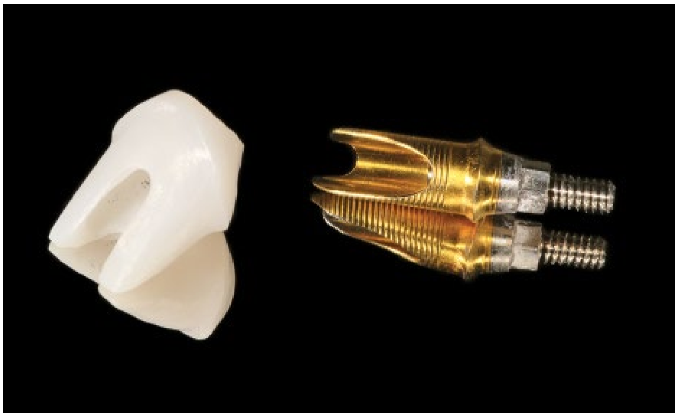

Figure 45.2 **(A)** Zirconia and titanium are used to construct a two-piece implant abutment, but only titanium contacts the implant platform.

Figure 45.2 **(B)** Zirconia and titanium parts are bonded together for the definitive abutment.

Figure 45.3 Example of monolithic zirconia implant abutment with ceramic crown and prosthetic screw. Only zirconia interfaces with the implant platform.

The first consideration is that in health the free gingival margin takes on a knife edge shape which may not be 2 mm in thickness. The second condition is that the ideal location of the abutment finish line for a cement-retained implant restoration be positioned 1 mm or less apical of the free gingival margin to facilitate ease of cement removal (Figure 45.4B and C).

The summation of these conditions involves factors of the dental implant's vertical, horizontal, and angular position along with the emergence profile of the restoration. Thus, most dental implant sites may require some development through tissue grafting. Many times zirconia abutments may be preferable over titanium abutments for anterior areas because the cross-sectional dimension of the labial free gingival margin is rarely greater than 2 mm in thickness when measured 1 mm or less apical from the crest of the healthy free gingival margin. Submerging the finish lines of the abutment deeper than 1 mm may gain more tissue thickness and solve the issue of discolored peri-implant tissues but may present a greater challenge in terms of residual cement removal.[24] Figure 45.4B–E is the continuation of Figure 45.4A. Note the improved peri-implant tissue color with

Figure 45.4 **(A)** Implant and healing abutment submerged in right maxillary central incisor position. Translucent peri-implant soft tissues reveal underlying metal.

Figure 45.4 **(B)** Monolithic zirconia implant abutment in place to evaluate ΔE between peri-implant soft tissues and adjacent tooth gingiva.

Figure 45.4 **(C)** Idealized finish line location to facilitate residual cement removal with aid of a deflection cord.

Figure 45.4 **(E)** Definitive bilayered zirconia crown on custom monolithic zirconia implant abutment.

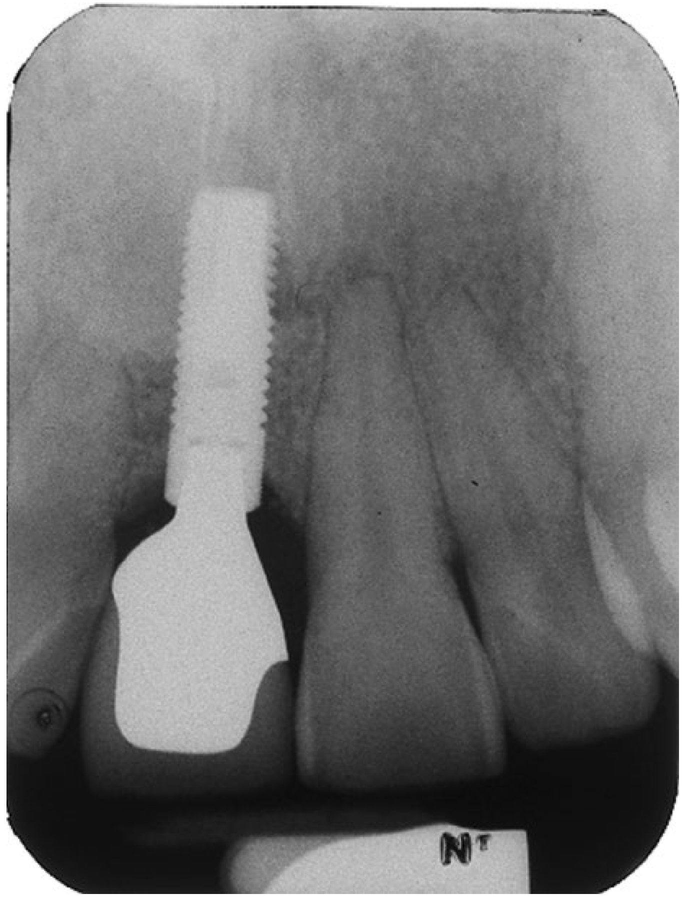

Figure 45.4 **(D)** Postcementation radiograph confirms complete cement removal in difficult to reach interproximal areas.

the definitive zirconia abutment in place (Figure 45.4B), and the effect of the deflection cord on the tissue color when placed to facilitate cement removal (Figure 45.4C). Figure 45.4D is a routine periapical radiograph to confirm no excess residual cement is left on the mesial and distal aspects of the abutment and implant platform. Figure 45.4E shows the ceramic crown with zirconia core conventionally luted on a zirconia abutment while demonstrating healthy tissue contours, color, and texture.

Restoration–implant or –tooth abutment interface

This interface is typically evaluated clinically by the fit of the restoration to the abutment. Marginal discrepancies of 18.3–117 µm for ceramic restoration adhesively or conventionally luted to teeth have been measured in in-vitro studies.[25–41] McLean and von Fraunhofer proposed a qualification for clinical acceptability for marginal discrepancy on teeth to range from 40 to 120 µm.[42] Ceramic restorations are well within such clinical acceptability parameters. However, the fit is not only influenced by the finish line preparation, quality of impression, and skill level of the laboratory technician. Nowadays, it is also affected by the manufacturing technique and level of technology of available computer-aided design/manufacturing (CAD/CAM) systems and the skills of the operator of the system.[35,36] If all variables are strictly governed in the fabrication of a ceramic restoration, clinicians should expect the marginal discrepancy to be in the low end of the range. The marginal discrepancy with ceramic restorations on ceramic implant abutments is probably similar to natural teeth, but the concern for secondary caries does not exist as it does with natural teeth.

Three considerations should be applied while evaluating the ceramic restoration–tooth or –implant abutment interface. The first consideration only pertains to dental implants. With a dental implant, this interface can be totally eliminated with the concept of screw retention. The benefit of eliminating this interface delivers a simpler design with fewer interfaces to maintain. Screw-retained implant restorations tend to have better plaque and bleeding indexes than cement-retained implant restorations do.[43] This interface has also been reported to cause periodontal irritation and peri-implant disease if residual excess cement is left undetected.[44,45] The challenge with a screw-retained restoration is the presurgical planning, interdisciplinary team communication, and skill level of execution to place the implant accurately. The implant has to be positioned with the screw access hole of the restoration located in an area which does not impair esthetics. Many times an esthetically located screw access hole is limited by the restorations path of insertion between the existing proximal contacts and the engaging components of the abutment and implant.

Figure 45.5A and B demonstrates a patient with failing mandibular incisors and less than ideal oral hygiene before and after oral hygiene instructions and cleaning noted at the periodontal reevaluation. To replace the failing mandibular incisors, a zirconia screw-retained implant-supported fixed partial denture was selected. Elimination of the restoration–abutment interface delivered prospective plans for periodontal maintenance. Additionally, the size of the abutments for a cement-retained fixed partial denture in the positions of the mandibular incisors on such narrow platform implants would have been small with thin axial walls. The durability of a one-piece abutment–framework complex may be more favorable. Lastly, the screw-retained restoration allows for simple retrievability if any prospective prosthetic maintenance or complications occur (Figure 45.5C–F).

The next consideration for the ceramic restoration–tooth or –implant abutment interface involves whether the restoration should be adhesively bonded or conventionally luted. The current high-strength all-ceramic restorations allow clinicians to use conventional methods to lute the restoration when isolation is difficult, there is compromised gingival health, or the finish line is subgingival.[1]

Once Buonocore[46] introduced a process of etching the tooth structure to increase the quality of dental adhesion in 1955, a door was opened for esthetic dentistry. Today, research and clinical experience has propelled continuous evolution of tooth-colored restorative materials, adhesive materials and techniques, and methods for more conservative treatment modalities. Currently, the enamel and glass-ceramic-based ceramic restoration bond is very predictable,[47–49] and research has reported improvement in the adhesive bond to less-predictable materials, such as dentin and oxide ceramics.[50–55]

Along with good predictability for bonding to enamel, adhesively retained all-ceramic restorations facilitate minimally invasive restorative procedures. Tooth preparations are no longer required to be governed only by the mechanical principles of resistance and retention form. Sound tooth structure may be conserved, since a bonded restoration is not dependent on the parallelism of opposing axial walls. The probability of catastrophic failure versus routine maintenance is many times decided by the quantity and quality of remaining tooth structure. An example of a catastrophic failure would be the subgingival horizontal fracture of a tooth restored with a complete crown. In contrast, a more favorable routine maintenance procedure would be to rebond a porcelain laminate veneer that has fractured or debonded due to the adhesive composite-resin fatigue. To rebond ceramic restorations to minimally prepared teeth is more desirable from a patient's procedural and financial point of view than the treatment required to restore or replace structurally compromised teeth. It is imperative that the contemporary dental patient be educated to return to the dental provider for maintenance on a routine basis as well as immediately when a problem emerges. Figure 45.6A–C shows an example of a dental patient with porcelain laminate veneers on the mandibular incisors who returned to have a maintenance visit to rebond a veneer. The rebonding of the porcelain laminate veneer was a low-stress and low-cost procedure for the patient comparatively to a catastrophic failure from a horizontal tooth fracture that might have occurred if the incisor had been prepared for a complete crown.

The third consideration for the ceramic restoration–abutment interface deals with the color and translucency of the abutment tooth. Natural colors from the underlying tooth may be revealed in the definitive restoration with ceramics of variable optical properties and thicknesses. The optical properties and variable

Figure 45.5 **(A)** Missing mandibular right central incisor.

Figure 45.5 **(B)** Radiograph reveals vertical bone loss on adjacent teeth.

Figure 45.5 **(C)** Monolithic screw-retained zirconia framework.

Figure 45.5 **(D)** Convex intaglio surface allows area to be flossed.

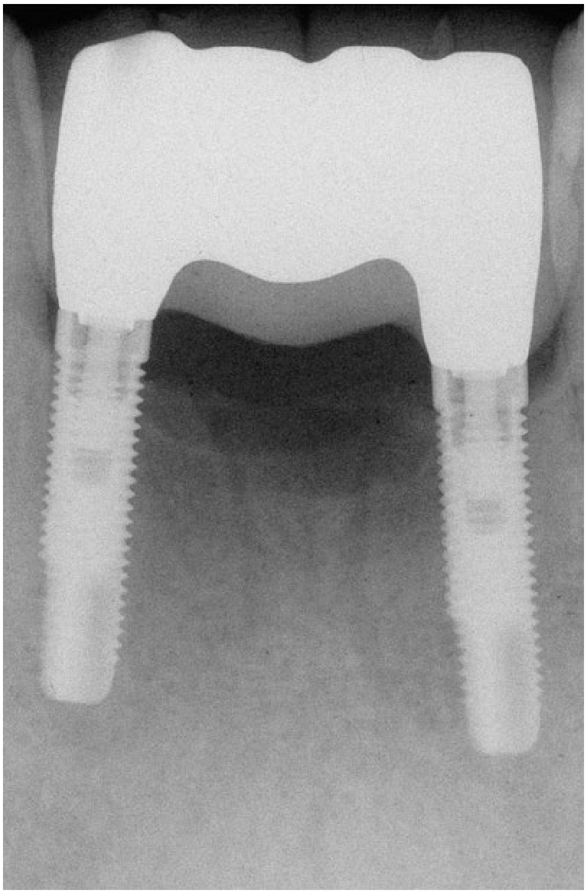

Figure 45.5 **(E)** Radiographic evaluation of restoration fit with implant platforms.

Figure 45.5 **(F)** Screw-retained bilayered prosthesis with zirconia framework

thicknesses of different dental ceramics can bring the inner color of the tooth out to the surface of the definitive restoration.[56] If the colors of the abutment are not desirable because of stains and/or restorative materials, masking is possible with opaque and thicker ceramics.[57–59]

Occlusal surface–opposing dentition interface

The ceramic occlusal surface–opposing dentition interface is the last interface considered. However, it is where all interfaces are collectively tested for durability. Many have noted that ceramic restorations have higher rates of failure on posterior rather than on anterior dentition.[3,60–62] These higher success rates for anterior restorations may be attributed to the fact that the posterior teeth generate higher occlusal forces (forces generated by muscles of mastication and transferred to the teeth) than the anterior teeth do. With the difference between anterior and posterior teeth in terms of occlusal load, patient factors of function along with evaluation of available ceramics and fabrication techniques need to be considered collaboratively when designing an all-ceramic restoration.

Contemporary dental ceramics and the manner of fabrication of the definitive restoration offer ample opportunities to achieve balance between durability and esthetics for both anterior and posterior teeth. Since the level of function at the occlusal interface is dependent on the location in the mouth, two philosophies

Figure 45.6 **(A)** Patient presentation with a debonded porcelain laminate veneer.

Figure 45.6 **(B)** Intaglio surface of porcelain laminate veneer shows signs of bond fatigue with discolored margin.

Figure 45.6 **(C)** Same porcelain laminate veneer after bonding procedure.

in restorative design have emerged. One design concept for the ceramic restoration is the bilayered restoration. The bilayered restoration has a core substrate to support and give strength to a veneer material as previously demonstrated in metal–ceramics. With all-ceramic bilayered restorations, concerns had developed with the veneer chipping, separation at the interface between the two materials, and/or fracture of the core. The second design is the monolithic concept. A complete gold crown is a classic example of a monolithic restoration. The monolithic ceramic restoration does not have an interface between two ceramic materials because it is fabricated from only one material. However, esthetics may be limited due to its monochromatic tendency.

Three categories of dental ceramics are available to create the two restorative design philosophies. They are the glass (etchable) ceramics, the glass-infiltrated ceramics, and the oxide ceramics. Each category has different esthetic and durability benefits for all-involved interfaces of a ceramic restoration.

Glass-ceramics (etchable)

Glass-ceramics molecular organization is multiphasic, amorphic, and has a random matrix that contains silica. Its molecular makeup gives glass-ceramics a dual quality of similar optical traits to that of natural teeth and the potential favorable mechanical properties (pending on the type of material). The optical and mechanical properties of the glass-ceramic are dependent on the ratio between the glassy and the crystalline phase. Ceramics with a greater percentage of the glassy phase will possess more translucency, opalescence, and fluorescence but are weaker. Glass-ceramics with a greater percentage of the crystalline phase cause more light to scatter, are less translucent, and deliver more strength. Glass-ceramic may be used as a veneer material over a core substrate made of a different ceramic material for a bilayer restoration or without a core for a monolithic restoration like a porcelain laminate veneer or a crown. Clinical success of single-unit glass-ceramic restorations is attributed to their properties of micromechanical and chemical bonding to resin composite. Resin bonding is possible because the material is etchable. Hydrofluoric acid primes the ceramic surface by the removal of exposed silica in the glassy matrix.[63] Holes in the glassy matrix, where the silica used to be, improve the wettability of the ceramic for the application of silane to facilitate a chemical bond.[63] In addition, these empty spaces become micromechanical retentive features for the resin composite. The duration of etching and the concentration of acid etchant change between types of glass-ceramic and manufacture. It is possible to overetch glass-ceramic and compromise its bonding.[64]

One type of ceramic in this group uses leucite as reinforcement for a base material to construct a monolith or a veneer material for a bilayer restoration. The thermal expansion of leucite is mismatched with the glassy phase to create internal compressive stresses within the ceramic that cause cracks to deflect during their propagation. Leucite-reinforced ceramics flexural strength is 104–184.8 MPa.[65,66]

An alternative hybrid glass-ceramic that has a flexural strength is 300–400 MPa with a fracture toughness of 2.8–3.5 MPa $m^{1/2}$ is lithium disilicate.[65] Owing to the mechanical properties of lithium disilicate, it can be used as a core substructure and veneered with another glass ceramic, as a veneer on a core substructure for a bilayered system or as a monolithic restoration. All three uses of lithium disilicate may be fabricated with a lost-wax technique and heat pressed, or partially crystallized lithium disilicate blocks can be milled with CAD/CAM technologies and then fired to achieve the final crystallization. Both monolithic and bilayered lithium disilicate are suitable for single-unit restorations, but strict requirements should be considered in case selection for short-span fixed partial dentures.[67,68] According to the manufacturer's recommendations adhesive cementation is not required, but in the cases of veneers, inlays, and onlays, however, it is recommended that lithium disilicate be etched with 5% hydrofluoric acid and then silanated and adhesively luted. Figure 45.7A–C depicts a clinical case that used monolithic lithium disilicate that was stained and glazed. Although the

Figure 45.7 **(A)** Mandibular central incisors with defective pin-retained cast onlays and composite resin restoring incisal and facial surfaces.

Figure 45.7 **(B)** Minimal abutment length was left once existing restorations were removed. Axial reduction was limited to 0.9 mm for lithium disilicate crowns.

Figure 45.7 **(C)** Translucency of monolithic lithium disilicate crowns with external staining and glazing reveals natural colors of underlying tooth structure.

defective pin castings required complete circumferential preparation of the abutments, the physical properties of lithium disilicate constricted the axial reduction to 0.9 mm. The etchable and translucent properties of lithium disilicate were taken advantage of for the different colored abutments.

Glass-infiltrated ceramics

The glass-infiltrated ceramics are a combination of the glass-ceramics and the oxide ceramics. To create the glass-infiltrated ceramic, partially sintered oxides like aluminum, magnesium–aluminum, or aluminum–zirconium are infiltrated with molten low-viscosity glass. Not as translucent as the glass ceramics, the glass-infiltrated alumina has been used for anterior and posterior copings in crowns. In addition, frameworks for anterior three-unit fixed partial dentures may also be constructed from these materials.[69–71] They are reported to have a flexural strength of 236–600 MPa and a fracture toughness of 3.1–4.61 MPa $m^{1/2}$.[72–75] Glass-infiltrated alumina with 35% partially stabilized zirconia has a flexural strength of 421–800 MPa and a fracture toughness of 6–8 MPa $m^{1/2}$.[72]

Glass-infiltrated alumina with 35% partially stabilized zirconia has the least amount of translucency, which may limit it to only the posterior copings and frameworks.[76,77] In contrast, when glass-infiltrated magnesium alumina is processed in the ceramic furnace under vacuum or via CAD/CAM it creates a highly translucent ceramic core that can be used for anterior restorations.[78]

Oxide ceramics

The oxide or polycrystalline ceramics are a group of ceramics that do not have a glassy phase. Another characteristic of the oxide ceramics that is different than the glass-ceramics is that their molecular makeup is very organized and closely spaced. The dense atomic organization gives the oxide ceramics their characteristic strength and reduced translucency. When the three groups of ceramics are compared for mechanical properties, the oxide ceramics far exceed the other two groups in strength. The two common dental ceramics present in the oxide family are the densely sintered high-purity alumina (Al_2O_3) and yttria tetragonal zirconia polycrystals (Y-TZP), also known as zirconium dioxide (ZrO_2) or zirconia. These two materials became available to dentistry through the development of CAD/CAM technology that enabled the design and milling of ceramics before or after they receive the final firing cycle and sophisticated refinement process to make a ceramic with uniform particle sizes so that mathematical equations can be used to calculate the exact amount of shrinkage from the milled CAD/CAM state to the fully sintered state and end up with a restoration with a precise fit.[79] Clinically, the densely sintered high-purity alumina has been used with adequate success for anterior and posterior cores for all ceramic crowns.[80,81] Its flexural strength is 487–699 MPa and fracture toughness of 4.48–6 MPa $m^{1/2}$.[66,72]

Zirconia consists of a tetragonal zirconia polycrystal phase at 1170–2370 °C that when stabilized with the addition of yttrium oxide (yttria) may maintain a tetragonal phase at room temperature. With the addition of yttrium oxide, zirconia is considered a metastable material (a state of equilibrium that will transform to a more stable state of equilibrium if disturbed). The metastable characteristic is unique to zirconia and gives it the mechanical property known as transformation toughening. Transformation toughening occurs when a crack is initiated. The equilibrium of the metastable zirconia in front of the crack is disrupted and transforms to a more stable monoclinic crystal phase. In the case of zirconia, the desire to transform is an excellent mechanical advantage because the stable monoclinic phase is larger in volume. The volumetric increase results in squeezing off the crack, disrupting the crack propagation and resulting in a net reduction of stress within the ceramic. Zirconia has an initial flexural strength of 900–1200 MPa and fracture toughness of 9–10 MPa $m^{1/2}$.[82] After significant accelerated hydrothermal aging, zirconia loses a significant amount of its initial flexural strength due to its metastable characteristics. However, it still maintains high values of flexural strength of over 800 MPa.[83] Zirconia may be used for anterior[84,85] and posterior copings, fixed partial denture frameworks,[86–88] and implant abutments.[3–5]

The optical properties of zirconia have some esthetic advantages. Cores can be fabricated to 0.3 mm in thickness to deliver a translucent anterior restoration or 0.5 mm and greater to mask discolored abutments and metal foundations.[89] By varying the core thickness, the ceramist can mask undesirable colors and allow light transmission in different areas all on one tooth. When multiple teeth of different colors are to be restored, varying the core thickness is also beneficial because the net effect gives all the cores the same foundation shade when placed on the teeth. Once the amount of masking and translucency is solved at the level of the core, the ceramist can use a similar recipe for the veneer buildups on multiple teeth (Figure 45.8A–D).

The challenge with zirconia as a core material for bilayered restorations has not been fracture of the zirconia core itself but predominantly cohesive chipping and fractures in the veneering porcelain.[87,90] To investigate this challenge, in-depth analysis of the driving causes of the cracks has currently been limited to factors of different cooling rates of the complex geometries of the restorations after firing in the ceramic furnace,[91] differences in the coefficients of thermal expansions between the zirconia core and veneering porcelain, and the thickness of the veneer.[90,91] Different laboratory techniques of veneer application, whether layering or heat pressing, may be found to be useful,[92,93] although reduction of the frequency and size of the chipping may be achieved through the support of an anatomically optimized zirconia core that provides an even thickness and occlusal support for the veneer material.[94]

A latest development in the efforts to minimize veneer chipping of bilayered zirconia restorations has been a movement toward a monolithic zirconia design. Disc-shaped pieces of zirconia can be milled into anatomically contoured zirconia restorations with CAD/CAM technologies. CAD/CAM anatomically contoured zirconia ceramics have been used to restore both teeth and dental implants. With the elimination of the veneer layer, the concern of veneer chipping was addressed and laboratory times for restoration fabrication were shortened. Ceramists no longer

Figure 45.8 **(A)** Dark-colored abutment and existing cast gold post and core present with multiple colors in need of masking.

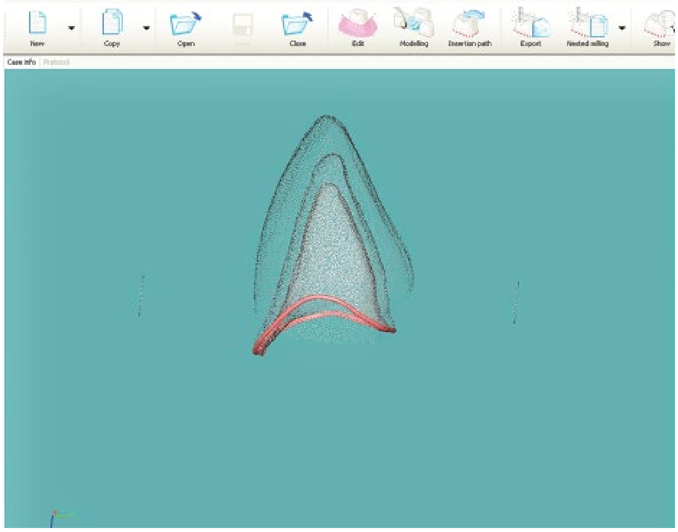

Figure 45.8 **(B)** CAD/CAM design of zirconia cores to evaluate available space for veneering ceramic.

Figure 45.8 **(C)** CAD/CAM fabricated zirconia cores ranging from 0.3 to 0.5 mm thick are placed on multicolored abutments to evaluate amount of color making.

Figure 45.8 **(D)** Definitive bilayered crowns with zirconia cores block out dark underlying abutment and give ideal esthetics with veneering ceramics.

had to layer full-contour veneers. However, a concern of accelerated wear on opposing dentition was raised because without the veneer the zirconia was now at the occlusal interface. A two-body wear test compared enamel wear against bilayered (zirconia core veneered with glassy ceramic) and monolithic (CAD/CAM anatomic contour zirconia) zirconia restorations.[95] Interestingly, the conclusions reported that less enamel wear at the occlusal interface was observed with the monolithic zirconia than with the bilayered zirconia restoration.[95] Furthermore, research has reported that highly polished zirconia is gentler to the opposing enamel than stained and glazed zirconia.[95,96] In areas of lower esthetic concern, polished zirconia may offer a nice alternative, but in other, more visible areas staining and glazing may still be preferred to improve the monochromatic appearance. However, because of the popularity of monolithic zirconia, manufacturing improvements have been made to increase translucency and colorfulness within a disc-shaped puck made for a milling machine. Some discs have multiple layers of different colored zirconia to help deliver a polychromatic effect in the definitive restoration.

In regard to how the restoration fits with a dental implant, known as *passive fit*, it is logical to have all connections machined. When multiple implants are planned to be splinted, the research on accuracy of fit is valuable. One study compared the three-dimensional distortion between cast and milled implant–prosthodontic frameworks on master casts.[97] In the study, a laboratory technician made nine cast frameworks following a proven protocol. Then the nine cast frameworks and master casts were laser-scanned and an additional nine frameworks were milled. All laboratory technicians were blinded in the study, meaning that they were uninformed about the study. The authors concluded that neither of the techniques for framework fabrication provided a completely passive fit.[97] However, the mean and standard deviation in three-dimensional distortion in the cast frameworks was $114 \pm 31.3\,\mu m$ and only $51 \pm 18\,\mu m$ in the milled frameworks.[97]

Figure 45.9 **(A)** Screw-retained monolithic zirconia prosthesis.

Figure 45.9 **(B)** Hygienic design of zirconia screw-retained implant-supported restoration facilitates continued exceptional oral hygiene.

Figure 45.9A and B is of a clinical case of a patient with severely compromised periodontium who was adamantly determined through good oral home care and routine periodontal maintenance to keep the remaining teeth. A screw-retained monolithic zirconia restoration was used to restore two posterior dental implants and give posterior support for the mandible. The screw-retained monolithic zirconia restoration was selected for the following properties.

1. Its CAD/CAM fabrication technique to facilitate prosthetic fit with two dental implants.
2. Its material properties for favorable biocompatibility with peri-implant soft tissues.
3. Its material properties for minimal bacterial surface adhesion and colonization.
4. Its prosthetic property of screw retention to deliver retrievability.

The screw-retained monolithic zirconia restoration may be considered the true contemporary periodontal prosthesis.

Another area that has a functional link to the occlusal interface is the connector of fixed partial dentures. The dental literature has reported that the primary cause of catastrophic failure of all ceramic fixed partial dentures is fracture of the connectors.[69,70,89–104] Fixed partial dentures with zirconia frameworks, on the other hand, have received favorable results with limited clinical fractures of the connectors.[86,93] Figure 45.10A–C depicts a clinical case of two fixed partial dentures with zirconia frameworks. Patient selection should include the evaluation of prospective abutment height and mobility along with the proposed tooth contours and proportions so that function of the restoration may not result in undesirable heavy stress concentrations within the connector area, in particular at the intaglio surface, which is subjected to tensile stresses.[105–108] Color and translucency of the proposed teeth abutments also need to be evaluated clinically with the aid of clinical photography to determine whether the ceramic needs to have any masking properties. Finally, diagnostic casts and wax-up aid in the determination of what restoration design and type of ceramic would be used when compared with the manufacturer's recommendations for minimal connector size (Table 45.1). Since the fixed partial denture connectors are functionally linked to the occlusal interface, the size of the connector has to have adequate bulk of material for strength but the size cannot violate the esthetic dimensions of the proximal contacts. Typically, contours and proportions of teeth are mirrored from the contralateral side of the area in need of reconstruction. Ceramics should be selected accordingly with respect of material requirements for minimal connector dimensions to prevent overcontoured proximal contacts. In situations where teeth morphologic information is not present, the clinician may have to use alternative measures. Stappert et al.[109] showed that the proximal contact height of natural maxillary anterior teeth had the tallest dimension at the dental midline and then diminished in height with the progression toward the mesial of the first bicuspid. The reported proximal contact height at the midline was 40% of the central incisor clinical crown length, 30% of the lateral incisor, 20% of the canine, and 20% of the first premolar. The simplified percentage rule (40–30–20–20) may be used as a helpful adjunct in information to the selection process of ceramics for fixed partial dentures. In summary, material selection for a fixed dental prosthesis may be guided by the use of a periodontal probe to measure the vertical height from the interproximal papilla to the marginal ridge or the incisal embrasure along with the aid of a diagnostic wax-up to predetermine the contours and proportions. Once the dimensions are determined, knowledge of the manufacturer's requirements in terms of a minimal connector size will aid in the selection of the appropriate ceramic.

When the occlusal interface is compared between ceramic restorations on natural teeth and dental implants, implant-supported restorations are considered to have more risk of veneer fracture allegedly due to the reduction of proprioception.[110] If true, the concept of retrievability for maintenance of ceramic implant-supported restorations would be valuable. The elaborate possibilities of ceramic core and framework design have greatly expanded with zirconia to address the

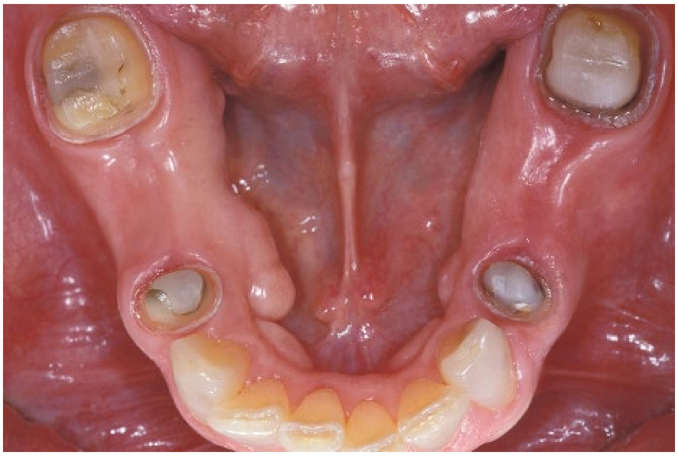

Figure 45.10 **(A)** Short posterior abutments with limited vertical space for fixed dental prostheses connectors.

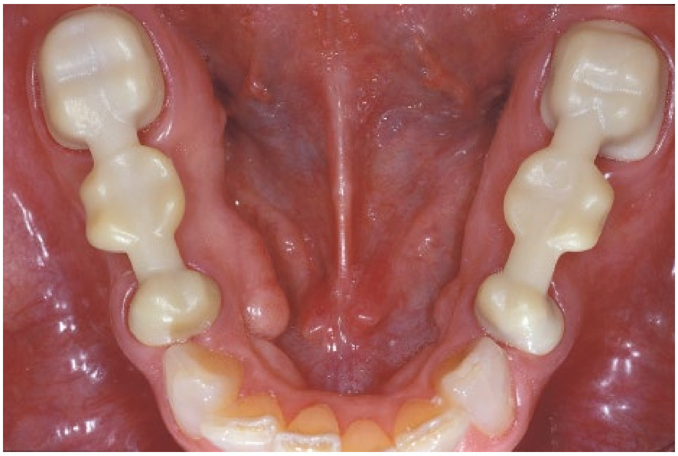

Figure 45.10 **(B)** Zirconia frameworks were selected for esthetics and strength in the connector areas

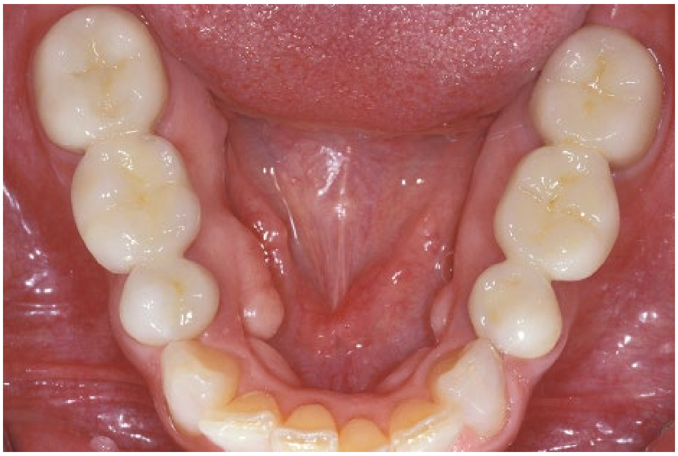

Figure 45.10 **(C)** Cementation of definitive bilayered ceramic fixed dental prostheses with ideal contours and proportions.

functional issue and retrievability. Historically, metal-ceramic screw-retained implant-supported restorations were criticized because of concerns with the esthetics of the screw access hole and its interference with the opposing dentition in terms of centric occlusal contacts and heightened risks of veneer chipping.[111–114] After both clinical and laboratory data were collected, no difference in fracture resistance was seen between screw- and cement-retained single-tooth metal-ceramic crowns.[115–117] Posterior implant-supported screw-retained ceramic restorations with zirconia cores may offer esthetic and functional solutions to the concerns that the metal-ceramic screw-retained restorations faced. The ceramic screw access hole can have the glassy veneer portion of the chimney etched, silanated, and restored with direct composite-resin restorative material. For a monolithic zirconia screw access hole, primers containing 10-methacryloyloxi-decyl-dihydrogen-phosphate are recommended, which has been shown to enhance the durability of composite resin bonded to zirconia.[112] When the all-ceramic access hole is restored with resin composite it is almost undetectable (Figure 45.11A and B).

Table 45.1 Manufacturer's Recommended Minimal Connector Size for Various Dental Ceramics in Different Situations

Core Material—System	
Lithium disilicate—e.MaxPress	16 mm² (1 pontic length ≤11 mm)
Glass-infiltrated alumina with 35% partially stabilized zirconia—In-Ceram zirconia	9 mm² (pontic length ≤6 mm) 12.25 mm² (pontic length ≤8 mm) 16 mm² (pontic length ≤16 mm)
Glass-infiltrated alumina—In-Ceram alumina	≥9 mm² (1 pontic)
Densely sintered high-purity alumina—Procera All-Ceram bridges	3 mm height/6 mm² (1 pontic)
Y-TZP—Lava Plus	7 mm² (1–2 pontics) 10 mm² (>2 pontics)
Y-TZP—Procera	3 height × 2.5 width/6 mm² (pontic length ≤21.0 mm)

Figure 45.11 **(A)** Ceramic screw-retained implant-supported restoration before insertion and restoration of screw access holes.

Figure 45.11 **(B)** Ceramic screw access hole restored with bonded composite at first occlusal 2 mm.

Maintenance issues with posterior screw-retained ceramic implant-supported restorations may also be simplified because they may be easily removed. Repairs done outside of the mouth facilitate ease of adhesive repairs with direct composite resin or indirect ceramic veneers and inlays.

Summary

With the principles established in this chapter, health and esthetics may be delivered to the patient through all the available dental ceramics. Detailed analysis of all the restorative interfaces involved within the definitive restoration may facilitate long-term maintenance for the patient since each interface has a different function. The abutment–implant interface requires a design that will not damage the implant fixture or cause premature prosthetic screw loosening or fracture. The abutment–soft tissue interface requires the use of materials that are highly biocompatible with the peri-implant tissues and do not adversely affect their color. The restoration–tooth interface needs are dependent on the needs of the tooth for conservation of sound structure and how its color will affect the definitive restoration. The restoration–implant abutment interface may be eliminated with screw retention for concepts of retrievability in high-function areas. Critical decisions on whether to adhesively bond, conventionally lute, or screw retain the definitive restoration may now be determined with plans for long-term maintenance in mind. At the occlusal surface–opposing dentition interface a balance must be established between durability and esthetics for the specific location of the restoration in the mouth along with considerations of the patient's level of function and parafunction. Most of the interfaces discussed are functionally linked to the occlusal interface and tested for durability through this link. Consequently, the summation of all the aforementioned considerations needs to be evaluated to reduce the probability of catastrophic failure. Currently, ceramic restorations present with abundant possibilities in terms of restoration design, type of material, conservation of tooth structure, delivery procedures, and retrievability. Subsequently, clinicians are not forced to treatment plan around one type of restoration or material any more to achieve high-quality esthetics, longevity, and function. Placement of material selection at the end instead of at the front of a treatment plan allows the clinician to process the needs of the patient first and the type of restoration required. Once these needs are established, the selection of the ideal dental ceramic for high esthetics and durability may be performed without compromising the long-term durability of both the tooth and the restoration.

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Chapter 46 Digital Impression Devices and CAD/CAM Systems

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The technological advancements that have enabled the use of three-dimensional (3D) digital scanners and mills to become an integral part of many industries for decades have been improved and refined for application to dentistry.

Unlike many other improvements in dental technology that have taken place, particularly within the past decade, which employ evolutionary changes in materials and instruments, the rapid explosion in the field of digital impressioning has been nothing short of revolutionary.[1] Since the introduction of the first dental computer-aided design/computer-aided manufacturing (CAD/CAM) system in the mid-1980s, product development engineers at a number of companies have enhanced the technologies and created in-office scanners and mills that are increasingly user friendly and able to produce accurately fitting dental restorations. These systems are capable of capturing 3D virtual images of tooth preparations, from which restorations may be fabricated directly (i.e., CAD/CAM systems) or fabricated indirectly (i.e., dedicated impression scanning systems for the creation of accurate virtual or physical master models). Dental laboratories have led the way in the adoption of CAD/CAM technology, utilizing digital systems to design restorations on virtual preparation images, scan physical impressions and models, and construct dental restorations. The application of these products is increasing rapidly in both dental offices and dental laboratories around the world and presents paradigm shifts both in the way that dental impressions are obtained and dental restorations are fabricated.[2]

Ronald E. Goldstein's Esthetics in Dentistry, Third Edition. Edited by Ronald E. Goldstein, Stephen J. Chu, Ernesto A. Lee, and Christian F.J. Stappert.

Concept of dental impression making

The most critical procedure in the workflow of creating precisely fitting fixed or removable dental restoration is the capture of an accurate impression of prepared or unprepared teeth, dental implants, edentulous ridges, or intraoral landmarks or defects. Unless a wax or resin pattern is made directly on the teeth, on the edentulous ridges, or in the defects, which is a time-consuming and generally impractical effort, the dentist or auxiliary must achieve an exact duplication of the site so that a dental laboratory technician, usually at a remote location, can create the restoration on a precise replica of the target site. Traditionally, the paradigm for transferring the necessary information from the patient's oral cavity to the technician's laboratory bench has been to obtain an accurate negative of the target site, from which the technician is able to fabricate an accurate gypsum positive replica duplicating the original intraoral structures.

The advent of highly innovative and accurate impressioning devices and CAD/CAM systems based on new technologies has created a disruptive paradigm shift in the concept for impression making. These systems are poised to revolutionize the way in which dental professionals already are and will continue making impressions for indirect restorative dentistry.[1]

From bites to bytes: a brief history

Impression making for restorative dentistry is a relatively recent concept in the millennia-old history of restorative dentistry. The earliest physical proof or record of prosthetic treatment to replace missing teeth goes back to Etruscan times, approximately 700 BC, in which teeth were carved from ivory and bone and affixed to adjacent teeth with gold wires. It was not until 1856 that documentation exists of the use of an impression material other than beeswax or plaster of Paris—which had inherent problems of distortion or difficulty of use respectively—for creating an oral prosthesis, when Dr Charles Stent perfected an impression material for use in the fabrication of the device that bears his name for the correction of oral deformities.[3]

The first use of an elastomeric material for capturing impressions of tooth preparations, as well as other oral and dental conditions, was not until 1937, when Sears introduced agar as an impression material for crown preparations.[4] In the mere 80 years that elastic impression materials have been in use, numerous formulations have been developed, all of which have exhibited particular shortcomings in the goal of obtaining precise reproduction of the oral structures.

The reversible hydrocolloid agar and the irreversible hydrocolloid alginate exhibit poor dimensional stability—because of the imbibition or loss of water respectively when sitting in wet or dry conditions—as well as in having low tear resistance. The Japanese embargo on the sale of agar to the United States during World War II spurred research into the development of alternative elastomeric impression materials. The polysulfide rubber impression material introduced in the late 1950s, originally developed to seal gaps between sectional concrete structures,[5] overcame some of the problems of the hydrocolloids. Nevertheless, polysulfide rubber was messy, possessed objectionable taste and odor, had long setting times intraorally, and underwent dimensional change after the impression was removed from the mouth due to continued polymerization with the evaporation of water and shrinkage toward the impression tray, leading to dies that were wider and shorter than the teeth being impressed.[6] This problem was overcome somewhat by the use of custom trays that allowed for 4 mm of uniform space for the material and by pouring up the impression within 48 h.[5] The introduction in 1965 of the polyether material Impregum™ by ESPE GmbH as the first elastomeric impression material specifically developed for use in dentistry afforded the profession a material with relatively fast setting time, excellent flowability, outstanding detail reproduction, adequate tear strength, high hydrophilicity, and low shrinkage. The material is still in use today in several formulations, although it exhibits problems with objectionable odor and taste, high elastic modulus (stiffness—often leading to difficulty in removing impressions from the mouth), and the requirement to pour up models within 48 h because of absorption of water in very humid conditions, which can lead to impression distortion.[6]

Condensation cure silicone impression materials subsequently were developed, but these also suffered from problems with dimensional accuracy. The creation of polyvinyl siloxane (PVS) impression materials solved the issues of dimensional inaccuracy, poor taste and odor, and high modulus of elasticity, and offered excellent tear strength, superior flow, and lack of distortion even if models were not poured quickly. The biggest drawback of the PVS impression materials, however, is that they are hydrophobic, which can lead to the inability to capture fine detail if problems with hemostasis and/or moisture control occur during impression making.

In addition to the many problems inherent in the accuracy of the elastomeric materials themselves, further distortions can occur by mistakes made in the mixing of the materials or in the impression-making technique, the use of nonrigid impression trays,[7,8] the transfer of the impression to the dental laboratory (often subjecting the impressions to variable temperatures in everything from delivery vehicles to post office sorting rooms to the holds of cargo jets), the need for humidity control in the dental laboratory to assure accuracy in the setting of the gypsum model materials, and so on.

Newer technologies that allow for the use of digital scanners for impression making are indeed a welcome development. Digital impression making does not require patients to sit for as long as 7 min with a tray of often foul-tasting and malodorous "goop" in their mouths, requiring that they open uncomfortably wide, often gagging. Further, these devices help calm dentists' anxieties about economic and time considerations when deciding to remake inadequate impressions, and they display high-resolution images on a monitor, which allows for views of prepared teeth that would otherwise be impossible to see directly in the patient's mouth.

Advances in computerization, optics, miniaturization, and laser technologies have enabled the capture of dental impressions. Three-dimensional digitizing scanners have been in use in dentistry for more than 25 years and continue to be developed and improved for obtaining virtual impressions. The stressful, yet critical task of obtaining accurate impressions has undergone a paradigm shift.[2]

The CAD/CAM dental systems that are currently available are able to feed data obtained from accurate digital scans of teeth directly into milling systems capable of carving restorations out of ceramic or composite resin blocks without the need for a physical replica of the prepared, adjacent, and opposing teeth. With the development of newer high-strength and esthetic ceramic restorative materials, such as lithium disilicate and zirconia, dental laboratory systems and techniques have been developed in which master models poured from elastic impressions are digitally scanned to create stereolithic models on which the restorations can be fabricated. It is evident, however, that such second-generation models are not as accurate as stereolithic models made directly from data obtained from 3D digital scans of the teeth provided by 3D digital scanners designed for impression making. Furthermore, current laboratory scanning systems allow for the design of restorations to be achieved directly on virtual dies and models, rendering the need for physical models obsolete.

Computer-aided design/manufacturing versus dedicated impression scanners

There are two types of digital impressioning devices on the market: CAD/CAM systems and dedicated impression scanners.

CAD/CAM systems are able to complete a restoration from start to finish: they scan the prepared tooth, design the restoration digitally using the scan data, and manufacture the restoration in a milling chamber. In order to be considered a CAD/CAM system, the design and manufacture elements must be integrated into the unit overall. There are currently two leading CAD/CAM systems on the market: CEREC® and Planmeca PlanScan®.

Dedicated impression scanners only involve the first step of the CAD/CAM systems: the digital data acquisition. These systems rely on sending the impression data elsewhere to complete the restorative process. In some cases, the data are sent to a model manufacturing facility where a physical model is created. The model is then sent to the laboratory and the restoration is completed. In other cases, there is no need for a physical model at all—the laboratory can use the digital model to design and fabricate a restoration completely digitally. This will be described in detail later in the chapter. Examples of dedicated impression scanners are the 3M™ True Definition Scanner, iTero®, 3Shape TRIOS®, and many more.

Computer-aided design/manufacturing systems

CEREC

The CEREC system, an acronym for ceramic reconstruction, was introduced in 1985 by Siemens Medical Technology Division (Sirona Dental Systems was spun-off in 1997). It was the first CAD/CAM system that allowed dentists to fabricate ceramic inlays and onlays at the chairside, and the system expanded its capabilities to include crowns, bridges, and laminate veneers.[9]

System features

The CEREC acquisition device is available in two different models: the Bluecam and the Omnicam. The Bluecam was introduced in 2009, using shortwave blue light to increase the precision of the scan data. The Omnicam, launched in 2012, features powder-free digital scanning in full color.

The system is available in two designs: the CEREC AC (Acquisition Center) mobile cart with an integrated CPU (Figure 46.1), or the CEREC AF (Acquisiton Flex), a tabletop unit that connects to a separate PC.

Figure 46.1 The CEREC AC Acquisition Center. *Source:* Reproduced with permission of CEREC, USA.

Workflow

CEREC Bluecam (Figure 46.2) features a highly visible blue light-emitting diode that senses when the area to be captured is in focus and automatically acquires a series of single images, which are then computed with great precision in order to create a virtual 3D model. The camera automatically detects the right moment to trigger the exposure, and the short capture time of the CEREC Bluecam prevents any blurring. In addition, the built-in shake detection system ensures that images are acquired only when the camera is held absolutely still. The CEREC software then automatically selects the optimum image data for the 3D model. The user can either place the CEREC Bluecam directly on the tooth or hover the camera above the tooth. As short, dense wavelengths are more precise than longer wavelengths (such as infrared), the CEREC AC boasts accurate and precise imaging.[10]

CEREC Omnicam (Figure 46.3) is optimized for powder-free scanning of natural tooth structures and gingiva. Simply place the camera over the relevant area and the scan starts automatically. The user moves the camera head closely over the teeth in a single, flowing process. The data are generated successively into a 3D model, which appears in color on the screen in real time. The scanning may be paused and resumed at any time.

Figure 46.2 The CEREC Bluecam scanner. *Source:* Reproduced with permission of CEREC, USA.

Figure 46.3 The CEREC Omnicam scanner. *Source:* Reproduced with permission of CEREC, USA.

Material selection

Current materials available for the CEREC system include Sironic inCoris TZI C (pre-shaded translucent zirconium oxide), inCoris CC (sintering metal), inCoris TZI (sintered zirconium oxide ceramic), CEREC Blocs C (feldspar ceramic), VITA Blocs, TriLuxe, IPS Empress CAD (leucite-reinforced ceramic), IPS e.max CAD (lithium disilicate), 3M Paradigm C (leucite-reinforced ceramic), Paradigm MZ100 (radiopaque composite), Zirlux® FC2 (full-contour zirconia), and Lava™ Ultimate (resin nano-ceramic).

Chairside fabrication

Following the design stage (Figure 46.4), the proposed restoration is sent to the in-office milling unit. CEREC offers three milling options: the CEREC MC (which produces fully anatomical single tooth restorations), the CEREC MC X, and the CEREC MC XL (Figure 46.5—which is capable of fabricating the complete CAD/CAM spectrum).

The milling unit must be loaded with the appropriate CAD/CAM block, as determined by the type of materials to be used, the size of the restoration, and the shade. The dentist selects the appropriate block of material, which is then loaded into the milling chamber. Upon completion of the milling cycle, the sprue is removed and the restoration is checked for marginal fit, contact, and occlusion before finishing. The restoration is then finished by polishing, glazing, or stacking. The milling times vary by unit size, detail, material, and milling unit, but are generally in the range of 6–15 min per unit.[11]

If the dentist wishes to have a physical model, the MC XL is capable of milling models. If a stereolithography apparatus (SLA) model is desired, the dentist can send the case from the scanner to the laboratory/Sirona infiniDent to have an SLA model fabricated. Surgical guides may also be milled with the MC XL milling unit, in combination with a Sirona 3D cone beam scan.

Laboratory fabrication

The CEREC system also allows the dentist to electronically send digital impressions to the laboratory when necessary; for example, in complex and/or highly esthetic cases. This feature, called CEREC Connect, sends the digital files to a laboratory in Sirona's inLab network, where the restorations are fabricated. Since CEREC uses selectively open architecture, the laboratory to which the cases are sent must be an approved CEREC inLab laboratory.

Support and education

When buying a CEREC unit, the dentist is given the opportunity to visit a two-day basic training course at one of several training locations across the country. Continued education courses related to the CEREC system are offered by relevant dental

Figure 46.4 Designing an implant crown using CEREC software. *Source:* Reproduced with permission of CEREC, USA.

organizations throughout the year (personal communicaiton, Julie Bizzell, Clinical CAD/CAM Marketing Manager, Sirona).

Planmeca PlanScan

The Planmeca PlanScan (Figure 46.6) replaces the E4D Dentist digital impression system that was originally launched in 2008 by D4D Technologies. The new Planmeca FIT system features the PlanScan digital impression scanner, PlanCAD software for CAD/CAM design of restorations, and the PlanMill 40 (Figure 46.7) for in-office milling of restorations.

System features

The PlanScan system comes with three removable tips, power cable, and scanner cradle. The two-piece cradle features a

Figure 46.5 The CEREC MC XL milling center. *Source:* Reproduced with permission of CEREC, USA.

Figure 46.6 Planmeca PlanScan scanner. *Source:* Figure courtesy of Planmeca, USA.

Figure 46.7 Planmeca PlanMill 40 milling system. *Source:* Figure courtesy of Planmeca, USA.

weighted base, or it can be wall mounted or separated to fit into a standard handpiece caddy.

Workflow

To capture the image, the user selects the proper scanning mode of the tooth (preoperative or wax-up), preparation, opposing teeth, buccal bite, and/or bite registration. To begin scanning, the user clicks the button on the scanner to activate the laser and rests the tip of the scanner gently on the teeth. With video-rate scanning, PlanScan captures and processes data almost as quickly as you move your hand.

Planmeca PlanCAD Design Center is a complete restorative design system with laptop convenience. The system automatically positions and shapes the selected tooth template to match the central grooves, cusp heights, and marginal ridges of the actual proximal dentition, creating a custom restoration for every patient.

Material selection

Current materials available for the PlanMill 40 include IPS Empress CAD (leucite-reinforced ceramic), IPS e.max CAD and Impulse (lithium disilicate), Paradigm C (leucite-reinforced ceramic), 3M Paradigm MZ100 (radiopaque composite), Telio CAD (acrylate polymer), Zirlux FC2 (full contour zirconia), Lava Ultimate (resin nano-ceramic), and BOB (acrylic burnout blocks).

Chairside fabrication

The Planmeca PlanMill 40 communicates with the PlanCAD Design Center (Figure 46.8) to mill same-day crowns, inlays, onlays, and veneers and fabricates restoration designs quickly and conveniently with wireless connectivity and Smart Mill touch-screen operation. Dual spindles simultaneously mill the latest metal-free materials on both sides of the restoration, with custom milling paths calculated for micrometer-precise accuracy. The automatic tool changer selects the appropriate bur and replaces worn burs automatically.

Laboratory fabrication

PlanScan supports a fully open architecture, which enables the user to seamlessly integrate and collaborate with other systems, as well as export case files in standard tessellation language (.stl) format to any third party for review or completion. Scan the upper and lower jaw and buccal view, and send the case easily to a partner lab through Planmeca Romexis or Cloud service or DDX.

Planmeca Romexis is a completely open image management system that integrates two-dimensional (2D), 3D, and CAD/CAM images with virtually any system, allowing the dental professional to import and export image files. Images can be viewed anywhere using the mobile applications. Studies and cases can be quickly shared between clinics or laboratories, helping dentists improve treatment planning for such specialized cases as implants, orthodontics, and endodontics. Restoration design work can begin immediately without creation of a physical model.

Support and education

S.O.S. is a remote proprietary service provided by Planmeca to assist in clinical and technical support. Each PlanScan system is equipped with high-speed internet access, which gives dental professionals and hardware and software experts the ability to remotely access any system to assist as needed in design, treatment, or diagnosis of any issues. Education is included with the purchase of the system, as well as advanced courses through Planmeca Digital Academy, an ADA CERP and PACE program provider.

Feature comparisons

Figure 46.9 provides a feature comparison of the CEREC and Planmeca PlanScan CAD/CAM systems.

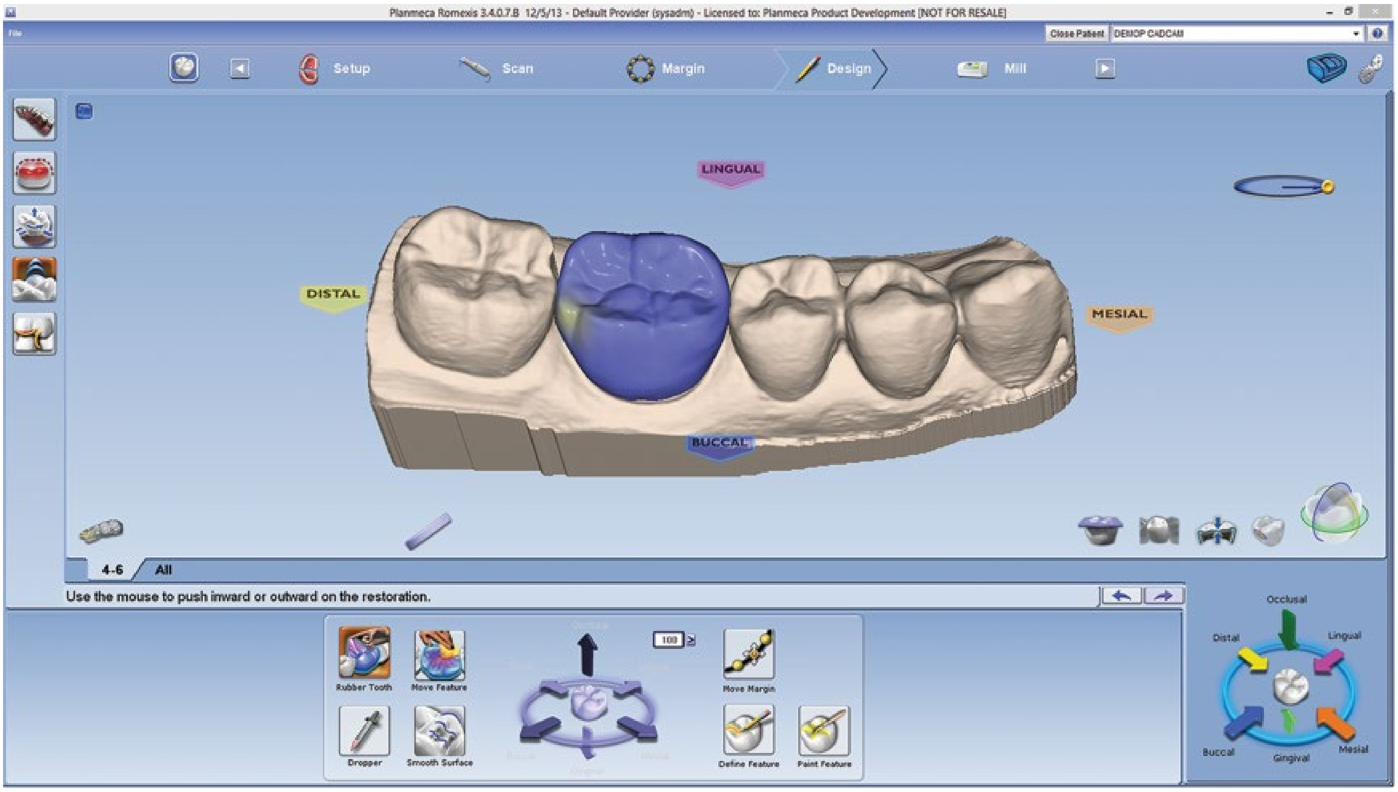

Figure 46.8 Planmeca PlanCAD crown design screenshot. *Source:* Figure courtesy of Planmeca, USA.

	CEREC	PlanScan
Manufacturer	Sirona	Planmeca/E4D Technologies
User Interface	Touch screen	Available as portable unit with laptop or integrated cart
System Architecture	Closed	Open
Powder Required?	*Omnicam*: No *Bluecam*: Yes	No
Workflow	*Omnicam*: Continuous color imaging generates a 3D model *Bluecam*: Single images combined to create a 3D model Restoration is then designed and sent to milling center	Blue laser projected pattern triangulation accurately captures hard and soft tissues of various translucencies, dental restorations, models and impressions
Types of Restorations	Inlays, onlays, veneers, crowns, bridges, abutments, surgical guides, Invlisalign, temporary restorations	Inlays, onlays, crowns, veneers, bridges, temporary restorations
Materials Available for Milling	Feldspar ceramic, glass ceramic, lithium disilicate ceramic, translucent zirconium oxide (TZI), hybrid, polymer blocks, metal (with CEREC Premium)	IPS e.max, Lava, Ultimate, Telio CAD, Zirlux FC Zirconia

Figure 46.9 Comparison chart of CAD/CAM systems.

Dedicated impression scanners

In some instances, dentists may wish to take advantage of the improvements that digital impressions provide, but they may still prefer to have the laboratory handle all restoration fabrication rather than using a chairside milling unit. In these cases, the dentist may opt for a dedicated impression scanner that captures a digital scan of the prepared teeth but does not continue with the process of milling the actual restoration in-office. Rather, the digital scan is transmitted to the laboratory, where trained technicians use laboratory CAD/CAM software to design and fabricate final restorations. Dedicated impressions scanners have both pros and cons—while they are less expensive than full CAD/CAM systems, such as CEREC and Planmeca

PlanScan, they also do not provide final restorations at the time of the first visit, thus requiring temporization and a second appointment.

One benefit of laboratory fabrication is that the esthetics can be optimized, leaving the design and esthetics to technicians who are specifically trained, rather than having the dentist spend time performing the process. Another factor that draws some dentists to dedicated impression scanners over CAD/CAM units is that the laboratory has full control over translucency, opacity, color, staining, and glaze, whereas milled restorations are made from solid blocks of material that require additional time and effort by the dentist to achieve improved esthetics.

Model fabrication

Although CAD/CAM systems do not require the fabrication of analog models on which the laboratory technician fabricates restorations, many dedicated impression scanners send data to model manufacturing facilities, where models are fabricated and sent to the laboratory. In some cases, the laboratory may not require models, as they can design and fabricate restorations using the original scan data obtained via the in-office scan. However, models are still used after the restorations are completed in order to check contacts and occlusion on the restoration itself rather than the digitized version. This allows for an additional quality control step that would not be possible without a physical model. Models made from digital scans may be fabricated in two different ways: SLA printing and model milling.

Stereolithography apparatus printing

SLA 3D printing uses a UV-sensitive liquid resin as the working material. A UV laser is projected on and moves across the reservoir of the resin build material, illuminating and hardening the liquid resin only in the areas where the part is being printed. Multiple models can be printed simultaneously by setting the laser to trace each individual part on a different area of the platform. The platform holding the part or parts lowers after each layer is printed, and a wiper blade spreads more resin uniformly across the working space.

The SLA printer can be set to print in different layer thicknesses, depending on how accurate the resulting model must be. For dental purposes, the individual layers of resin are built in layers ranging from 50 to 150 µm. The UV laser makes pass after pass, tracing the outline of the next layer for each part in the print job, repeating the process until the model is complete.

Model milling

Models may also be milled from a block of material using a similar technique to restoration milling. The scan data is sent to a milling machine and the entire model is milled from a solid puck of material.

The iTero system uses a model milling technique for model fabrication. iTero models have removable dies that are milled separately from the rest of the arch.

Dedicated impression scanner models

3M *True Definition Scanner*

The 3M True Definition Scanner was launched in 2012, based on the original Lava Chairside Oral Scanner's 3D in motion technology by Brontes Technologies in Lexington, Massachusetts.

System features

The 3M True Definition Scanner system consists of a CPU, a touch-screen display, and a scanning wand, which has a small, lightweight, beveled tip (Figures 46.10 and 46.11). The scanning wand is a 3D high-resolution trinocular optical impression system.

Workflow

Proper retraction and a light dusting of 3M High-Resolution Scanning Spray are required prior to scanning the teeth. The

Figure 46.10 The 3M Mobile True Definition Scanner system. *Source:* Figure courtesy of 3M Oral Care, USA.

clinician moves the small, lightweight wand over the teeth. The 3M True Definition Scanner captures 60 images per second. The “3D in motion” technology then reconstructs the video data to create a highly accurate 3D model of the oral anatomy (Figure 46.12). This process happens in real time, enabling the user to control the scan, making adjustments throughout the scanning process. The system also incorporates a 3D visualization feature that shows the scanned teeth in a stereoscopic mode, using traditional 3D glasses.

Open and trusted connections

3M True Definition Scanner digital impression files can be used with any system that accepts an.stl file. 3M also collaborates with leading manufacturers to ensure seamless integration with a broad range of CAD/CAM, digital implant and orthodontic appliance workflows. The trusted connection process includes comprehensive technical and clinical validation, ensuring performance and quality that meets the highest standards. These

Figure 46.11 The 3M Mobile True Definition monitor and wand, showing a full arch scan on the screen. *Source:* Figure courtesy of 3M Oral Care, USA.

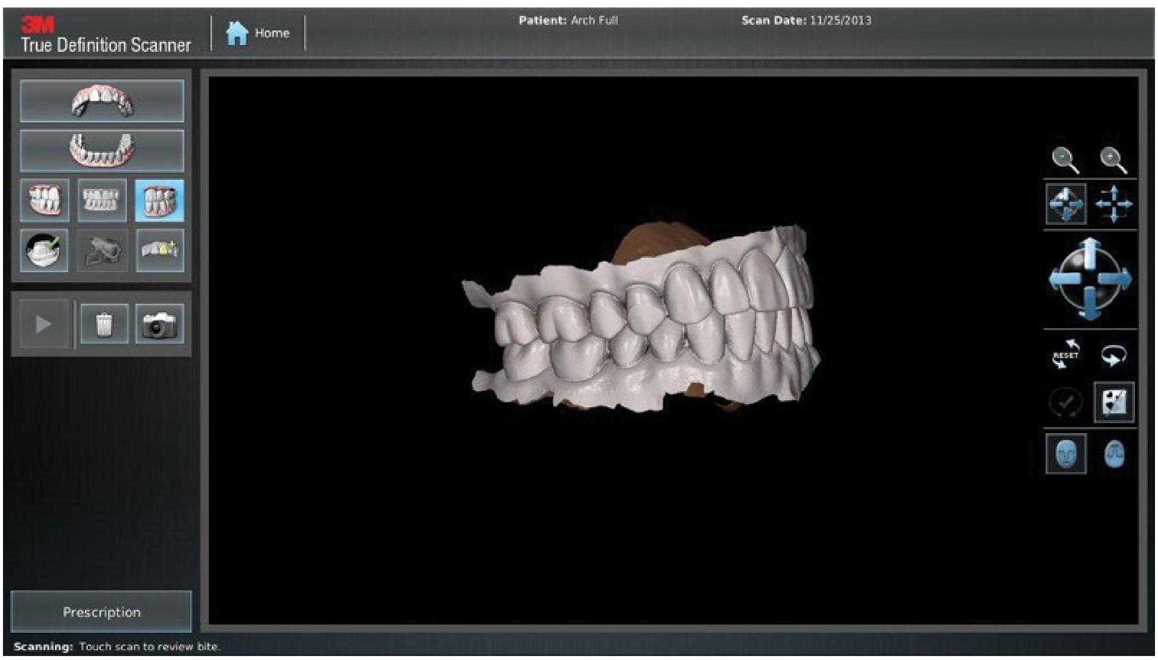

Figure 46.12 Bite registration scan on the 3M True Definition Scanner. *Source:* Figure courtesy of 3M Oral Care, USA.

connections provide the benefits of an integrated system without the drawbacks of a proprietary network. Additional trusted connections with leading dental product manufacturers are continually being tested and validated for future integration.

Model fabrication

Once the scan is complete, the data file is immediately available to the lab via the 3M Connection Center. Once downloaded, the technician marks the model and begins designing the final restoration. The processed data set can also be sent to a model manufacturing center, where an SLA model is fabricated. The model can be used for traditional hand finishing but is no longer necessary in a purely digital workflow.

Dental laboratories also have the option of working with an open file format for the design and production of a model from their own 3D printer (personal communication, Peter Golden, Professional Relations Manager, 3M ESPE; personal communication, Ashley Haslund, Global Marketing Communications Specialist, 3M ESPE).

iTero Element™ scanner

The iTero Element intraoral scanner (Figures 46.13 and 46.14) was released in 2015 as Align Technology Inc.'s latest version of the iTero scanner line. The iTero scanner was first introduced to the dental market in 2007 by Cadent, which was acquired by Align Technology in April 2011.

System features

The iTero Element intraoral scanner uses parallel confocal imaging technology, whereby laser and optical scanning captures a 3D color image of the contours of the patient's teeth, gingival structures, and bite. The iTero Element intraoral scanner captures 20 scans per second of laser light in perfect focus without the use of powder to coat the teeth, which allows for contact of the wand and tooth, resulting in an accurate 3D digital impression.

The iTero Element scanner (Figure 46.15) is a smaller and lighter version of previous scanners, and it features a multitouch HD display and integrated gyro technology in the wand so the user can rotate models on the screen with a flick of the wrist.

Workflow

The iTero Element software automatically detects and repositions scanning start and stop points when you move to a new scanning position within the scanned segment. During the scan, iTero Element software is engineered to simultaneously process the scan. It automatically stitches together images for rendering in the correct order, adapts to changes in positioning, and detects and removes soft tissue (Figure 46.16).

An integrated color sensor in the iTero Element scanner and the patented dual-aperture lens system are designed to simultaneously capture 2D images in color with highly accurate 3D laser scanning. Color scanning can make it easier to immediately distinguish between gingival and tooth structures for a more precise clinical evaluation.

The iTero Element scanner is designed to automatically save scan data every 2 s and save it to the system's hard disk, so in the event of a power outage the scan data are safe.

Models

iTero models are milled on a five-axis milling machine and are made from a proprietary polyurethane material. The free gingival tissue is preserved during the construction of the model, thus allowing the laboratory to take into account the gingival profile around the teeth to be restored.

iTero scanner and Invisalign treatment

In 2011, Cadent was acquired by Align Technology (makers of Invisalign clear aligners) to allow the iTero scanner to be used for

Figure 46.13 The iTero Element intraoral scanner. *Source:* Figure courtesy of Align Technology Inc., USA

Figure 46.14 The iTero Element Scanner with counter stand. *Source:* Figure courtesy of Align Technology Inc., USA

Figure 46.15 The iTero Element Scanner scanning wand. *Source:* Figure courtesy of Align Technology Inc., USA

full arch scans intended for Invisalign treatment planning. The iTero Element scanner is able to scan entire arches and digitally transmit the scan data to Align in order to create Invisalign clear aligners. The scanner also has exclusive access to the Invisalign Outcome Simulator, which helps patients visualize the potential outcome of Invisalign treatment.

3Shape TRIOS

System features

3Shape TRIOS is a powder- and spray-free system. The TRIOS handheld device is based on a pistol design, which provides maximum support and stability during the scan, and provides

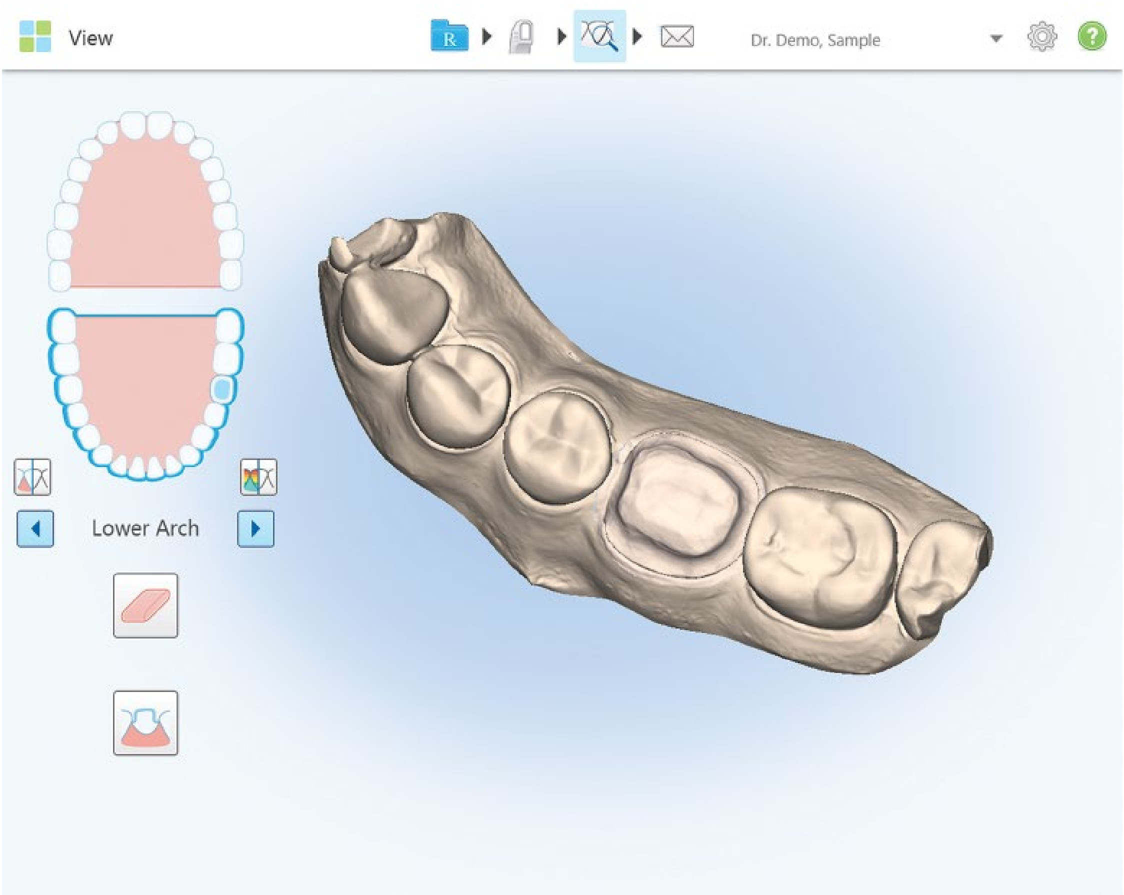

Figure 46.16 Screenshot of a crown prep on #19 on the iTero Element scanner.

the user with an ergonomic grip for perfect control. Two different systems are available: a mobile cart (Figure 46.17), featuring a touch screen monitor, CPU, and scanning wand; and a pod system (Figure 46.18), which offers more flexibility with a smaller footprint, featuring a portable scanning wand connected to a laptop (either Mac or PC configurations are available).

The 3Shape TRIOS requires a reusable, autoclavable scan tip. The tip may be flipped for scanning of the upper or lower jaw, and there is no need to hold the scanner at a specific distance or angle for focus. The user may even rest the scanner on the teeth for support during the scan. The scanning wand features an integrated anti-mist heater to automatically ensure an optimal temperature for undistorted and crystal-clear scanning.

After scanning, the user can apply the software's tools for clinical validation of the digital impression (Occlusal Clearance tool, Insertion Direction tool, and Rotate/Zoom tools help validate impression quality, and a comment section aids in communication with the laboratory). The scanner is color calibrated, which allows the user to select a shade directly on the scanned arch, which reduces user error during the shade selection process (Figures 46.19 and 46.20).

Workflow

The digital order form, which may be customized by individual laboratories based on the restorations they offer, is filled out prior to scanning. Since powdering the teeth and gingiva is not required with the TRIOS, the user simply moves the scanner tip along the surface of the teeth. Designed for high-speed impression capture, 3Shape's Ultrafast Optical Sectioning™ technology captures more than 3000 2D images per second – 100 times faster than conventional video cameras.

The scan tip can easily be flipped to facilitate fast scanning of both the upper and lower jaws. After obtaining both the upper

Figure 46.17 The 3Shape TRIOS system. *Source:* Figure courtesy of 3Shape.

Figure 46.18 The 3Shape TRIOS pod. *Source:* Figure courtesy of 3Shape.

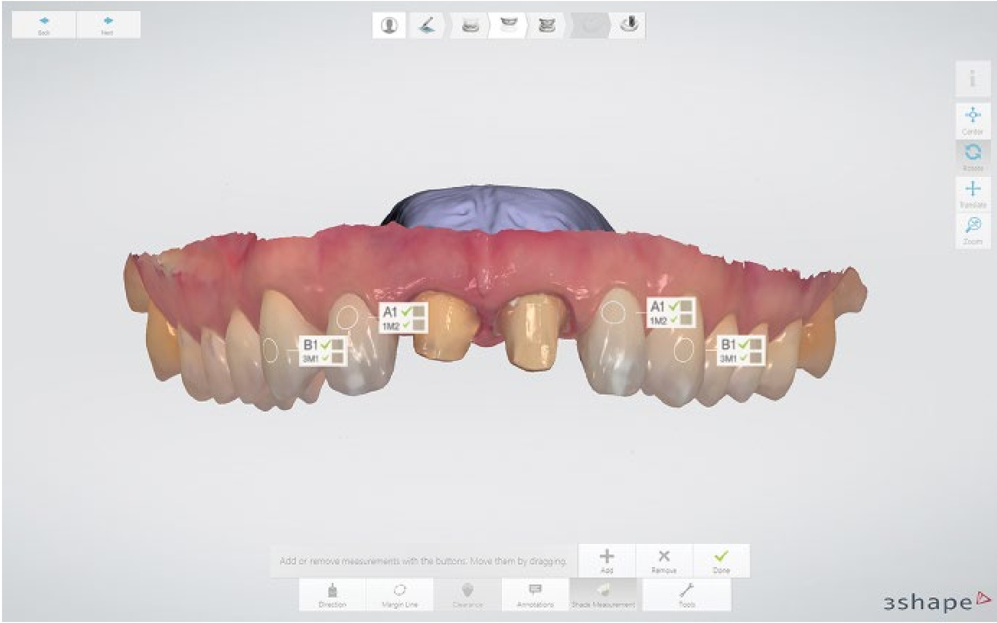

Figure 46.19 A screenshot of a completed 3D scan of prepared teeth #8 and #9. The scanner is color calibrated to reflect the accurate shading of the teeth and the soft tissue in the mouth. *Source:* Figure courtesy of 3Shape.

Figure 46.20 A scan of the lower arch showing two scan bodies attached to implants. *Source:* Figure courtesy of 3Shape.

and lower scans, the bite is quickly scanned and the software then automatically aligns the three scans together.

As the scan progresses, small tips and messages on the touch screen keep the user informed of the scan progression. Image capture can be paused and resumed by pressing the button on the handheld scanner.

By selecting the shade scan tool, the user is able to scan over the existing scan, this time capturing the actual shade of the teeth with the color-calibrated scanner. The user can then touch on any area of any tooth and select which part (or parts) of the tooth the restoration should match.

Once the scan is completed and verified, the press of a button digitally transmits the scan data to the laboratory.

Model fabrication

TRIOS scans do not need to go through a specific processing center after scanning. Rather, TRIOS scans may be sent to any laboratory using 3Shape CAD/CAM software. The scan is received in the laboratory within minutes. A digital laboratory model is designed in the laboratory directly from the digital impression, and the restoration is digitally designed on the 3D model. If necessary, the model may be manufactured locally, either by the laboratory or a third-party printing/milling service provider (personal communication, Martin Poulsen, International Product Manager, 3Shape).

Feature comparisons

Figure 46.21 provides a feature comparison of the three dedicated impression scanner systems discussed here.

Open versus closed architecture

CAD/CAM and impression scanners run software that captures a 3D image and converts it to an.stl file. The architecture of a system refers to its ability (or, in some cases, its inability) to import and/or export.stl files from other systems made by other manufacturers.

An open architecture CAD/CAM system is able to integrate data from any other brand of scanner or software. An open architecture system can use the .stl file from another impressioning system to design and/or fabricate restorations.

A selectively open architecture CAD/CAM system is only able to integrate with specific components that are selected by the system's manufacturer. For example, some milling units may not be capable of fabricating consistently high-quality restorations when using a specific brand of acquisition software. In this case, the mill manufacturer may not allow for integration with that specific scanning system, but may still be compatible with other scanners made by other reputable manufacturers.

A closed architecture CAD/CAM system does not integrate with any components manufactured by any other company. Closed architecture systems are fully proprietary.

Computer-aided design/manufacturing in the laboratory

In addition to improving the quality, speed, and ease of in-office impression taking, the digitization of dentistry has also revolutionized the laboratory fabrication of restorations. Recent advances in CAD/CAM technology in the laboratory have resulted in a completely new and improved method of creating highly esthetic and accurate restorations.

Analog versus digital impression accuracy

With the incorporation of CAD in the laboratory, technicians rely on an accurate digital scan on which they design, and later manufacture, restorations. There are currently two different workflows for digital manufacturing. In cases where analog impressions are utilized, the process requires scanning of an analog model in a desktop 3D scanner and scanning it into a CAD program. The second workflow involves the laboratory receiving the .stl file directly from the in-office scanner.

When working with the analog impressions and related workflow, the analog models are created. The protocol for analog model fabrication involves several steps, from impression taking to model pouring. Each step in the model fabrication process introduces error or discrepancies in the final model. When eliminating the analog impression, related model and die fabrication, and the scanning of a physical model, studies showed a reduction in inaccuracies of 75 μm or more (personal communication, Bob Cohen, CDT, Custom Automated Prosthetics).

	3M True Definition Scanner	iTero Element	TRIOS
Manufacturer	3M ESPE	Align Technology	3Shape
User Interface	Touch screen	High definition multi-touch display	Cart: Touch screen Pod: Laptop
System Architecture	Open	Open	Open
Powder Required?	Yes	No	No
Workflow	3D In Motion captures live video at 60 images per second	Continuous color scanning, at a rate of 20 scans per second	Ultrafast Optical Sectioning combines hundreds or thousands of color-calibrated 3D pictures
Types of Restorations	Crowns, bridges, inlays, onlays, veneers, implant workflows, partial dentures, clear aligners, orthodontic appliances, models	Inlays, onlays, crowns, bridges, veneers, custom abutments, Invlisalign, orthodontic appliances	Inlays, onlays, crowns, post & cores, veneers, temporary crowns, RPDs, implant abutments, surgical guides, orthodontic appliances
Model Fabrication	Stereolithographic (SLA)	Milled	Printed and/or milled, depending on lab

Figure 46.21 Comparison chart of dedicated impression scanners.

Digital laboratory workflow

The process by which a restoration is manufactured digitally involves four steps: scanning, CAD, CAM, and final fabrication.

Scanning models

In cases where the laboratory receives an analog impression or model that must be digitized prior to restoration fabrication, the first step is to input the 3D model into a laboratory scanner. Some scanners have the ability to scan both impressions (PVS and alginate) and gypsum models, while others are only able to scan gypsum models.

Inside the scanner, cameras move around the model (and in some cases the model is also able to be tilted and rotated on a movable platform inside the chamber) until the model is fully scanned. In minutes, an entire scanned model appears on the screen, ready to be digitally ditched in preparation for restoration design.

Computer-aided design

CAD is the process by which crowns, inlays, onlays, veneers, bridges, and other restorations are digitally designed. Most CAD software is bundled with a laboratory scanner, with the exception of Exocad, which is standalone CAD software that can import .stl files from open-architecture laboratory scanners made by a variety of manufacturers (sold separately). For decades, laboratory technicians have spent hours waxing-up restorations on stone models. Using CAD software, the technician is able to digitally mark the margins on the 3D model and place a digital die spacer of uniform thickness. The digitization of the die spacer eliminates a major source of error in crown fabrication, since laboratory spacer is a thin liquid that does not set in a uniform thickness on the die—the fluid nature of the liquid causes it to pool in thicker layers in concave areas of the die and to thin out in other areas. CAD software is able to ensure ideal thickness of die spacer in all areas of the restoration.

Using a design database, the technician designs a digital wax-up of the final restoration. Some laboratories have their own proprietary design libraries, and other laboratories use the database that comes standard with their CAD software. Simple clicks of the mouse can adjust occlusal and interproximal contact areas, material thickness, and emergence profile in seconds as opposed to minutes or even hours when done on a physical wax-up on a stone model (Figure 46.22). When restorations do not require an intermediate wax-up step, the final restoration design may be sent directly to the final manufacturing/fabrication step.

Computer-aided manufacturing

CAM refers to the use of computer software to program the machinery that is responsible for the milling or printing of intermediate and final restorations.

CAM is separate from the actual design of restorations—it is the communication between the CAD software and the milling units. This involves the selection of where on the puck of material a crown should be milled, how thick the layers of wax should be during wax printing, and so on.

Fabrication

Wax Printing

When the restoration of choice requires investment and burnout, such as e.max (lithium disilicate) or metal, the actual casting or pressing process has not changed with the advent of CAD/CAM dentistry. The major difference is in how the wax-up is created.

The digital wax-up is designed in the CAD software program on a 3D model, the same way as with any other digitally designed restoration. Once the digital wax-up is completed, the next step is to create a physical wax model of the restoration. This can be accomplished either by wax printing or wax milling. Wax printing is similar to inkjet printing, but instead of ink being jetted or sprayed onto paper in a single layer, a resin

Figure 46.22 3Shape CAD software is capable of designing restorations in minutes with the use of specialized digital tools at the technician's fingertips. *Source:* Figure courtesy of Custom Automated Prosthetics.

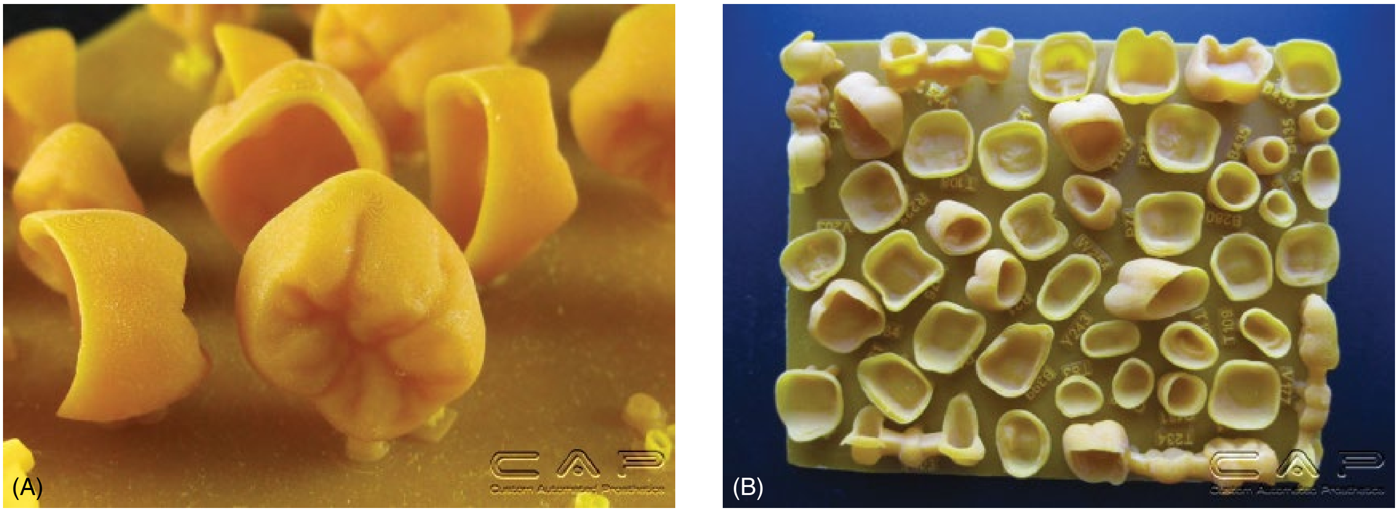

Figure 46.23 **(A, B)** Wax printing creates accurate wax-ups of restorations without the need for hours of manual work by technicians. Multiple restorations may be printed on a single sheet, each with an identifying code printed beside it. *Source:* Figures courtesy of Custom Automated Prosthetics.

Figure 46.24 Crowns milled from a puck of CAP FZ (Custom Automated Prosthetics) full-contour zirconia. *Source:* Figure courtesy of Custom Automated Prosthetics.

or wax is jetted onto support material, and then onto previously sprayed layers until the part begins to take on depth and shape (Figure 46.23). Wax printers can print single copings and full crowns to multiple-unit bridge copings, models, and even partial denture frameworks. Wax mills use burs to carve out the wax models from a solid puck of hard wax. Both techniques result in accurate wax-ups that can be invested and burned out.

Selective laser sintering

Selective laser sintering is an additive manufacturing technique that uses a high-power laser to fuse small particles of powdered metal (e.g., chromium–cobalt or gold alloys) into a coping, framework or full contour crown that has a desired 3D shape. As with SLA printing, the laser selectively passes over the surface of the powder and fuses the metal on the surface of a powder bed in incremental layers. After each cross-section is scanned, the powder bed is lowered by one layer thickness, a new layer of material is applied on top, and the process is repeated until the part is completed. This process uses CAD/CAM data to directly manufacture the metal, doing away with the need for wax-ups, investment, burnout, and casting.

Milling

In-office mills, such as CEREC and Planmeca PlanMill 40, utilize small blocks of material for each restoration. Laboratory mills generally use large "pucks" of material that can fit 20 or more restorations at a time. Mills can fabricate restorations from a variety of materials, ranging from plastic to ceramic to metal.

Clinical cases

Clinical case 46.1

A 42-year-old male patient presented in March 2012 with the chief complaint that he was trapping food between his lower left molars. On examination, it was determined that the veneering porcelain on an IPS eMax (Ivoclar Vivadent) veneered lithium disilicate crown on the endodontically treated tooth #19 had sheared at the distobuccal aspect, allowing for the entrapment of food between #18 and #19. The crown had been luted in July 2009.

In keeping with the dentist's office policy, which warranties indirect restorations for 5 years, and in keeping with the dental laboratory's commensurate policy, the patient was informed that the crown would be remade at no fee. Normally, the situation would dictate that the patient be anesthetized, the defective crown removed, retraction achieved via cord packing or laser troughing, an elastomeric impression obtained, an opposing impression taken, an interocclusal registration made, and a new provisional crown provided.

Fortunately, the impression that was obtained for this crown nearly 3 years earlier was achieved with a digital scan using the Lava C.O.S. impressioning system (3M/ESPE). The file for the crown was easily accessed from the system's case archive and the file was resubmitted to the dental laboratory for a new all-zirconia crown, to be made using virtual models without the need for obtaining physical models from 3M/ESPE. The patient was dismissed without removing the defective crown, was provided with an interproximal brush, and was instructed to use the brush to avoid food retention in the affected area.

When the patient returned to the office 2 weeks later, the defective crown was removed without the need for anesthesia and without affecting the tooth preparation. The new crown, which fit as accurately as the original, was luted using a self-etching resin cement.

Clinical case 46.2

A 63-year-old female patient presented in July 2009 with the chief complaint that her upper bridgework was loose. The bridges, extending from #3–#5, #6–#11, and #12–#14, had been made in April 1995. The patient was a heavy smoker and had undergone numerous periodontal procedures prior to the restorative treatment. Following the placement of the fixed partial dentures, she again began to exhibit periodontal problems, so she was referred to a periodontist for maintenance recare, and she was instructed to schedule for annual restorative reevaluation. Despite repeated attempts to reappoint her for restorative checkups, she never responded to telephone or written communications.

She was not seen again until July 2009, when she appeared with the maxillary bridges exhibiting a 3+ mobility with 2 mm of compressibility. She apologized for her absence and lack of communication and implored the dentist to help her "save her teeth." After radiographs confirmed the near absence of osseous support for the abutment teeth, the dentist explained to the patient that he would not be able to save her teeth, and began to explain the restorative course of treatment for fabrication of an interim immediate full upper denture.

As soon as the dentist described the need to begin treatment with an alginate impression needed to create a study model, he stopped the explanation. He realized that the viscosity of the unset alginate would likely shift the bridges laterally and even compress them apically, resulting in a highly inaccurate study model and, even worse, probably extract the fixed partial dentures and the teeth on removal of the impression from the mouth, leaving the patient edentulous at the first of what was to be a series of five visits.

The dilemma was quickly resolved when the dentist thought about alternative means of capturing an impression of the maxillary bridges without displacing them. His office had a 3M/ESPE Lava C.O.S. impressioning device, which had been in use for capturing impressions of inlays, onlays, crowns, small bridges, and laminate veneers.

Although the treatment indications offered by the manufacturer did not include removable prostheses, the dentist realized there was no alternative but to use the scanner in this case. After all, the palatal mucosa was a static surface, as was the gingivae and mucosa on the facial aspect of the bridges, and the only mobile soft tissue that would come into play was at the deepest extent of the buccal and labial vestibules and, in stretching out the cheeks and lips to capture the image of the soft tissue, it would accomplish the same desired result as border molding with a conventional elastomeric impression.

The scan was performed with minimal difficulty, transmitted to 3M/ESPE, and the SLA models (capturing the palate and vestibules) were articulated according to the scan and were provided to the dental laboratory. The dental technician made a stone copy of the maxillary model, rearticulated it with the opposing cast, cut off the maxillary teeth, and waxed up and processed the interim immediate full upper denture, which was placed in the dental office following the removal of the patient's maxillary teeth (Figures 46.25 and 46.26).

The alignment of the teeth, the basic fit of the denture, and the occlusion were well within normal limits. A chairside hard reline was performed after several months, and the patient was so pleased with the denture that she requested no additional treatment until her death over 2 years later from complications due to lung cancer.

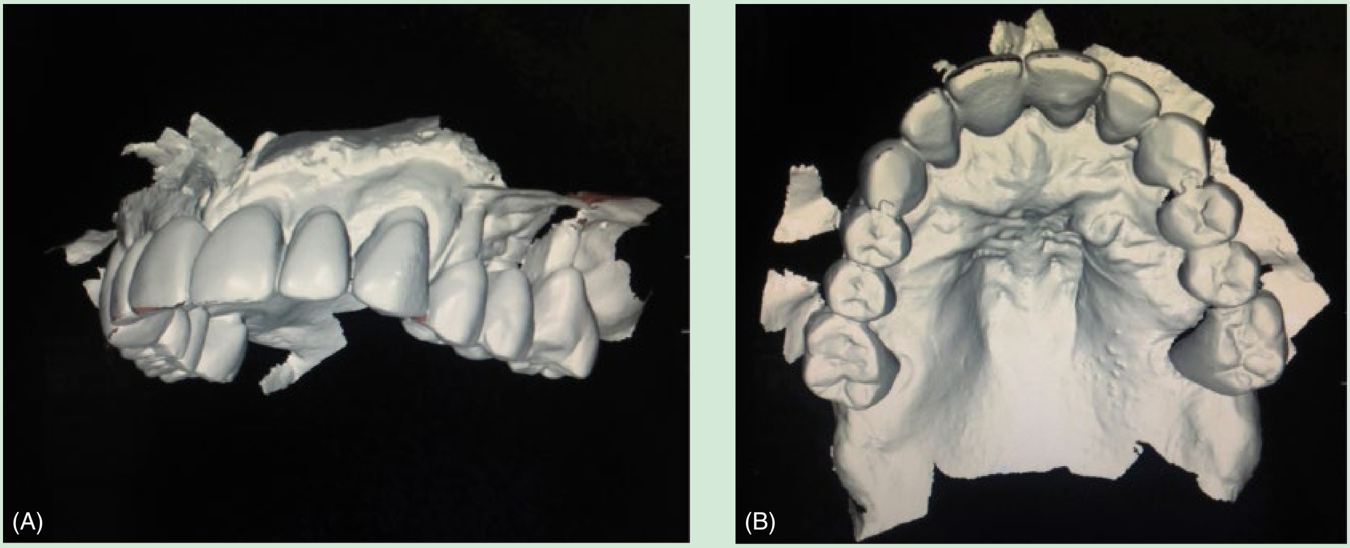

Figure 46.25 **(A, B)** Screen shots from digital scans of the patient's dentition, including the palate and the buccal and labial soft tissues. Note that the scans were able to capture images of the soft tissues to the full depth of the vestibules.

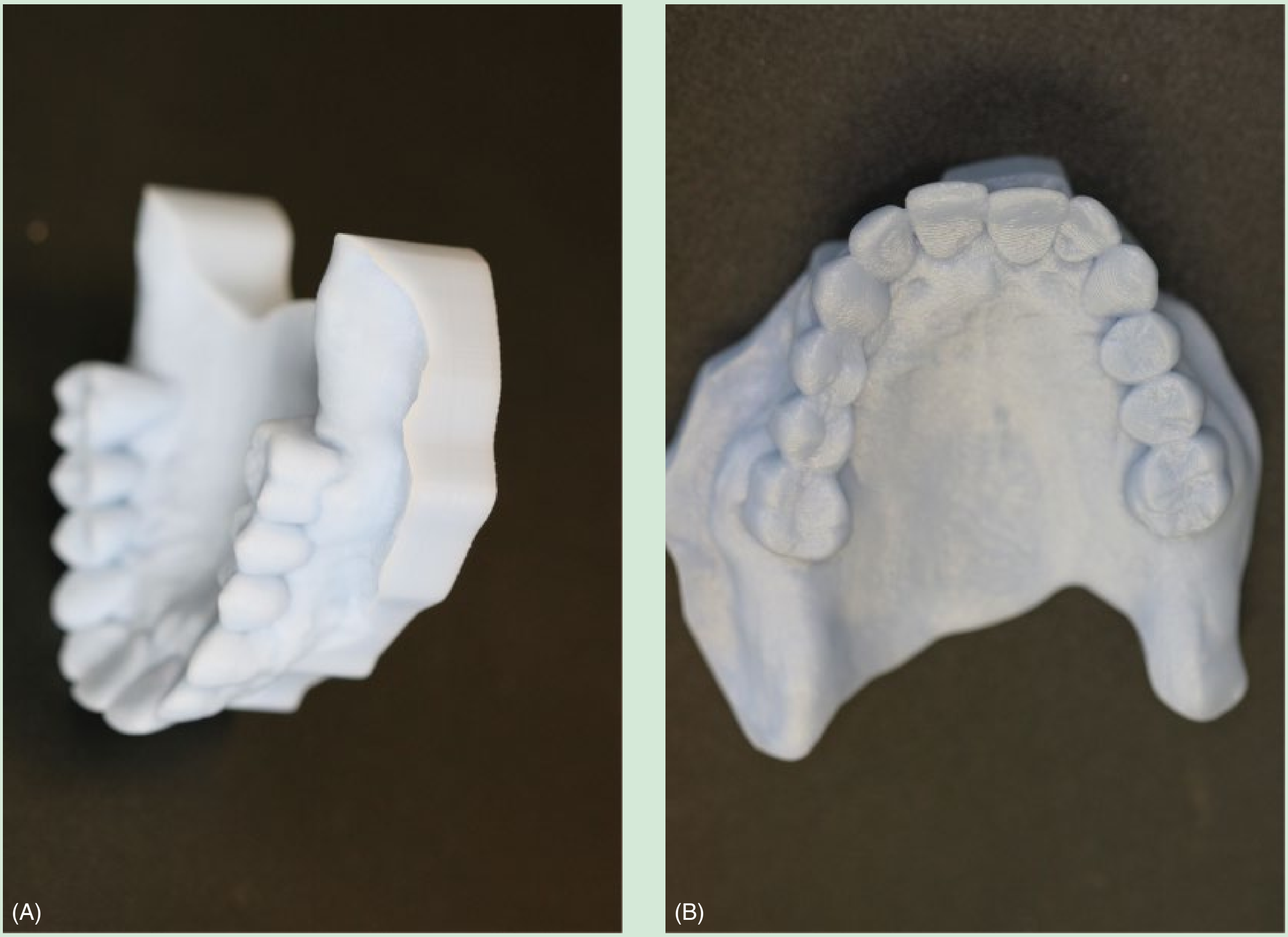

Figure 46.26 **(A, B)** Full-arch stereolithic models made from scans taken on a second patient with a similar problem to the case study (i.e., impossibility of elastomeric impression capture due to extensive caries under abutment crowns #6 and #7 of a #3–X–X–#6–#7 bridge and extreme bridge mobility).

Clinical case 46.3

A 66-year-old female patient presented in January 2010 for a restorative examination, at which time it was determined that she required new full cast gold crowns with mesio-occlusal rest preparations on teeth #2 and #15, porcelain-fused-to metal crowns on teeth #6 and #11 with distal semiprecision female attachments and cingulum ledges with small depressions above and on the mesial extent of the ledges, and a metal-based acrylic maxillary removable partial denture replacing the missing teeth #3–#5 and #12–#14, with rests extending onto teeth #2 and #15 with semiprecision male attachments and lingual clasps resting on the crowns ledges, with small bulges at the mesial tip of the clasps, engaging the depressions on the crowns (Snap-Lok attachments).

At the visit, she told the dentist she had been holding off having the treatment done for a few years but that, as she was aware the office had been using a digital impressioning system that would obviate the need for conventional elastomeric impressions, she was thrilled to proceed. She explained that she dreaded conventional impressions and would lose sleep over the very thought of having them done, as she was both claustrophobic and a severe gagger.

The dentist explained to her that the approved indications for the Lava C.O.S. offered by the manufacturer, 3M/ESPE, did not include removable prostheses. The patient said that, if the scanner could not be used, she would hold off on treatment until the situation deteriorated to the "crisis stage."

The dentist told the patient that, having had prior experience with the scanner for an edentulous case, he would be willing to try capturing an accurate impression of the four crown preparations and the palate and vestibules. He said that he should at least be able to achieve accuracy with the crowns but that, if the partial denture framework did not fit accurately, there might be a need to take a conventional elastomeric impression for the partial denture, picking up the four crowns. She said she was willing to take that chance.

The scan (Figure 46.27) was performed fairly easily, transmitted to 3M/ESPE, and the SLA models (capturing the palate and vestibules) were articulated according to the scan and were provided to our laboratory.

The dental technician fabricated the crowns and the partial denture framework and returned them to the dental office for try-in and confirmation of the occlusal registration (Figure 46.28).

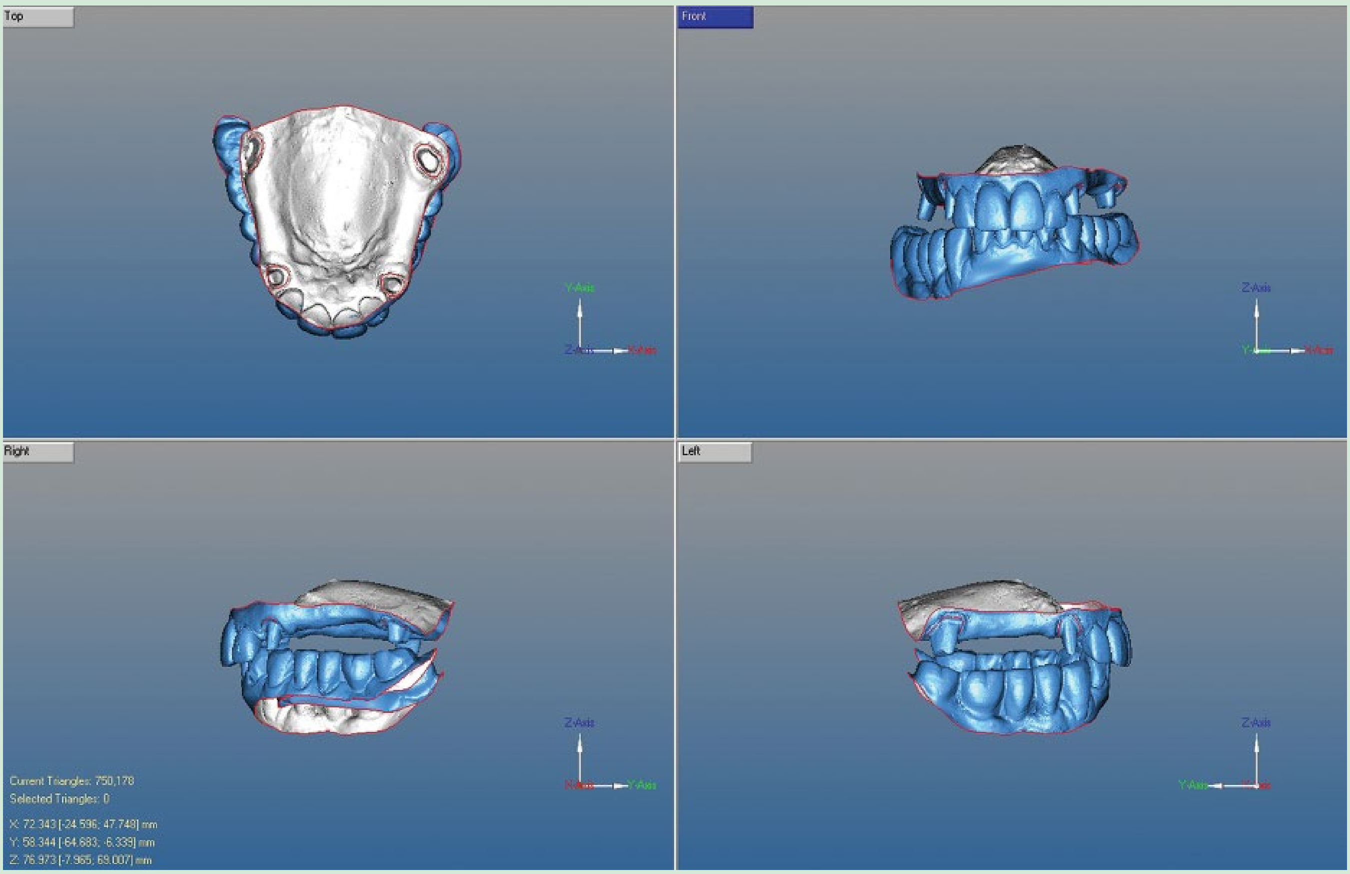

Figure 46.27 Screen shots from digital scans of the patient's dentition, including the palate and the buccal soft tissues. Note that the scans were able to capture images of the soft tissues to the full depth of the vestibules.

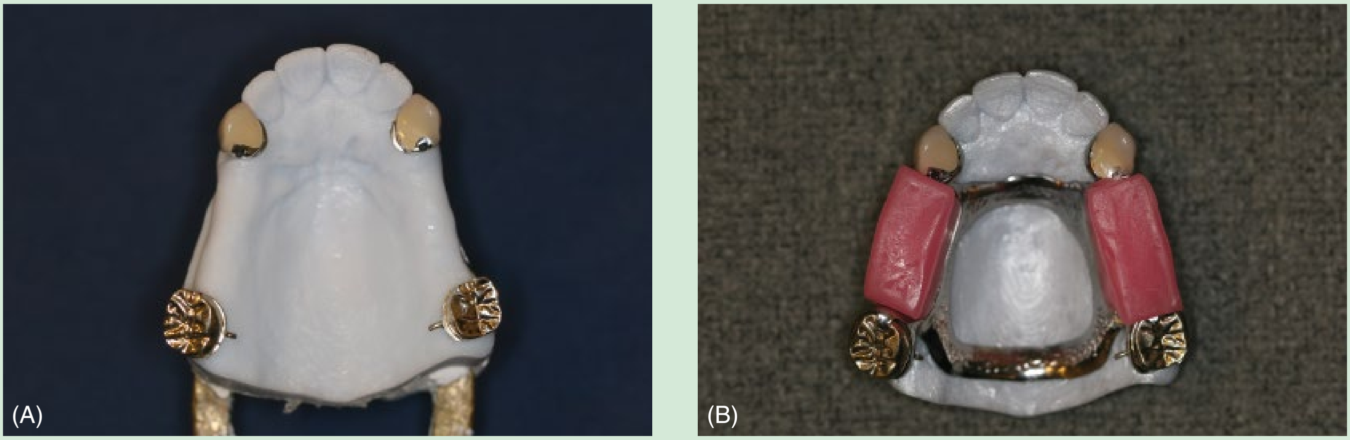

Figure 46.28 **(A, B)** The master stereolithic model with the four crowns in place and with the semiprecision removable partial denture framework and wax bite blocks ready for try-in and for the occlusal registration.

It was noted that the fit of the partial denture framework intraorally matched precisely the fit on the model.

The case was completed in June 2010, with cementation of the crowns and delivery of the removable partial denture. The patient immediately commented on how much more comfortable the partial denture was, relative to her previous prosthesis. The semiprecision attachments fully engaged the female attachments and the lingual clasps seated fully and engaged the depressions on teeth #6 and #11, the rests on teeth #2 and #15 were fully seated in the rest preparations with no need for occlusal adjustment, and the two palatal straps of the partial denture framework were just touching the palatal tissue, without compressing it and with no space between them and the palate (Figure 46.29).

The record noted that the accuracy of the fit of the partial denture was the best the dentist had seen in 37 years of clinical practice. In more than 2 years since the completion of the case, the patient has not required any adjustment of the removable partial denture.

Figure 46.29 The finished case with the crowns luted and the semiprecision removable partial denture inserted.

Summary

When many dentists graduate from dental school, they put on virtual "blinders" and continue to perform dental procedures just as they were taught in school and are often nervous or unwilling to learn new procedures, even as technologies evolve. In some cases, dentists are concerned that the learning curve for new technology is too great and that "you can't teach an old dog new tricks." Recent research advanced by Norman Doidge[13] shows that neuroplasticity in the brain exists throughout the human lifespan and that the cerebral cortex is capable of constantly undergoing improvements in cognitive functioning. This means that any task that requires highly focused attention or the mastery of new skills helps to improve the mind, especially memory. Admittedly, learning to use the digital scanners or CAD/CAM systems discussed in this chapter means acquiring new skills and mastering new techniques, which will take some time and patience. The bottom line, however, is that the end result of developing the ability to use these new technologies will empower dentists to learn more about the dentistry they perform and enable them to provide their patients with well-fitting restorations.[2]

"Disruptive technology" is a term invented by Professor Clayton M. Christensen of Harvard Business School to describe a new technology that unexpectedly displaces an established technology.[14] Digital dental impressioning and CAD/CAM systems are disruptive technological advancements that surpass the accuracy and efficiency of former techniques for obtaining replicas of prepared teeth for the purpose of fabricating restorations, and their adoption by dentists and dental technicians is rapidly eclipsing the use of elastomeric impression materials and conventional laboratory procedures.

The ultimate goals of dentists dedicated to quality restorative dentistry are to make their treatment of patients as accurate, stressless, and as efficient as possible. The companies that have developed systems to help dentists and dental technicians achieve these goals are constantly enhancing the precision and scope of indications of their products to improve the quality of the dentistry provided.[1] Virtual has become a reality.[2]

Acknowledgements

We gratefully acknowledge the invaluable help of Paul Feuerstein, DMD, of Billerica, MA, and of Bob Cohen, CDT, of Custom Automated Prosthetics and Advanced Dental Technology of Stoneham, MA, in the research for this chapter.

Disclosure

We use the 3Shape TRIOS system for digital impressioning in our practice.

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Chapter 47 Maintenance of Esthetic Restorations

Ronald E. Goldstein, DDS, Kimberly J. Nimmons, RDH, BS, Anita H. Daniels, RDH, and Caren Barnes, RDH, BS, MS

Chapter Outline

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As patients increasingly demand esthetic dental restorations, the ability of dentists to create such restorations has also steadily increased. However, satisfying the patient's esthetic expectations requires more than attention to appearance. The restorations must function well and continue to look good over time. While some patients successfully maintain their restorations for decades, others need to replace them in less than 5 years. Material selection, placement, and fabrication techniques are major factors in the longevity of esthetic dental restorations. However, professional oral maintenance and the patient's oral hygiene regimen are equally important.

This chapter addresses the basic elements of an oral hygiene program for successful long-term maintenance of both tooth- and implant-supported esthetic restorations. Additionally, the chapter discusses the roles of the patient, dental hygienist, and dentist in creating individualized oral hygiene programs.

Ronald E. Goldstein's Esthetics in Dentistry, Third Edition. Edited by Ronald E. Goldstein, Stephen J. Chu, Ernesto A. Lee, and Christian F.J. Stappert.

Although considerations for maintaining tooth-supported and implant-supported restorations are similar, important elements distinguish their maintenance regimens, so each is discussed separately.

Maintenance of esthetic restorations supported by natural dentition

Pre-treatment

Ideally, an effective program of patient oral care should be established before any restorative treatment is initiated. Optimal results are more likely to be obtained if the soft tissue is in the best possible health before tooth restoration begins.[1] Moreover, patients who lack appropriate self-care routines are likely to develop additional problems after receiving even the most appealing restorations, thus reducing the life expectancy of those restorations.

Patients need to be educated and urged to commit to professional maintenance visits as well as a thorough oral self-care regimen. They must understand and have the abilities to implement the concepts of brushing, interdental cleaning, choosing the appropriate dentifrice, and using a manual or powered toothbrush as prescribed by the dental hygienist.

Posttreatment visit

Once a patient's esthetic restorations have been delivered, a posttreatment visit is essential. At this visit, the dental team should make sure the soft tissue has healed properly, all excess cement has been removed, all margins are smooth, and all interproximal areas can easily be reached with floss or an appropriate interproximal plaque removal device. The best way to positively determine if all the cement has been removed is to take a digital X-ray (Figure 47.1) It should be emphasized that dental floss is not the most appropriate interdental cleaning aid for most individuals.[2,3] Although patients may have been using dental floss for many years, they may be using it incorrectly. Plus, patients who have new esthetic restorations may begin brushing and flossing much more vigorously. The most frequent abuse of flossing is the use of a direct side to side motion after the floss has been placed between the teeth, thus slicing into the interdental papilla (Figure 47.2). It is necessary to continuously monitor patients to make sure they are flossing properly. If the patient's interproximal spaces can accommodate cylindrical or cone-shaped interdental brushes, these tools are likely to be much more effective than dental floss.[2,3] If interdental brushes (Figure 47.3) are recommended for interdental plaque and debris removal, they should not have exposed wire that holds the bristles in place.[4] Instead, an alternative such as soft picks (e.g., GUM® Soft-Picks®) (Figure 47.4), which have rubber bristles, should be used. Patients should be instructed in the proper use of interdental stimulators or any other type of interdental cleaner. Many patients have lost their interdental papilla as a result of using these devices improperly.

At the initial posttreatment visit, photographs should be taken to serve as a tissue and tooth-restoration baseline for future successful maintenance of the patient's restorations. The dental hygienist can use the intraoral camera to illustrate the fine details of the new restorations to the patient. The intraoral camera can also be used as an effective teaching and motivational tool (Figure 47.5). The images of the lingual aspect and interproximal margins of the restoration captured on the intraoral camera can enable patients to see these often-neglected surfaces. When enlarged on a video screen, intraoral images of inflamed tissue, plaque, and/or accumulating stain can be far more powerful than what is visible with a hand mirror. Intraoral imaging also allows the patient to see how healthy tissue and sound restorations appear. Photos of newly placed restorations can be compared at subsequent maintenance visits to detect early signs of inflammation or change in the health or appearance of the tissues.

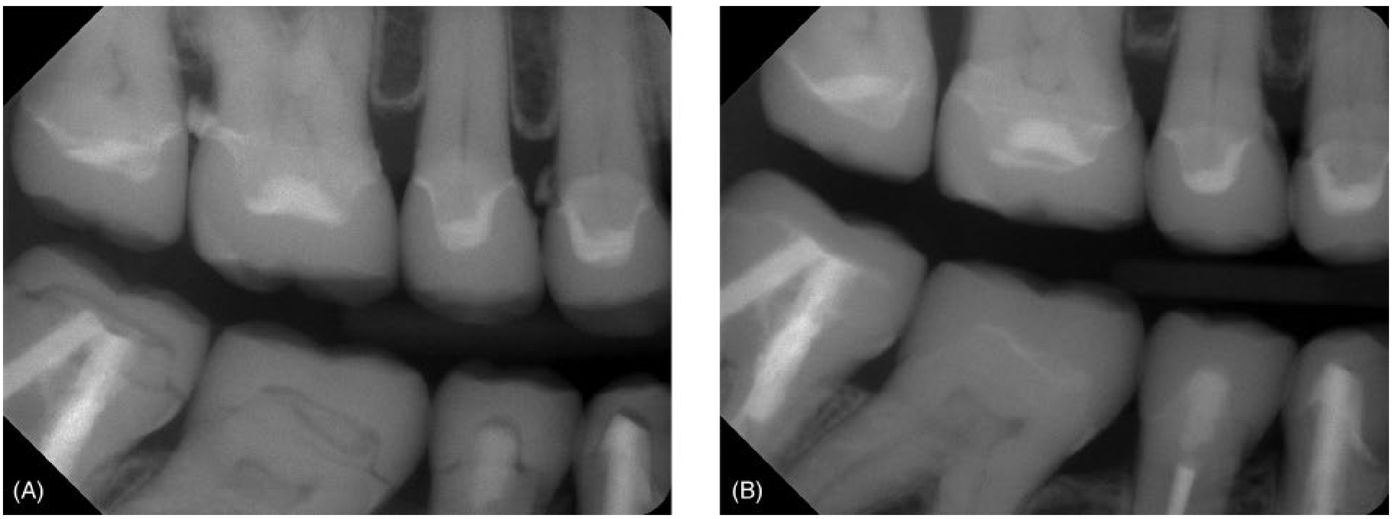


Figure 47.1 **(A, B)** Digital radiographs are a safe and effective way to determine if residual cement remains following the cementation of a restoration.

Figure 47.2 **(A)** Diastema closed with direct bonding. **(B)** This patient lived out of state, and the dentist did not see her for 5 years. The patient presented with a complaint of space reoccurring between her teeth. **(C)** When asked to show her use of dental floss, the patient demonstrated the technique shown. **(D)** It was noted that once the patient placed the floss she used a side to side motion that was guillotining her papilla and causing the space to open.

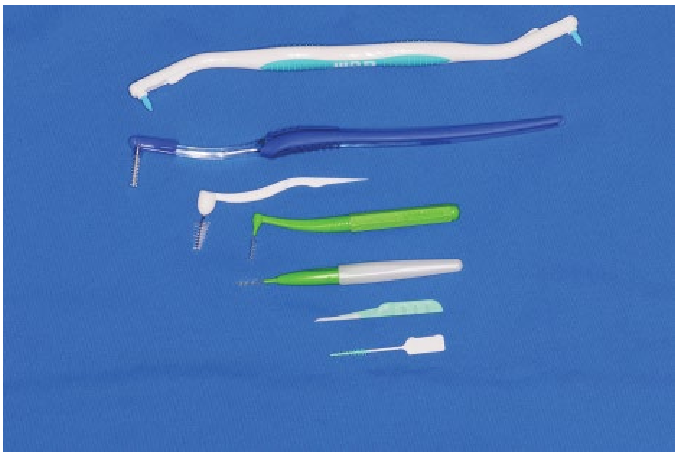


Figure 47.3 Interproximal brushes come in assorted shapes and sizes to allow for custom selection for each patient's needs.

Following restorative therapy, baseline digital radiographs should be taken in accordance with each patient's specific needs.[4] For example, if a patient reports sensitivity in a certain area, this might be caused by cement wash-out. A bitewing radiograph of the area can allow for identification, assessment, and appropriate treatment of the cause of the discomfort. Detecting and eliminating small problems at the postoperative visit can help to avoid larger problems later.

Traditionally, four horizontal bitewing radiographs of posterior teeth are taken annually.[5] However, the dental team also should consider taking three vertical bitewing radiographs of the anterior teeth. These are helpful for monitoring a patient's anterior restorations, whether they consist of composite resin bonding, porcelain veneers, crowns, or implant-supported restorations. In fact, a series of seven vertical bitewing radiographs (four posterior and three anterior) will provide a clear view of interproximal areas to check for decay and/or bone loss. A full-mouth radiographic series should be taken every 2–5 years, depending on the patient's individual situation and

Figure 47.4 Sunstar Soft-Picks offer a safe and effective means of interproximal plaque control.

incorporating the radiographic guidelines prescribed by the American Dental Association (Table 47.1).

The postrestorative visit also provides an excellent opportunity to provide site-specific oral self-care instructions and review the patient's oral hygiene regimen. After seeing their new smiles, some patients become keenly interested in oral care and highly motivated to protect their investment. Their intense new interest in oral hygiene ironically can lead to tissue damage, recession, or root-surface abrasion at the restorative margins if patients are using improper brushing or flossing techniques or products. It is prudent for the dental hygienist to ask patients to demonstrate their mastery of plaque-removal techniques so that adjustments can be made should the patient need assistance with the oral self-care techniques. A dialogue should be established regarding oral self-care products that are appropriate for the patient's individual needs, which provides an opportunity for the dental hygienist to ensure that the patients understand what products they should be using and why they are important.[3] This also serves as an important time to confirm that patients are not using products or techniques that may have detrimental consequences[6] (Figure 47.6). A summary of the dental hygiene maintenance visit procedures can be seen in Table 47.2.

Oral care products

The hygienist in an esthetically oriented dental practice should always consider oral care products that are compatible with the esthetic restorative materials. This task is simplified if the practice has delivered the esthetic restoration(s), as contemporary

Figure 47.5 An intraoral camera inspection is one of the most effective tools a hygienist can use to show potential problems to a patient or attending dentist and especially to reinforce good oral care techniques and tissue heath.

Table 47.1 Recommendations for Prescribing Dental Radiographs[a]

Type of Encounter	Patient Age and Dental Developmental Stage				
	Child with Primary Dentition (Prior to Eruption of First Permanent Tooth)	Child with Transitional Dentition (After Eruption of First Permanent Tooth)	Adolescent with Permanent Dentition (Prior to Eruption of Third Molars)	Adult, Dentate or Partially Edentulous	Adult, Edentulous
New patient[b] being evaluated for dental diseases and dental development	Individualized radiographic examination consisting of selected periapical/occlusal views and/or posterior bitewings if proximal surfaces cannot be visualized or probed. Patients without evidence of disease and with open proximal contacts may not require a radiographic examination at this time.	Individualized radiographic examination consisting of posterior bitewings with panoramic examination or posterior bitewings and selected periapical images.	Individualized radiographic examination consisting of posterior bitewings with panoramic examination or posterior bitewings and selected periapical images. A full mouth intraoral radiographic examination is preferred when the patient has clinical evidence of generalized dental disease or a history of extensive dental treatment.		Individualized radiographic examination, based on clinical signs and symptoms.
Recall patient[b] with clinical caries or at increased risk for caries[c]	Posterior bitewing examination at 6–12 month intervals if proximal surfaces cannot be examined visually or with a probe.			Posterior bitewing exam at 6–18 month intervals.	Not applicable
Recall patient[b] with no clinical caries and not at increased risk for caries[c]	Posterior bitewing examination at 12–24 month intervals if proximal surfaces cannot be examined visually or with a probe.		Posterior bitewing examination at 18–36 month intervals.	Posterior bitewing examination at 24–36 month intervals.	Not applicable
Recall patient[b] with periodontal disease	Clinical judgment as to the need for and type of radiographic images for the evaluation of periodontal disease. Imaging may consist of, but is not limited to, selected bitewing and/or periapical images of areas where periodontal disease (other than nonspecific gingivitis) can be identified clinically.				Not applicable
Patient for monitoring of growth and development	Clinical judgment as to need for and type of radiographic images for evaluation and/or monitoring of dentofacial growth and development		Clinical judgment as to need for and type of radiographic images for evaluation and/or monitoring of dentofacial growth and development. Panoramic or periapical exam to assess developing third molars.	Usually not indicated.	

(Continued)

Table 47.1 (Continued)

Type of Encounter	Patient Age and Dental Developmental Stage
Patient with other circumstances, including, but not limited to, proposed or existing implants, pathology, restorative/endodontic needs, treated periodontal disease and caries remineralization	Clinical judgment as to need for and type of radiographic images for evaluation and/or monitoring in these circumstances.

Source: modified from table 1 in *The Selection of Patients for Dental Radiographic Examinations. Revised 2012.*[5]

[a]The recommendations in this chart are subject to clinical judgment and may not apply to every patient. They are to be used by dentists only after reviewing the patient's health history and completing a clinical examination. Because every precaution should be taken to minimize radiation exposure, protective thyroid collars and aprons should be used whenever possible. This practice is strongly recommended for children, women of childbearing age, and pregnant women.

[b]Clinical situations for which radiographs may be indicated include but are not limited to the following. *A. Positive historical findings:* (1) Previous periodontal or endodontic treatment. (2) History of pain or trauma. (3) Familial history of dental anomalies. (4) Postoperative evaluation of healing. (5) Remineralization monitoring. (6) Presence of implants or evaluation for implant placement. B. *positive clinical signs/symptoms:* (1) Clinical evidence of periodontal disease. (2) Large or deep restorations. (3) Deep carious lesions. (4) Malposed or clinically impacted teeth. (5) Swelling. (6) Evidence of dental/facial trauma. (7) Mobility of teeth. (8) Sinus tract ("fistula"). (9) Clinically suspected sinus pathology. (10) Growth abnormalities. (11) Oral involvement in known or suspected systemic disease. (12) Positive neurologic findings in the head and neck. (13) Evidence of foreign objects. (14) Pain and/or dysfunction of the temporomandibular joint. (15) Facial asymmetry. (16) Abutment teeth for fixed or removable partial prosthesis. (17) Unexplained bleeding. (18) Unexplained sensitivity of teeth. (19) Unusual eruption, spacing, or migration of teeth. (20) Unusual tooth morphology, calcification, or color. (21) Unexplained absence of teeth. (22) Clinical erosion.

[c]Factors increasing risk for caries may include but are not limited to: (1) High level of caries experience or demineralization. (2) History of recurrent caries. (3) High titers of cariogenic bacteria. (4) Existing restoration(s) of poor quality. (5) Poor oral hygiene. (6) Inadequate fluoride exposure. (7) Prolonged nursing (bottle or breast). (8) Frequent high sucrose content in diet. (9) Poor family dental health. 10) Developmental or acquired enamel defects. (11) Developmental or acquired disability. (12) Xerostomia. (13) Genetic abnormality of teeth. (14) Many multisurface restorations. (15) Chemo/radiation therapy. (16) Eating disorders. (17) Drug/alcohol abuse. (18) Irregular dental care.

Figure 47.6 This patient had a habit of improper tooth brushing technique. The use of too much pressure is easily surmised.

restorative materials often are hard to identify accurately. If the practice has not delivered the restorations, then dental records, radiographs, and tactile sensitivity all can be useful in identifying their composition.[7–10] Tactile sensitivity can be enhanced with knowledge of the surface texture associated with various materials. Microfilled composites, for example, have a smooth surface texture upon placement. Glass ionomers also have a smooth surface; however, they lack the gloss associated with hybrid and microfilled composites.[11,12]

Ideally, patients should use oral care products that are compatible with the materials from which their esthetic restorations are fabricated.[7–10] In general, dentifrices should be nonabrasive, contain fluoride, and work well with both manual and powered toothbrushes. (For a list of abrasivity of dentifrices, see Table 47.3.) Both manual and powered toothbrushes should have soft bristles. Some power toothbrushes have been reported to prevent and remove extrinsic stains.[11,12] Preventing such stains is essential, since many patients have had whitening procedures performed prior to placement of esthetic restorations.[11]

Many patients question whether or not they should be using a mouth rinse. If mouth rinses are recommended, they should be mild and nonstaining, with antibacterial properties (e.g., TheraSol, Mgf, Smart Mouth, Triumph, OraTec, Inc. Pharmaceuticals). Dipping the toothbrush tip into a few drops of such a mouth rinse and using that instead of toothpaste at least once daily may be advisable. A nonshredding and nonwoven dental floss (Glide, W&L Gore & Associates, Total, or Colgate-Palmolive) can work well for most restorative patients. Certain patients cannot easily use nonwaxed floss, especially if they have too tight and imperfect contact areas. These patients who have light contacts may find tape or larger rope floss easier to use (Figure 47.7).

Patients should be informed of the role diet plays in the demineralization and remineralization of tooth structure. For example, the cariogenic effects of long-term exposure to

Table 47.2 Summary of Dental Hygiene Care at Maintenance Visits Following Dental Implant Placement

<table>
<tr><th>Pretreatment Visit</th><th>Postrestorative Treatment Visit</th><th>Ongoing Maintenance Visit</th></tr>
<tr><td>Establish oral self-care regimen</td><td>Confirm soft tissue healing</td><td>Two–four dental hygiene maintenance visits per year</td></tr>
<tr><td>Patient commits to dental hygiene maintenance visits</td><td>Confirm interdental areas can be accessed for cleaning</td><td>Evaluate patient compliance with oral self-care regimen</td></tr>
<tr><td colspan="2">Intraoral photographs for documentation, patient education, and motivation</td><td>Take intraoral photographs for documentation, patient education, and motivation</td></tr>
<tr><td colspan="2">Take four baseline vertical bitewing radiographs annually; consider additional three anterior vertical bitewing radiographs</td><td>Take full mouth radiographic survey every 2–5 years</td></tr>
<tr><td colspan="2">Site-specific oral hygiene instructions</td><td>Site-specific oral hygiene instructions</td></tr>
<tr><td colspan="2">Recommend oral care products specific for patient's needs</td><td>Using magnification loupes, inspect margins of restorations and soft tissue associated with implant</td></tr>
</table>

Table 47.3 The Relative Dentin Abrasivity (RDA) Values for Commonly Available Toothpastes[3]

Toothpaste	RDA Value
Straight baking soda	7
Arm & Hammer Tooth Powder	8
Arm & Hammer Dental Care	35
Oxyfresh	45
Tom's of Maine Sensitive	49
Arm & Hammer Peroxicare	49
Rembrandt Original	53
CloSYS	53
Tom's of Maine Children	57
Colgate Regular	68
Colgate Total	70
Sensodyne	79
Aim	80
Colgate Sensitive Max Strength	83
Aquafresh Sensitive	91
Tom's of Maine Regular	93
Crest Regular	95
Mentadent	103
Sensodyne Extra Whitening	104
Colgate Platinum	106
Crest Sensitivity	107
Colgate Herbal	110
Aquafresh Whitening	113
Arm & Hammer Tarter Control	117
Arm & Hammer Advance White Gel	117
Close up with Baking Soda	120
Colgate Whitening	124
Ultra Brite	130
Crest MultiCare Whitening	144
Colgate Baking Soda Whitening	145
Pepsodent	150
Colgate Tarter Control 165	165

FDA recommended RDA limit: 200. ADA recommended RDA limit: 250.

The RDA index: 0–70, low abrasive; 70–100, medium abrasive; 100–150, highly abrasive; 150–250, regarded as harmful limit.

sugars in products such as breath mints, hard candies, and throat lozenges may decrease the life expectancy of their restorations. In addition, certain foods and drinks consumed by the patient can affect the oral pH. As the oral cavity becomes acidic, tooth structure more readily demineralizes. Patients can aid in the prevention of caries development through excellent daily plaque removal, nutritional awareness, and the use of appropriate products. A key role of the dental hygienist in caries prevention is to assess each patient's risk factors. Based on the risk factors identified, the dental team can educate the patient on preventive and therapeutic care strategies, as well as products designed to minimize risk of caries development.

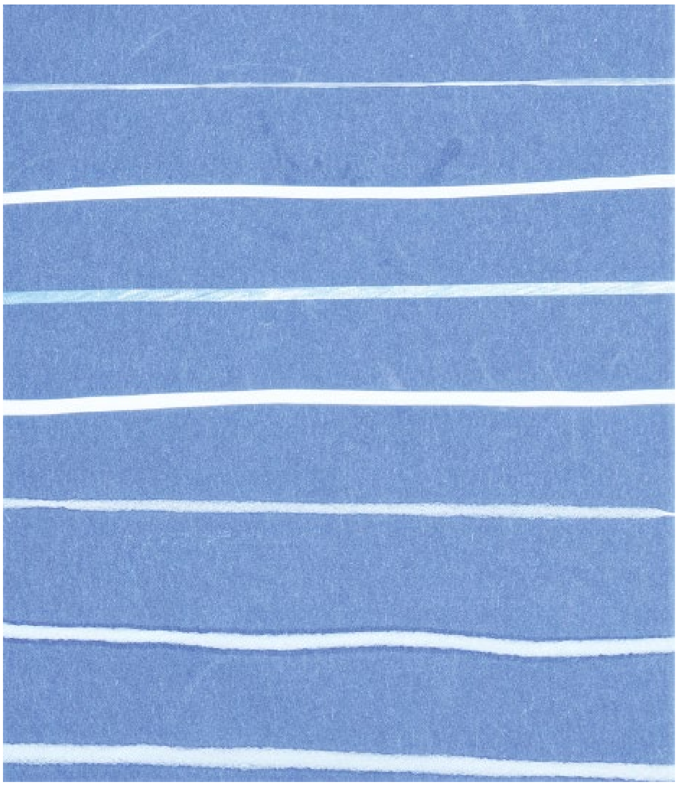


Figure 47.7 The availability of many types of dental floss allows a custom selection to meet each patient's oral care needs.

Ongoing professional maintenance

After the postoperative visit, there is a standard of recommending two to four dental hygiene maintenance appointments annually. However, more frequent visits may be advisable for patients with extensive esthetic restorations. It is essential that the frequency of dental hygiene maintenance visits be based on the individual patient's needs and determined by the level of the patient's self-care compliance, risks, needs, and periodontal status.

At each dental hygiene maintenance appointment, the dental professional can carefully inspect the restorative margins with an explorer and small surgical suction tip. The suction tip dries the tooth and can gently retract the soft tissue enough to provide a direct view of the subgingival margin (Figure 47.8). Further, the use of loupes (magnifying glasses) can greatly enhance the dental hygienist's ability to detect marginal discrepancies.[13]

Polishing

Polishing during dental hygiene maintenance visits can pose a serious threat to successful maintenance of esthetic restorations. This is because many dental professionals use whatever type of polishing paste is at hand.[10] Some prefer using coarse-grit paste, in the belief that it removes all stains ranging from light to heavy, thus saving time. Sales of coarse-grit polishing paste have been reported to make up 80% of total polishing paste sales, compared with 10% for medium grit.[10,14] While the use of coarse-grit pastes may initially save time, such pastes can significantly damage the surface characterization of esthetic restorative surfaces, produce hypersensitivity, roughen tooth and restorative surfaces, and accelerate staining and the retention of dental plaque and calculus.[7–14]

Ideally, polishing grits should be used in a progression of coarse, medium, and fine applications. If a coarse polish is required, the surface should also be polished with medium and fine polishes. Each time a different grit of polish is used, the rubber cup must be changed to prevent contamination of the grit sizes. It is essential for dental hygienists and dentists to understand the special polishing requirements for each type of esthetic restorative material, as these restorations can be severely compromised if the wrong products or procedures are used. The major categories of esthetic restorative materials include porcelain, composites, and glass ionomers.

Figure 47.8 Gentle tissue lift provided by the use of small surgical suction tip assists in the direct visual inspection of a restoration's margin.

Porcelain

Glazed and previously polished porcelain restorations resist staining much better than unglazed porcelain. Typically, such restorations can be polished with a dry diamond paste and a Robinson brush.[10] Although rubber polishing instruments can remove stain and create a highly polished surface in a single step, rubber polishing instruments can also be followed with a diamond paste.[10]

Unglazed porcelain restorations that have become roughened should be smoothed prior to polishing, using dry diamond paste applied with a felt wheel or Robinson brush.[10] If the unglazed porcelain surface is stained but smooth, a rubber polishing cup and diamond paste can work effectively.[15]

The resin cement used for sealing bonded porcelain restoration margins absorbs stains more readily. Care must be taken to avoid removing too much resin cement during polishing, or else marginal ditching can result, along with increased vulnerability to leaking, plaque retention, and dental caries. If no stain is present and only plaque removal is required, a cleaning agent that does not contain abrasives (e.g., ProCare, Young Dental Mfg.) can be used with a rubber polishing cup.[7–10]

Composites

Manufacturers' recommendations should be followed when choosing a product to polish an esthetic restoration made of composite materials. However, there are many occasions when identification of the type of composite or glass ionomer material may not be possible. When that is the case, polishing of the esthetic restoration can be safely completed using a cleaning agent that does not abrade the surface of the restoration.[7–10]

The ability to distinguish between hybrids and microfilled composites can enable dental hygienists to consistently achieve better polishing results. Hybrid composites tend to have a rougher surface.[10] It may not be possible to achieve a highly polished surface on restorations made from them. Rubber finishers and polishers, followed by a composite polishing paste, is recommended.[15]

Use of a rubber polisher can enable microfilled composites to be polished rapidly, followed by a composite polishing paste. An aluminum oxide polishing paste fabricated for composite restorations is recommended for hybrid composites.[10] This should be applied with a water-filled rubber polishing cup. Extra-fine aluminum oxide paste can then be used as a final polish.

Glass ionomers

Restorations made from glass ionomers lack the shiny, smooth, undetectable surface achievable with polished esthetic composite materials.[10] Glass ionomers typically have a rougher surface, and polishing with light pressure at slow speed is recommended.[10] A fine finishing disk or rubber polisher can be used to remove persistent stains on this material. Desiccation of glass ionomer restorations, which can lead to cracking and premature deterioration, can be mitigated by lubricating the restoration with petroleum jelly or water before polishing.[16]

Both manual and powered instrumentation used by dental hygienists at dental hygiene maintenance appointments should be chosen to produce the smoothest surfaces possible for teeth and restorative materials without damaging those surfaces or jeopardizing the marginal integrity of cemented castings. Powered instrumentation with ultrasonic scalers can damage both hybrid and microfilled composite restorations, glass ionomers, laminate veneers, and titanium implant abutments.[17] Ultrasonic instruments also can fracture porcelain and change the margins of amalgam restorations.[18] Air-polishing instruments also should not be used on any esthetic restoration, including composite, glass ionomer, and porcelain-cemented restorations. Air polishing can devastate the surface characterization of composite and glass ionomer restorations, remove the resin matrix, and expose the filler particles. Although air polishing does not harm porcelain, it can remove the cement surrounding the margins and cause aggressive "ditching" around the interface among the tooth, cement, and porcelain, leaving a location for plaque to accumulate.[19]

Maintenance of esthetic implant-supported restorations

Early dental implants did not support the most esthetic of restorations. They were originally developed as a last option for providing edentulous patients with limited masticatory function and improved speech. In exchange, patients often had to settle for non-esthetic appearances and unsightly, exposed implant components.

Fortunately, countless advances have been made in implant design and biocompatible materials. Today, implants can be expected to support restorations that not only function indistinguishably from natural dentition but also are beautiful and long lasting. When maintaining and evaluating the health of the hard and soft tissues supporting dental implants, several important factors must be considered. Careful patient selection and meticulous case planning followed by proper professional and patient self-care are essential to a long-lasting and esthetically successful implant restoration.

The next section reviews the clinical considerations when evaluating dental implants and their surrounding tissues. Both in-office care and home care techniques are then reviewed.

Clinical evaluation of dental implants

Numerous criteria have been proposed for evaluating dental health, and over time these criteria have changed.[20] A consensus conference in 2008 updated and clarified clinical indices of implant success, including pain, mobility, radiographic crestal bone loss, probing depths, and peri-implant disease. Table 47.4 summarizes these findings.[21]

Table 47.4 Dental Implant Health Scale

Implant Quality Scale Group	Clinical Conditions
I. Success (Optimum Health)	(a) No pain or tenderness upon function (b) No clinical mobility (c) <2 mm radiographic bone loss (d) No history of exudate
II. Satisfactory survival	(a) No pain on function (b) No clinical mobility (c) 2–4 mm radiographic bone loss (d) No history of exudate
III. Compromised survival	(a) May have sensitivity on function (b) No clinical mobility (c) Radiographic bone loss >4 mm (d) Probing depth >7 mm (e) May have history of exudate
IV. Failure (clinical or absolute failure)	Any of the following criteria: (a) Pain on function (b) Mobility (c) Radiographic bone loss >1/2 length of implant (d) Uncontrolled exudate (e) No longer in mouth

Source: International Congress of Oral Implantologists (ICOI), Pisa, Italy, Consensus Conference 2007.[21]

Pain

Although pain is not a common complication once implants have healed, it can occur if vital structures are traumatized during surgery, if the implant body is mobile, or if the implant body has fractured. More frequently, complaints about pain at implant site are associated with the surrounding soft tissues. Soft-tissue pain can be caused by trauma, loose prosthetic components, or residual cement at cement-retained restoration sites.

Mobility

A healthy tooth will exhibit clinical movement, both vertically and horizontally, as allowed by its periodontal ligament, but once an implant has achieved osseointegration, it does not exhibit clinical mobility. While studies have revealed slight movement of healthy dental implants, there should be no clinically visible mobility.[22]

Radiographic crestal bone loss

The ICOI consensus determined that bone loss should be measured from the time of placement, rather than from earlier radiographs. It also said that for an implant to be judged successful, less than 2 mm of crestal bone loss should occur. This differed slightly from the historic expectation[23] of 1.5 mm of crestal bone loss in the first year after placement and 0.1 mm each year thereafter (Figure 47.9).

Research in the field of dental implants is presently focusing on eliminating even minimal crestal bone loss by means of design changes, such as the Laser-Lok surface (BioHorizons) and platform switching.

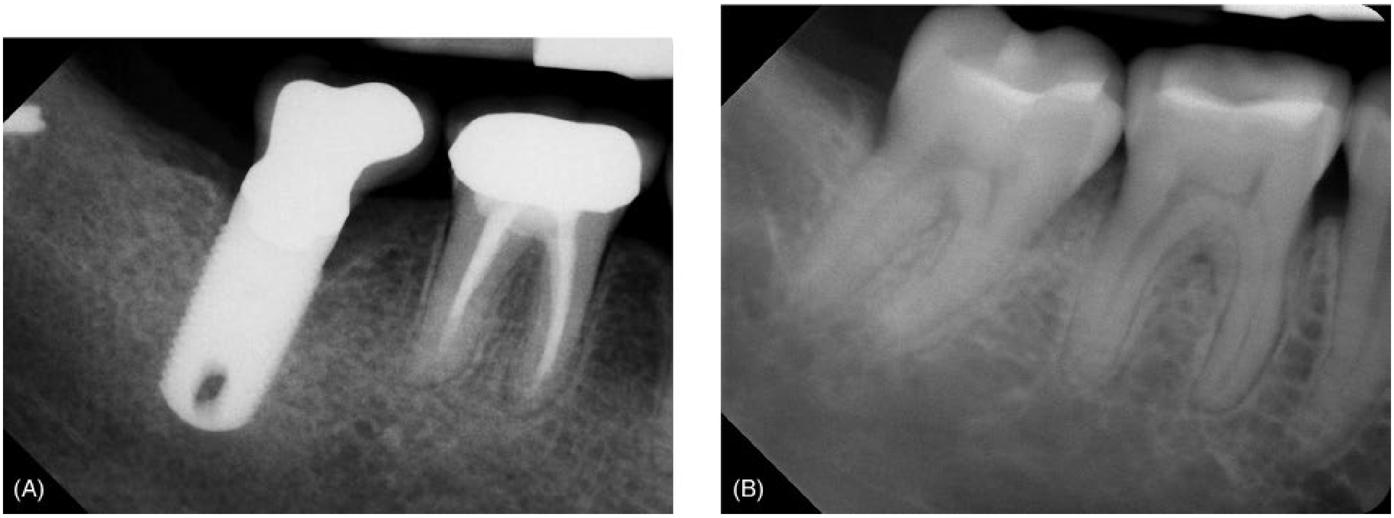


Figure 47.9 **(A, B)** Crestal and circumferential bone loss as seen on a radiograph.

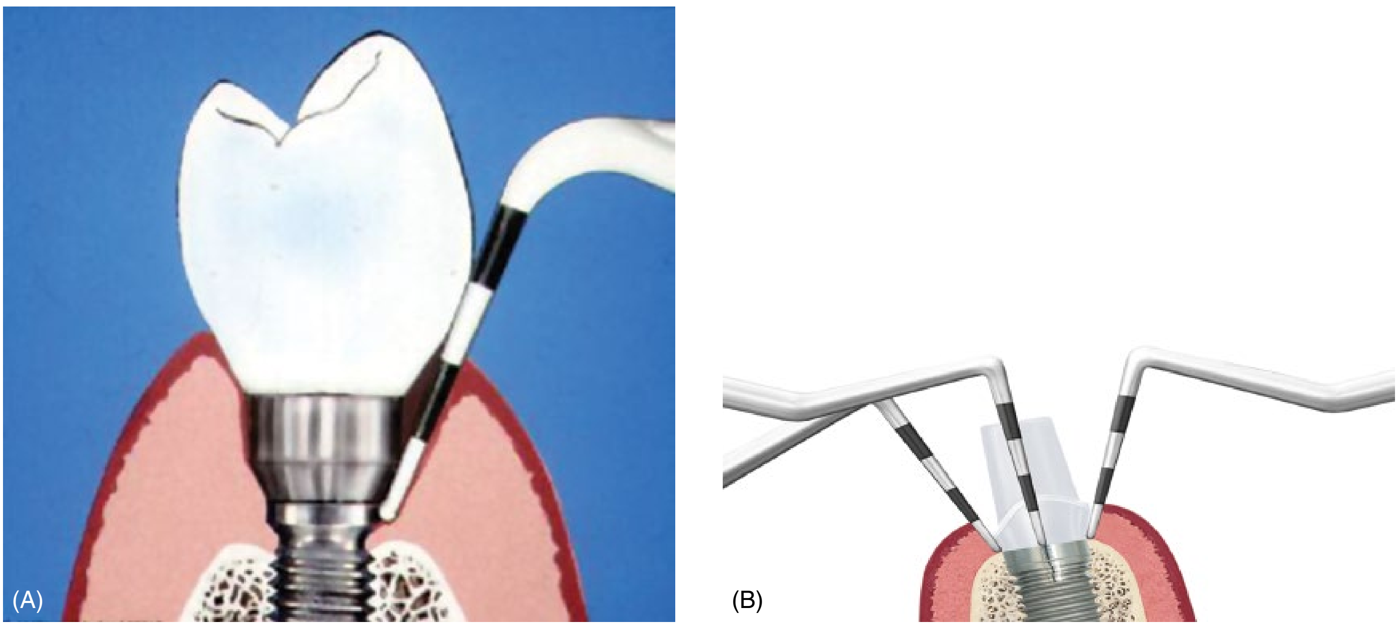


Figure 47.10 **(A)** Proper positioning to show probing around restored implant. **(B)** A plastic periodontal probe (see Figure 47.11B) can be gently swept through the peri-implant sulcus to visualize symptoms of inflammation or disease. The depth of the sulcus is surgically created and therefore corresponds to abutment collar height, rather than an indication of attachment loss. A better indicator of bone loss is a radiograph.

Probing depths

When measuring a periodontal pocket around a tooth, the probe goes through the sulcus and the junctional epithelium, stopping at the zone of connective tissue attachment. The place where fibers insert into the cementum creates a definitive stopping point. None of the connective tissue fibers can insert into the implant body, however, making it difficult to ascertain the appropriate stopping point for a probe. The parallel orientation of these fibers also makes the peri-implant sulci more susceptible to bacteria. The ICOI consensus does not recommend routine probing, but it finds value in baseline probing measurements, as well as probing in the presence of other symptoms (Figure 47.10).

Peri-implant disease

In the absence of residual cement, the most likely cause of peri-implantitis is bacteria. As for teeth, bone loss and an increase in pocket depths around implants leads to the development of a niche for anaerobic bacteria. Patients with a history of periodontal disease are more likely to have these bacteria in their mouths and are thus at greater risk for peri-implant disease.[24]

In-office hygiene care of implant-supported restorations

Hygiene maintenance visits often involve the care of dental implants and the restorations they support, along with the patient's tooth-supported esthetic restorations. However, the approach to cleaning the two classes of restorations differs slightly.

The appropriate instruments and accepted standard-of-care protocols may vary and require an individualized approach. Dental professionals must also provide appropriate implant self-care instruction to each patient. Without guidance, patients may assume that the care required for their dental implants is identical to that required by their natural teeth or conventional restorations.

Probing

Once osseointegration has been confirmed and the definitive implant restoration has been delivered, baseline peri-implant sulcular depths should be charted. The peri-mucosal seal around implants consists of junctional epithelium with a hemidesmosomal attachment and connective tissue fibers that mostly are oriented parallel to the implant. This attachment is fragile and may be more susceptible to trauma from probing than the multidirectional connective tissue fibers that attach to the cementum of a tooth. Because of this, subsequent implant probing should be performed only in response to a clinical indication, such as a visual change in the tissues, mobility, patient-reported symptoms, or radiographic evidence.[25] With dental implants, a deeper pocket depth alone does not necessarily indicate disease. It may be in part due to the depth of the implant placement or the shape of the restorative components. More important to look for is an increase in pocket depth that occurs over time or other signs of disease in addition to the pocket depth. Careful clinical inspection is important, as any deep pocket may potentially harbor anaerobic bacteria.[26]

Accurate monitoring of peri-implant tissues requires consistent clinical observation and thorough records. Recently, specific bacterial pathogens have been identified as those most commonly found to cause peri-implantitis. Annual bacterial screening at professional hygiene appointments may be helpful in assessing the risk of peri-implant infections and allow for very early intervention. OralDNA Labs offer the MyPerioPath saliva test which can be used to screen for *Actinobacillus actinomycetemcomitans*, *Porphyromonas gingivalis*, *Fusobacterium*, and *Treponema denticola*—the pathogens most commonly implicated in peri-implantitis (Figure 47.11A).

When peri-implant probing is performed, this should be accomplished using a probe specifically designed for implants. Implant probes, such as the Colorvue (Hu-Friedy) or PDT Sensor Probe (DenMat; Figure 47.11B), offer improved visibility and help to ensure that the correct amount of pressure is used during probing. Misch has discussed the need to take care not to scratch the implant when utilizing a metal probe, as any such scratch may create a niche for bacteria.[27] The use of nonmetal probes also decreases the chance of scratching or otherwise marring the implant's titanium surface or damaging the peri-implant epithelial fibers. Misch also warns against probing any site of natural dentition with a history of periodontal disease before probing an implant site. As the attachment is fragile, one can introduce bacteria from the dentition into the implant site.[27] To minimize this chance, different probes should be used around implants and natural teeth. According to Garber, dipping the probe into an antimicrobial agent (e.g., chlorhexidine) before and during probing may minimize cross-contamination from tooth sulci to peri-implant tissues (personal communication, Dr David Garber, April 2005).

Radiographs

Radiographic evaluation may be more valuable for implant assessment than probing. Annual vertical bitewing radiographs are diagnostic for areas of one to four implants and should be supplemented with periapical films. If a patient has five or more implants, a panoramic radiograph should be taken every other year and supplemented with periapical films as necessary. When evaluating crestal bone loss, it is important that the radiographs be perpendicular to the implant body so that the threads on both the mesial and distal sides are clearly visible.[26] This can usually be best accomplished with vertical bitewings. Periapical and panoramic films will best visualize for peri-implantitis and loss of integration along the body of the bone-to-implant interface.

Digital radiography, which provides clear and easily studied images, can be a valuable tool for examining implants during maintenance. The digital radiographic image also can be manipulated to provide contrast, color, clarification, and magnification. The "eagle-eye" feature on the Sirona® system is especially helpful when examining bone-to-implant surfaces.

Intraoral examination

A periodontal probe may be the instrument of choice for assessing the health of gingival tissues and underlying bone supporting natural teeth; however, implants require even more meticulous clinical examination. The tissues surrounding any implant should be evaluated for redness, thinning, swelling, tenderness, bleeding, suppuration, or recession. Even minor changes should be noted and investigated. As with all esthetic restorations, it is helpful to document the tissue status, healthy or not, with an intraoral camera. Clinical photographs provide accurate comparisons that can be reviewed during periodic maintenance visits.

The implant examination also should include an occlusal check and review for mobility. Occlusal discrepancies can result from several factors, such as a change in the natural dentition or bone loss. If noted, they should be further evaluated. If the implant, abutment, or restoration appears to be loose or mobile, a radiograph may help determine why. Common causes include cement wash-out under a crown or loosening of a retention screw. Screw-access openings for screw-retained implant-supported restorations should be checked and resealed as needed.

As with natural teeth, parafunctional occlusal stresses may cause bone loss and affect the longevity of the dental implant. Over time, changes in the patient's occlusion may affect the stability and lifespan of any implant-supported restoration.

MYPERIOPATH®
FINAL REPORT

ORALDNA LABS
Innovations in Salivary Diagnostics

Patient | **Ordering Provider** | **Sample Information**

Specimen#: 0000000000
Accession#: 201611-08469
Specimen: Oral Rinse(P)

Collected: 11/12/2016 10:30
Received: 11/13/2016 12:01
Reported: 11/16/2016 12:30

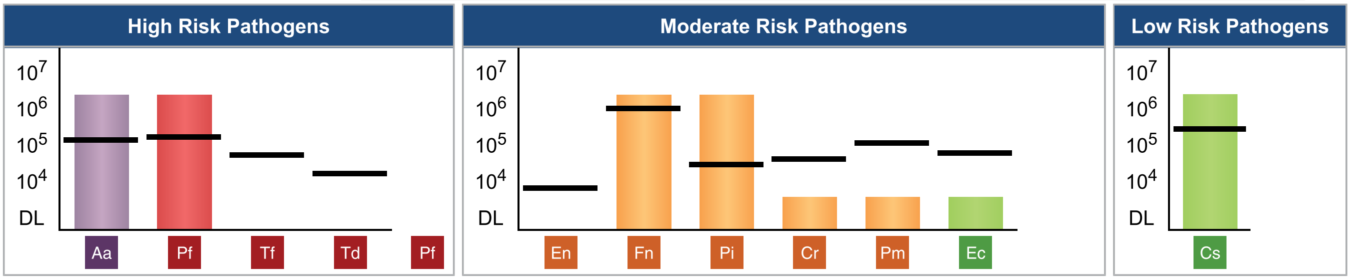
MYPERIOPATH MOLECULAR ANALYSIS OF PERIODONTAL AND SYSTEMIC PATHOGENS

Result: PATHOGENIC BACTERIA DETECTED, 5 ABOVE THERAPEUTIC THRESHOLD Aa Pg Pg Pi Cs

Bacterial Risk: HIGH - Very strong evidence of increased risk for attachment loss

Legend
▬ = Therapeutic Threshold*
DL = Detection Limit

Result Interpretation: Periodontal disease is caused by specific, or groups of specific bacteria. Threshold levels represent the concentration above which patients are generally at increased risk for attachment loss. Bacterial levels should be considered collectively and in context with clinical signs and other risk factors.



Pathogen	Result	Clinical Significance
Aa **Aggregatibacter actinomycetemcomitans**	**High**	Very strong association with PD: Transmittable, tissue invasive, and pathogenic at relatively low bacterial counts. Associated with aggressive forms of disease.
Pf **Porphyromonas gingivalis**	**High**	Very strong association with PD: Transmittable, tissue invasive, and pathogenic at relatively low bacterial counts. Associated with aggressive forms of disease.
Fn **Fusobacterium nucleatum/periodonticum**	**High**	Strong association with PD: adherence properties to several oral pathogens; often seen in refractory disease.
Pi **Prevotella intermedia**	**High**	Strong association with PD: virulent properties similar to Pg; often seen in refractory disease.
Cs **Capnocytophaga species (gingavalis,ochracea,sputigena)**	**High**	Some association with PD: Frequently found in gingivitis. Often found in association with other periodontal pathogens. May increase temporarily following active therapy.
Cr Campylobacter rectus	**Low**	Moderate association with development of PD: usually found in combination with other suspected pathogens in refractory disease.
Pm Peptostreptococcus (Micromonas) micros	**Low**	Moderate association with PD: detected in higher numbers at sites of active disease.
Ec Eikenella corrodens	**Low**	Moderate association with PD: Found more frequently in active sites of disease; often seen in refractory disease.

Not Detected: (Tf) Tannerella forsythia, (Td) Treponema denticola, (En) Eubacterium nodatum

Additional information is available from OralDNA.com

Methodology: Genomic DNA is extracted from the submitted sample and tested for 10 species-specific bacteria and 1 genus of bacteria known to cause periodontal disease. The bacteria are assayed by real-time quantitative polymerase chain reaction (qPCR). Bacterial loads are reported in log copies per mL of sample (e.g. 1x10^3 = 1000 bacteria copies per mL of collection). *Modified from: Microbiological goals of periodontal therapy; Periodontology 2000, Vol. 42, 2006, 180-218. This test was developed, and its performance characteristics determined by OralDNA Labs pursuant to CLIA requirements. This test has not been cleared or approved by the U.S. Food and Drug Administration. The FDA has determined that such clearance or approval is not necessary.

OralDNA Labs, A Service of Access Genetics, LLC, 7400 Flying Cloud Drive , Eden Prairie, MN 55344 Phone: 855-672-5362; Fax: 952-942-0703 www.oraldna.com
CLIA#: 24D1033809   CAP#: 7190878

PL-000388-B

Web enabled system provided by: access genetics

Figure 47.11 **(A)** MyPerioPath (OralDNA Labs) lab report identifies the presence of any of the top 11 pathogens associated with periodontal infections. Reproduced with permission of Access Genetics, LLC.

Figure 47.11 **(B)** The Goldstein Colorvue Prove (Hu-Friedy) has 1/2 mm increments up to 3 mm and 13 mm total in length. It is more comfortable for patients plus much easier to see in the mouth.

An occlusal check using articulating paper or the T-Scan II (Tekscan, Inc.) should be done annually. Patients with implant-supported restorations may also be prescribed an appropriate occlusal appliance to guard against parafunctional habits. Checking patient compliance with wear and care of the occlusal guard is recommended as part of the routine maintenance visit. Cleaning and adjusting the guard can be accomplished at the same time.

Locally applied chemotherapeutics

When tissue inflammation or radiographic bone level changes are observed, it does not necessarily mean the implant has failed or will inevitably do so. It is important to determine if the patient has peri-implantitis (involving bone) or mucositis (localized to tissues). Often, patients will not feel any pain from either of these conditions, which underscores the need for frequent maintenance visits for early detection and care. Early intervention with a locally applied antibiotic or antimicrobial, such as Arestin® (OraPharma, Inc.) or Atridox® (CollaGenex Pharmaceuticals, Inc.), may help decrease the bacterial load. This may effectively slow or reverse the inflammation associated with peri-implant disease.[28]

The use of antimicrobials such as chlorhexidine gluconate may also help control plaque and bacteria around dental implants. Rinses may be utilized with in-office irrigation or used long term at home.[29] Peri-implant irrigation should be done with a plastic irrigation tip designed for safe use around implants. For patients prone to occasional peri-implant tissue inflammation, an at-home regimen of daily cleansing with an antimicrobial rinse applied with soft manual toothbrush or a gentle power toothbrush may be helpful. The minimally abrasive and variable speed Rotadent (DenMat) plaque-removal instrument is ideally suited for daily gentle cleansing under and around the tissues of an implant. The densely compacted microfilaments of a Rotadent (DenMat) make it hydrophilic, which improves its capacity to apply medications directly under and around the tissues of an implant during routine brushing. Using a Rotadent (DenMat) for implant daily care also will remove plaque, disrupt biofilm, and decrease tartar buildup (Figure 47.12).

Figure 47.12 Rotadent brush head (DenMat).

Scaling

At each maintenance visit, removal of any biofilm, plaque, and/or calculus from the implant-supported restoration(s) is indicated. Traditional metal hand instruments can easily mar or scratch titanium implant abutments, and roughened surfaces make these metals more susceptible to biofilm, bacterial plaque, and calculus buildup, which in turn increases the chance of peri-implant inflammation. Therefore, surface damage should be minimized by using one of the scalers specifically designed for maintenance of dental implants (Figure 47.13A).

Several companies manufacture implant scalers and curettes. One example is Implacare (Hu-Friedy Manufacturing Company, Inc.) (Figure 47.13B). These hand instruments are typically made of plastic, titanium, or nylon. They are gentle but effective in removing accumulations around implants, and the scientific literature supports their use during implant hygiene/maintenance appointments.[30]

Controversy exists concerning the use of sonic or ultrasonic instruments around implants. To prevent damage to the implant surface and the peri-mucosal seal, power scalers should be used with extreme caution. Some manufacturers offer a plastic or carbon composite tip that is placed over the metal end of the sonic or ultrasonic instruments to reduce the chances of their damaging the implant. Even with the use of protective plastic sleeves, a clinician must use caution not to shred or chip the tip by inadvertently using it on any accessible implant threads. Small particles of plastic in an implant sulcus may provide a source of tissue irritation or infection.

Polishing

With proper care, the titanium surface of an implant abutment should not lose the highly polished finish created initially by the manufacturer. Because dental professionals rarely if ever need to restore an implant component's polished surface, "polishing" in the traditional sense does not apply to implants. The only indication for polishing an implant or the restoration that it supports may be for plaque removal, which can be safely accomplished with air polishing using sodium bicarbonate.[31] However, such prophylaxis must be accomplished with little or no abrasion to the titanium surface or the esthetic restorative material used to fabricate the restoration.

The implant components, including the restoration, may be cleaned with a traditional round soft rubber cup and a nonabrasive cleaning agent (e.g., ProCare). Rotadent (DenMat) brush tips and mandrels, designed for use on slow-speed handpieces, will achieve gentle and effective removal of plaque around implants. If no polishing agent is desired, one can simply use an antimicrobial liquid such as chlorhexidine, Listerine, or TheraSol.

Figure 47.13 **(A)** Plastic scalers such as these from AIT Prophy+may be safely used for removing debris around implant-supported restorations, without imparting damage to the implant collar, implant abutment, or restoration. **(B)** Hu-Friedy implant scalers.

Figure 47.14 **(A)** This 13-year-old girl spent more time brushing her hair than her teeth, resulting in heavy plaque buildup and enamel decalcification. **(B)** Thorough prophylaxis plus home care instruction resulted in considerable plaque reduction. **(C)** The tapered brush head available from Rotadent (DenMat) is an excellent choice for patients with open interdental spaces.

One other situation worth considering is when a lack of keratinized gingiva is noted adjacent to dental implants. Considerable controversy has surrounded the question of whether this condition is harmful. Historically, an insufficiency of keratinized gingiva around teeth was considered undesirable and prompted the development of various gingival augmentation techniques. However, by 1994, the consensus of the European Workshop on Periodontology was that treatment for the sole purpose of increasing the apicoronal width of the gingiva to maintain periodontal health and prevent the development of soft-tissue recession around teeth could not be justified.[32]

Caution about the need for augmenting a lack of keratinized gingiva around implants also appears to be warranted. Results of numerous long-term implant studies have found little or no difference in the survival rate for implants surrounded by keratinized gingiva versus those adjacent to a dearth of it.[33–37] However, most of the implants studied have had smooth surfaces, rather than the textured surfaces that have more come to predominate. The impacts of a lack of keratinized gingiva on plaque consequences, inflammation, probing depths, recession, and bone loss also remain unclear in the face of contradictory research findings.

The conclusion of one recent comprehensive literature review[38] was that the need for keratinized gingiva around implants appears to be patient specific, with no method presently available to distinguish who would benefit from tissue augmentation. The reviewers concluded that it might be beneficial for chronically inflamed sites, locations where recession or continued loss of clinical attachment or bone continues despite periodontal therapy and good oral hygiene, sites that appear sore during brushing despite the appearance of gingival health, where a dental history suggests a predisposition to periodontitis or recession, where there is persistent patient noncompliance, or to improve esthetics.

Patient self-care

The long-term success of any implant and its restoration depends on several factors. These include the patient's genetic predisposition to inflammation and any systemic conditions that may affect their ability to fight bacterial infections in the mouth. Daily oral care by the patient is also critical to keeping the bioburden on the peri-implant area and oral cavity to a homeostatic minimum (Figure 47.14A and B).

Genetic considerations

A patient's genetic susceptibility to peri-implantitis should be considered prior to implant placement and during maintenance. Laine et al. have reported that the *IL-1* gene mutation is associated with implant complications.[39] The presence of this mutation can be determined by a salivary diagnostic evaluation (Celsus One™, OralDNA Labs (a service of Access Genetics), Eden Prairie, MN) (Figure 47.15). The patient's genetic risk result may then be used for establishing treatment and the frequency of dental hygiene maintenance. Additionally, a genetically positive patient may be more motivated to maintain an excellent daily care regimen to lessen the chance of a bacterial infection that in turn may cause implant complications.

Patient oral care instructions should include detailed risk factor explanation, verbal guidance, visual demonstration, and hands-on experience. As with all oral hygiene instruction, the techniques and products recommended should be individually chosen, and their effectiveness should be reevaluated during every maintenance visit. Constructive improvements should be taught, and techniques that are working well should be praised. Patients should understand that even in the presence of a genetic risk they can positively influence the health of their implants and surrounding tissues by minimizing other contributing factors, such as an increased bacterial load due to inadequate oral hygiene.

Interproximal/circumferential cleaning

Unlike the curves of a natural tooth, implants have a cylindrical and smooth profile. Many commercially available flosses, interproximal cleaners, and oral irrigation systems are safe for use around implants. Floss choice should be based on clinical indication. A single-tooth implant with intimate tissue adaptation may be best cleaned with flat, smooth floss. Traditional flossing of the mesial and distal surfaces is required, but floss should also be used on the facial/lingual surfaces. Patients must learn an implant-specific technique for looping the floss and then cleaning the implant circumferentially. Thicker woven flosses

Celsus One™

FINAL REPORT

Sample, Report
Date Of Birth: 09/20/1980
Gender: Female

Sample Information
Specimen#: 3033031027
Accession#: 201702-09869
Specimen: Oral Rinse(P)

Collected: 02/11/2017
Received: 02/12/2017 12:57
Reported: 02/15/2017 11:31

Reason for Testing: Patient assessment/post treatment, Diabetes, Cardiovascular disease

CELSUS ONE: GENETIC ANALYSIS FOR MARKERS OF ORAL AND SYSTEMIC INFLAMMATION

Type of Immunity	Gene Marker	Genotype	Inflammation Index
Innate	Beta-defensin 1 **(DEFB1)**	G/A	**Low Risk**
	CD14 **(CD14)**	T/T	
	Toll-like receptor 4 **(TLR4)**	AA/CC	
Acquired	Tumor necrosis factor alpha **(TNF-alpha)**	C/C	**Intermediate Risk**
	Interleukin 1 **(IL1)**	TT/CT	
	Interleukin 6 **(IL6)**	C/C	
	Interleukin 17A **(IL17A)**	G/G	
	Matrix Metallopeptidase 3 **(MMP3)**	5A/5A	

Interpretation:

The genotypes for markers DEFB1, CD14 and TLR4 for this individual collectively predict a normal phenotype for the innate immune system and a low risk for chronic systemic inflammation. Specifically, the expected level of gene expression, and or levels of these proteins, is normal in response to environmental and disease causing bacteria and other effectors of inflammation. See comment.

The genotypes for markers TNF-alpha, IL1, IL6, IL17A, and MMP3 predict a slightly enhanced immune response to specific pathogens and an intermediate risk for chronic systemic inflammation. Based on this, gene expression and the corresponding protein levels, in response to disease causing bacteria and the other effectors of the acquired immune system, are predicted to be increased. See comment.

Disclaimer: The reported genotypes are a subset of the group of genes that comprise the complete immune system. This genetic analysis may not detect specific immunologic diseases or predict the health and effectiveness of a person's immunity for specific diseases. Such an evaluation may require genetic counseling and testing directed to characterize those genetic conditions.

Comments:

The innate immune system is the body's first line of defense against pathogenic organisms and a major cause of oral and systemic inflammation. The innate immunity functions to create a physical and chemical barrier to bacteria, the recruitment of inflammatory cells to the site of infection, the release of cytokines and the activation of the complement cascade to localize and eliminate bacteria and recruit antigen-recognizing lymphocytes. The acquired immune system involves the production of specialized cells that eliminate or prevent pathogen growth and is the basis for immunologic memory.

- **Periodontitis:** The genotype for the innate immune system marker, DEFB1, predicts an inability to maintain a balance of commensal oral bacteria. Thus, there is a predisposition to periodontal pathogenic bacterial infection. The acquired immune system IL1 and MMP3 genotypes predict an accentuated inflammatory response to pathogenic periodontal bacteria. The cytokine IL1 acts in concert with TNF-alpha to stimulate bone resorption by osteoclasts and to promote the release of matrix metalloproteinases. Further, the presence of a 'T' allele in both the IL1 alpha and beta polymorphic loci is associated with an increased severity of chronic periodontitis. Individuals with the MMP3 5A/5A genotype have elevated levels of gene transcription and an increased local expression of MMP3, and are 3 times more likely to develop chronic periodontitis.
- **Cardiovascular:** Chronic inflammation is implicated in the etiology of cardiovascular disease (CVD). There is also strong evidence to support that polymorphisms within the promoter regions of the cytokine genes for IL1, IL6 and MMP3 are linked to levels of gene expression which are associated with chronic inflammation. The cytokine IL1 beta upregulates the recruitment of inflammatory cells and the levels of matrix metalloproteinase to the site of cholesterol deposition at sites of atherosclerosis. Matrix metalloproteinases function to remove extracellular matrix products which is considered a risk factor to destabilize arterial plaque. Specifically, the 5A/5A genotype is associated with a higher risk of myocardial infarction (MI) at young age (males < 60 years) which increases to a 10-fold risk in those who smoke.
- **Type II Diabetes:** The 'T' allele of the IL1 beta gene is correlated with elevated serum glucose and altered glucose homeostasis. Further, it has been shown that insulin producing beta cells in the pancreas in persons with type 2 diabetes mellitus (T2DM) also have increased levels of the cytokine IL1 beta. Consequently, clinical studies conclude that the IL1 SNPs are associated with development of diabetic nephropathy through interactions with other pro- and anti-inflammatory mediators.

Figure 47.15 Celsus One. *Source:* Reproduced with permission of Access Genetics, LLC.

Sample, Report **09/20/1980** **201702-09869**

Gene Marker	Nucleic Acid Assignment	Reference Sequence Number (rs)	Overview
Beta-defensin 1 (DEFB1)	3 prime variant G>A	rs1047031	Defensins have been identified to be produced as an immediate response to pathogenic bacteria lipopolysaccharides (LPS) and are important elements of the innate immune system. These proteins have broad-spectrum antimicrobial activity against bacteria, fungi and some viruses. The G>A (guanine to adenine) nucleotide base variant in the three-prime untranslated region of this gene has been shown to be associated with increased risk for both chronic and aggressive periodontitis. (1)
CD14	-260 C>T	rs2569190	CD14 is a receptor present on monocytes, macrophages, neutrophils and some B cells, and dendritic cells that recognizes bacterial cell wall lipopolysaccharides (LPS). Thus, it can stimulate the innate immune response via tumor necrosis factor alpha (TNF-alpha) production. Individuals possessing the C/C genotype at position -260 have been reported to have a two-fold increased susceptibility to periodontitis. Conversely, the T/T genotype has been identified in a significantly higher frequency in healthy individuals. The T/T genotype has also been associated with a decreased prevalence of Prevotella intermedia. (2)
Tumor necrosis factor alpha (TNF-alpha)	-857 C>T	rs1799724	Tumor necrosis factor-alpha (TNF-alpha) is a type of messenger protein, that is produced by white blood cells. TNF-alpha helps regulate the immune response through promotion of inflammation and prompts the production of other cells involved in the inflammatory response. TNF-alpha cytokine production in -857 T allele carriers tends to be elevated, and the incidence of the variant allele is reported to be significantly higher in periodontitis patients than in healthy subjects. (3)
Toll-like Receptor 4 (TLR4)	+896 A>G +1196 C>T	rs4986790 rs4986791	Toll-like receptors (TLRs) are signal molecules essential for the cellular response to bacterial cell wall lipopolysaccharides (LPS) and are viewed as important connector elements between the innate and acquired immune responses. TLR4 cytokine expression has been shown to be increased in both macrophages and gingival fibroblasts located in inflamed gingival tissues indicating its importance in the inflammatory process. Studies have shown that two TLR 4 variants, 896 A>G and 1196 C>T are frequently inherited together and individuals who inherit a composite genotype that contains the 896 G allele are hyporesponsive to LPS stimulation. (4)
Interleukin 1 (IL1)	-889 C>T +3954 C>T	rs1800587 rs1143634	Interleukin 1 (IL1) cytokines induce other immune cells to secrete matrix metalloproteins (MMPs) and prostaglandins that enhance the inflammatory processes in periodontal tissues. Additionally, IL1 is a strong stimulator of connective tissue degradation. The IL1 alpha -889 single nucleotide polymorphism (SNP) has been identified to be in complete linkage with the IL1 alpha +4845 SNP which has previously been reported in combination with the IL1 beta +3954 C>T SNP. Multiple studies have reported that the presence of a T allele in each of the IL1 alpha and IL1 beta genotypes are associated with periodontal disease severity. (5,6,7)
Interleukin 6 (IL6)	-174 C>G	rs1800795	The interleukin-6 (IL6) cytokine is involved in a wide variety of biological functions. It is produced in response to inflammatory stimuli such and tumor necrosis factor (TNF-alpha), interleukin 1, and bacterial and viral infection. IL6 is a regulator of B-cell responses, is a stimulator of osteoclast differentiation and bone resorption and is an inhibitor of bone formation. It has also been shown that carriers of a single G allele are more predisposed to periodontitis than C/C carriers and individuals carrying the G/G genotype have a further increased risk of periodontitis. (8)
Interleukin 17A (IL17A)	-197 G>A	rs2275913	IL17 consists of a group of cytokines produced by activated T-lymphocytes as an element of the acquired (secondary) immune response. IL17A, a specific IL17 cytokine, appears to have a strong feedback effect on regulation and enhancement of the innate (initial) immune response through recruitment of neutrophils and macrophages that secrete TNF-alpha and IL1 beta. IL17A G/A and A/A genotypes are reported to be present in higher frequencies in patients with periodontitis than the G/G genotype. The A allele of IL17A has also been associated with more severe clinical parameters such as probing depth, clinical attachment loss and enhanced gingival tissue inflammation. (9)
Matrix Metallopeptidase 3 (MMP3)	-1171 5A/6A	rs3025058	Matrix metallopeptidase (MMPs) comprise the most important pathway to tissue destruction resulting from periodontal disease. The primary function of MMPs is the pathological breakdown of extracellular matrix, most importantly collagen type I, which is found in the periodontal ligament and alveolar bone organic matrix. Studies report that individuals with the 5A/5A genotype are approximately two- to three-fold more likely to develop periodontitis than individuals with 5A/6A or 6A/6A genotypes. (10)

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Figure 47.15 (Continued)

Sample, Report **09/20/1980** **201702-09869**

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Methodology: Genomic DNA was subjected to amplification by methods of target enrichment, a version of nested patch PCR, and then sequenced using a MiSeq. The resulting DNA sequences were analyzed using alignment and base call algorithms in the Kailos Blue software. The patient report was created by the review of these analyzed data along with the selection of medical comment and recommendations via TeleGene, a proprietary laboratory information system of Access Genetics, LLC. The analytical and performance characteristics of these laboratory-developed tests (LDT) were determined by Kailos Genetics pursuant to Clinical Laboratory Improvement Amendments (CLIA 88) requirements. It has not been cleared or approved by the U.S. Food and Drug Administration (FDA). The FDA has determined that such clearance or approval is not a requirement prior to use for clinical purposes.
Technical assay performed by Kailos Genetics, Huntsville, AL 855-323-0680

Web enabled system provided by: access genetics

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Figure 47.15 (Continued)

are indicated for larger interproximal spaces or for the long expanses of a bar-retained prosthesis.

The choice of interproximal brushes and cleaners should also be based on the area where they will be used. Larger spaces may be best cleaned with interdental brushes; these come in various shapes, including an interproximal Rotadent (DenMat) brush, and can be selected to fit. Smaller interdental brushes are also helpful in narrower interproximal spaces (Figure 47.14C).

Irrigation

Water irrigation units, such as the Hydro Floss (Hydro Floss, Inc.), are beneficial in implant maintenance. However, personalized instruction with such units is important. The water stream must be directed interproximally and horizontally between implants so the patient does not inadvertently damage the peri-implant seal. There are specially designed subgingival tips that can be utilized safely and effectively for daily cleansing and biofilm disruption. As with natural teeth, interproximal and circumferential cleaning of implants is recommended on a daily basis (Figure 47.16) (Hydro Floss, Inc.).

Brushing

Twice-daily brushing is recommended to remove oral debris and bacterial plaque accumulations. Implant self-care should be accomplished using a soft traditional toothbrush (Nimbus Microfine (Nimbus Dental) GUM Deep Clean), or a very gentle power brush, as previously discussed. While many traditional and mechanical brushes are available for over-the-counter purchase, the professionally dispensed Rotadent (DenMat) with its patented microfilaments is perhaps the gentlest and most effective tool for daily cleaning around implant-supported esthetic restorations. Its dense brush head does a superior job removing bacterial plaque, while the action is gentle to soft tissue and nonabrasive to the abutment (Figure 47.17).

Bacterial monitoring

One of the newest tools available for monitoring implant health involves the science of salivary diagnostics. From a patient's saliva sample, an analysis can be obtained that provides a detailed report of a patient's existing bacterial profile. Recognizing the role of bacteria in peri-implant mucositis as well as peri-implantitis, the dental team and patient can use the bacterial report to monitor bacterial risk and identify bacterial infections prior to the development of any clinical signs and symptoms.

Intraoral camera

Patients need to be able to recognize healthy peri-implant tissue. An intraoral camera can be a very helpful teaching tool. A common problem associated with implants is a piece of food

Figure 47.16 **(A)** Water irrigation, such as a Hydro Floss, can be an effective part of oral care for many patients. **(B)** Hydro Floss in use. (Hydro Floss, Inc.)

Figure 47.17 Hands-on demonstration with a hand mirror is essential in order for a patient to understand that a brush must be carefully placed to accomplish effective plaque removal.

or shred of floss lodged in the peri-implant space. Patients tend to be less aware when this occurs than when a similar object lodges under the soft-tissue around a natural tooth. Careful soft tissue observation by implant recipients should be a part of their daily oral care. They should immediately report to their dentist or hygienist any tissue irregularities, including tenderness, redness, swelling, or other symptoms around the implant. Early preventive steps can be taken to avoid a severe infection, and this can make the difference between the implant's long-term success and failure.

Conclusion

According to a 2010 study in the *Journal of the American Dental Association*, the placement of dental implants is increasing while other dental procedures are in decline.[40] Patients reportedly are seeking dental implants in record numbers. The global dental implants market is expected to be USD 6.81 billion by 2024, based on a 2016 report by Grand View Research, Inc.[41] As implants continue to become a desirable and routine choice for esthetic restorative dentistry, dental professionals increasingly will be caring for implant-supported esthetic restorations. Patients presenting for implant therapy should be counseled in self-care requirements prior to placement and continually as part of ongoing maintenance. The critical role of hygiene care for implant-supported restorations can directly affect the implant's lifespan. As with other esthetic restorative dentistry, the combined efforts of the well-trained dental professional and well-educated patient can maximize the beauty and lifespan of esthetic implant-supported teeth.

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