The ideal goal of modern dentistry is to restore the patient to normal contour, function, comfort, esthetics, speech, and health. A dentist provides this restoration for a living, whether removing caries from a tooth or replacing several teeth. What makes implant dentistry unique is the ability to achieve this ideal goal regardless of the atrophy, disease, or injury of the stomatognathic system. However, the more teeth a patient is missing, the more challenging this task becomes. As a result of continued research, diagnostic tools, treatment planning, implant designs, materials, and techniques, predictable success is now a reality for the rehabilitation of many challenging clinical situations.

The number of dental implants used in the United States increased more than tenfold from 1983 to 2002. More than 700,000 dental implants are inserted each year. The number of implants continues to increase steadily, with more than $150 million of implant products sold to North American dentists in 2002 compared with $10 million in 1983, with an expected growth sustained at 9.4% for the next several years. More than 90% of interfacing surgical specialty dentists currently provide dental implant treatment routinely in their practices, 90% of prosthodontists restore implants routinely, and more than 78% of general dentists have used implants to support fixed and removable prostheses compared with 65% 15 years ago.

The increased need and use of implant-related treatments result from the combined effect of a number of factors, including the following:

1. An aging population living longer
2. Tooth loss related to age
3. Consequences of fixed prosthesis failure
4. Anatomical consequences of edentulism
5. Poor performance of removable prostheses
6. Consequences of removable partial dentures
7. Psychological aspects of tooth loss and needs of aging baby boomers
8. Predictable long-term results of implant-supported prostheses
9. Advantages of implant-supported prostheses

EFFECT OF AN AGING POPULATION

According to the literature, age is related directly to every indicator of tooth loss. Therefore the aging population is an important factor to consider in implant dentistry. When Alexander the Great conquered the world, he was only 17 years old; however, life span at that time was only 22 years of age. Since 1910, life expectancy has increased more rapidly than in any other time in history. In 1980, 30% of the U.S. population was older than 45 years, 21% was older than 50, and 11% was older than 65. In 1995, 15 years later, these individuals were more than 60 years of age. The over-65 age group is projected to increase to more than 20% of the population within the next 50 years (Fig. 1-1). Life expectancy has increased significantly past the age of retirement; in 1965 the average life span was 65 years; in 1990 it was 78 years. Life expectancy in 2001 was 85 years for a nonsmoking individual of normal weight. A 65-year-old person now can expect to live more than 20 years; a person 80 years old can expect to live 91/2 more years (Fig. 1-2). One person from a 65-year-old couple has a 50% chance of living to 92 years of age and a 25% chance of living to 97 years of age. Women represent two thirds of the population over the age of 65 years. A healthy 65-year-old woman has a 50% chance to live to 88 years old and a 25% chance to live to 94 years old. For a 70-year-old patient to ask “Is it worth it for me to spend $30,000 to repair my mouth at my age?” is not unusual. The response should be positive because the life expectancy of such a person will be more than 2 decades, and the person’s current oral situation normally will worsen if not corrected at this time.

Social pleasures, including dining and dating, continue throughout advanced life. In the past, geriatric dentistry meant inexpensive treatment emphasizing nonsurgical approaches. Yet the poverty rate for the elderly is less than 10%, and retiree median income has grown 8% in recent years. According to the last census, the median net worth of retirees is 15 times the net worth of those younger than 35 years and 3 times as high as “working families” 35 to 44 years of age. Almost 20% of today’s retirees have a net worth more than a quarter of a million dollars. Today the full scope of dental services for elderly patients is increasing in importance to the public and the profession because of the increasing age of society. Treatment alternatives involving fixed prostheses with implant support should be presented to almost any patient. Only after discussion of all treatment options can the dentist truly appreciate a person’s desires related to the benefit of implant dentistry.
AGE-RELATED TOOTH LOSS

Dental services for elderly patients clearly represent a growing demand for the dental profession. In 2000, 28.8% of all income from a dentist came from patients 60 years and older, which represented only 12% of dentists’ income in 1988. When the dentist is more than 40 years old, income from those patients represents 64.3% of the dentist’s income, whereas in 1988 it was 30.3%. Clearly, the demographics of the population have changed the economics of dental practice dramatically.

The posterior regions of the mouth often require the replacement of a single tooth. The first molars are the first permanent teeth to erupt in the mouth and unfortunately are often the first teeth lost as a result of decay, failed endodontic therapy, or fracture (usually after endodontics). They are important teeth for maintenance of the arch form and proper occlusal schemes. In addition, the adult patient often has one or more crowns as a consequence of previous larger restorations required to repair the integrity of the tooth. Longevity reports of crowns have yielded disparate results. The mean life span at failure has been reported to be 10.3 years. Other reports range from a 3% failure rate at 23 years to a 20% failure rate at 3 years. The primary cause of failure of the crown is caries followed by endodontic therapy. The tooth is at risk for extraction as a result of these complications, which are a leading cause of single posterior tooth loss in the adult. One estimate is that a $425 crown for a 22-year-old patient will cost $12,000 during the patient’s lifetime to replace or repair this device.

SINGLE-TOOTH EDENTULISM

The most common treatment of choice for replacement of a posterior single tooth is a three-unit fixed partial denture. This type of restoration can be fabricated within 1 to 2 weeks and satisfies the criteria of normal contour, comfort, function, esthetics, speech, and health. Because of these benefits, a fixed partial denture has been the treatment of choice for the last 6 decades. The bone and soft tissue considerations in the missing tooth site are few. Every dentist is familiar with the procedure, which is accepted widely by the profession, patients, and dental insurance companies.

In the U.S. population, 70% of persons are missing at least one tooth. Almost 30% of the 50- to 59-year-olds examined in a U.S. national survey exhibited single or multiple edentulous spaces bordered by natural teeth. In 1990 in the United States, more than 4 million fixed partial dentures were placed. Treatments to replace single teeth with a fixed prosthesis represent 7% of the annual dental reimbursement from insurance companies and more than $3 billion each year. Only one third of the population in the United States has dental insurance, and many patients who do not have insurance are reimbursed only 50% of treatment costs. Hence the entire three- to four-unit fixed partial denture costs in the United States may approach more than $10 billion each year.

A three-unit fixed partial denture also presents survival limitations to the restoration and, more important, to the abutment teeth. In an evaluation of 42 reports since 1970, Creugers, Kayser, and Van’t Hof calculated a 74% survival rate for fixed partial dentures for 15 years.
Walton, Gardner, and Agar28 and Schwartz, Whitsett, and Berry21 have reported mean life spans of 9.6 and 10.3 years, respectively. However, reports are inconsistent, with as little as 3% loss over 23 years to 20% loss over 3 years.18,20–29 Caries and endodontic failure of the abutment teeth are the most common causes of prosthesis failure.28 Up to 15% of abutment teeth for a fixed partial denture require endodontic therapy, compared with 3% of non-abutment teeth that have crown preparations. The long-term periodontal health of the abutment teeth also may be at greater risk, including bone loss.26

Unfavorable outcomes of fixed partial denture failure include not only the need to replace the failed prosthesis but also the loss of an abutment and the need for additional pontics and abutment teeth in the replacement bridge. The abutment teeth of a fixed partial denture may be lost at rates as high as 30% within 14 years.27 Eight percent to 12% of the abutment teeth holding a fixed partial denture are lost within 10 years. The most common reason for single-tooth loss is endodontic failure or fracture of the teeth (usually after endodontic therapy). Because 15% of abutment teeth require endodontics and root canal therapy is 90% successful at the 8-year mark, many abutment teeth are lost. In addition, the abutment teeth are more prone to caries when splinted together with a pontic. The carious lesion at the crown margin may render the tooth a structural failure, even if endodontic treatment is possible.

Almost 80% of abutments prepared for a three-unit fixed partial denture have no restoration or are restored minimally. Rather than removing sound tooth structure and crowning two or more teeth, increasing the risk of decay, endodontic therapy, and splinting together of teeth with pontics, which have the potential to decrease oral hygiene ability and increase plaque retention, a dentist may replace the single tooth with a dental implant (Box 1-1).

### SINGLE-TOOTH IMPLANTS

A treatment option to replace a posterior single missing tooth is a single-tooth implant. For years, patients were advised to place their desires aside and accept the limitations of a fixed partial denture. However, many dentists feel the most natural method to replace a tooth is to use an implant, rather than preparing adjacent teeth and joining them together with a prosthesis. The primary reasons for suggesting the fixed partial denture were its clinical ease and reduced treatment time. However, if this concept were expanded, extractions would replace endodontics and dentures even could replace orthodontics. The primary reason to suggest or perform a treatment should not be related just to treatment time or difficulty of performing the procedure but instead to the best possible long-term solution for each individual.

Since 1993, single-tooth implant survival has demonstrated that this procedure is the most predictable method of tooth replacement. More refereed reports for single-tooth implant replacement occur in the literature than for any other method of tooth replacement. All reports demonstrate a higher survival rate for single-tooth implants than for any other method of tooth replacement. For example, in 1993, Schmitt and Zarb31 reported no failures for 40 implants placed in 32 patients (28 in the maxilla, 12 in the mandible, with 27 in the anterior region and 13 in the posterior). After up to 6.6 years, all implants were functional. In 1994, Ekfeldt, Carlsson, and Borgeson32 reported a 4- to 7-year retrospective study of 77 patients who received 93 implants. Two implants were lost, both within the first year of function (2% failure rate, one each anterior and posterior). In 1995, Haas et al.33 also reported on 76 single-tooth implants. Their evaluations extended for 6 years, and they observed a 2.6% implant loss.

A series of reports in 1991, 1994, and 1996 by Laney and colleagues reported on a multicenter prospective study consisting of 92 patients who received 107 implants with a cumulative survival rate of 97.2% at 3 and 5 years.34–36 Plaque and gingival indexes were indicative of soft tissue health. In 1996, Malevez et al.37 also presented a retrospective study of 75 patients treated with 84 endosteal screw-type implants (71% of the implants were in the anterior region). This study found a cumulative failure rate of only 2.4% at 5 years. In 1997, Gomez-Roman et al.38 published a 5-year report on 696 endosteal implants in 376 patients. Almost 300 of these were single-tooth implants with a 96% overall survival.

A multicenter prospective clinical study initiated with the Maestro Dental Implant System from BioHorizons in 1996 was reported in 2002.39 The posterior regions of the jaws received a total of 38 single-tooth implants: 15 in the maxilla and 23 in the mandible. The implant survival rate was 100% over 5 years. Another report by Misch et al.40 yielded 100% success for single-tooth implants in the posterior maxilla. Therefore although posterior single-tooth replacement is a relatively new treatment alternative to dentistry, many studies have been published since 1990 with reported survival rates ranging from a low of 94.6% to a high of 100% for 1 to 10 years. The median of these reports is 2.8% implant loss with a mode of 5 years. In comparison a fixed partial denture failure rate may be as high as 20% within 3 years, and 50% survival at 10 years is expected. As a result, the single-tooth implant exhibits the highest survival rates presented for single-tooth replacement. As important, no reports indicate a loss of an adjacent tooth, which is a considerable advantage. The longevity of the implant crown has not been determined adequately, however, because these reports do not extend as long as those of other treatment options.
Despite some limitations and obvious clinical challenges, the single-tooth implant represents the treatment of choice. When adjacent teeth are healthy or when the patient refuses the preparation for the fabrication of a traditional three-unit fixed partial restoration, a posterior single-tooth implant is an excellent solution. Other advantages of this modality over a fixed partial restoration include the decreased risk of caries on the abutment teeth, a decrease in risk of endodontics of abutment teeth, the improved ability to clean the proximal surfaces of the adjacent teeth (which decreases the risk of decay and periodontal disease), a decrease in risk of cold or contact sensitivity with a brush or scaler on the abutment teeth, improved esthetics of the adjacent teeth, the maintenance of bone in the edentulous site, the psychological advantage (especially with congenitally missing teeth or the loss of a tooth after a crown restoration), and the decreased risk of abutment tooth loss from endodontic failure or caries. These advantages are so significant to the health and periodontal condition of the adjacent teeth and maintenance of the arch form that the single-tooth implant has become the treatment of choice in most situations (Box 1-2).

### TOTAL EDENTULISM

The present elderly population is benefiting from today’s advanced knowledge and restorative techniques. In the National Institute of Dental Research national surveys the occurrence of total edentulism in a single arch, 35 times more frequent in the maxilla, was slight in the 30- to 34-year-old age group but increased at age 45 years to 11% and then began to remain constant after 55 years at about 15% of the adult population. A total of 12 million persons in the United States have edentulism in one arch, representing 7% of the adult population.

Total edentulism occurs in 10.5% of the adult population or almost 18 million persons. Total edentulism has been noted in 5% of employed adults 40 to 44 years old and gradually increases to 26% at 65 and almost 44% in seniors more than 75 years old. As expected, older persons are more likely to be missing all of their teeth. Gender was not associated with tooth retention or tooth loss once adjustments were made for age (Fig. 1-3).

The percentages of one- or two-arch edentulism translate into more than 30 million persons or about 17% of the entire U.S. adult population. To place these numbers in perspective, 30 million persons represent approximately the entire U.S. black population or the whole population of Canada. This number represents 48 million arches. Hence complete edentulism remains a significant concern, and the affected patients often require implant dentistry to solve several related problems. If four implants were used to help support each complete edentulous arch, a total of 192 million implants would be required, yet only 700,000 implants are inserted each year.

### PARTIAL EDENTULISM

The prevalence of partial edentulism is also of interest because the number of implants often used in these patients is growing. The 1988-1991 survey found that only 30% of these patients had all 28 teeth. Partially dentate patients had an average of 23.5 teeth. In the 1987 report of employed adults ages 18 to 34, the average number of missing teeth was fewer than two of 28 teeth. However, this number rapidly increases to an average of 10 teeth missing in adults 55 to 64 years old. Partially edentulous seniors older than 65 years have lost an average of 17.9 teeth, with older seniors having lost three more teeth than the younger seniors. Statistics for partial edentulism are similar for men and women. The greatest transition from an intact dental arch to a partially edentulous condition occurred in the 35- to 54-year-old group. The growth rate for this baby boomer portion of the population is approximately 30%, greater than any other age group. Therefore the need for implant services will increase dramatically during the next several decades.

The most common missing teeth are molars. Partial free-end edentulism is of particular concern because in these patients, teeth often are replaced with removable partial prostheses. This condition rarely is found in persons younger than 25 years. Mandibular free-end edentulism is
greater than its maxillary counterpart in all age groups. Unilateral free-end edentulism is more common than bilateral edentulism in maxillary and mandibular arches in the younger age groups (25 to 44 years). About 13.5 million persons in these younger age groups have free-end edentulism in either arch.

In 45- to 54-year-old patients 31.3% have mandibular free-end edentulism and 13.6% have free-end edentulism in the maxillary arch. About 9.9 million persons in the 45- to 54-year-old group have at least one free-end edentulous quadrant, and almost half of these have bilateral partial edentulism.10 The pattern of posterior edentulism evolves in the 55- to 64-year-old group in which 35% of mandibular arches show free-end edentulism compared with 18% of maxillary arches. As a result, about 11 million persons in this age group are potential candidates for implants. An additional 10 million persons show partial free-end edentulism at age 65 or older (Fig. 1-4). Additional studies documented that in the population of noninstitutionalized U.S. civilians, one out of five had a removable prosthesis of some type.41-43 The total number of potential patients in the U.S. survey with at least one quadrant of posterior missing teeth is more than 44 million persons.10 If each of these arches requires three implants to support a fixed prosthesis, 132 million implants added to the 192 million for edentulous patients would be required.

When the partially edentulous figures are added to the previous edentulous percentages, almost 30% of the adults in the United States are candidates for a complete or partial removable prosthesis. The need for additional retention, support, and stability or the desire to eliminate a removable prosthesis are common indications for dental implants. As a result, 74 million adults and 90 million arches are potential candidates for dental implants. Because a minimum of five appointments is required to implant and restore a patient, every U.S. dentist would need 20 appointments every month for 20 years to treat the present posterior partial and complete edentulous population with implant-supported prostheses. The population evolution to an increased average age, combined with the existing population of partially and completely edentulous patients, guarantees the future of implant dentistry for several generations of dentists.

### ANATOMICAL CONSEQUENCES OF EDENTULISM

#### Consequences on the Bony Structures

Basal bone forms the dental skeletal structure, contains most of the muscle attachments, and begins to form in the fetus before teeth develop. Alveolar bone first appears when Hertwig’s root sheath of the tooth bud evolves (Fig. 1-5).44 The alveolar bone does not form in the absence of primary or secondary tooth development. The close relationship between the tooth and the alveolar process continues throughout life. Wolff’s law states that bone remolds in relationship to the forces applied.45 Every time the function of bone is modified, a definite change occurs in the internal architecture and external configuration.46 Bone needs stimulation to maintain its form and density. Roberts et al.47 report that a 4% strain to the skeletal system maintains bone and helps balance the resorption and formation phenomena. Teeth transmit compressive and tensile forces to the surrounding bone. These forces have been measured as a piezoelectric effect in the imperfect crystals of durapatite that compose the inorganic portion of bone.48 When a tooth is lost, the lack of stimulation to the residual bone causes a decrease in trabeculae and bone density in the area, with loss in external width and then height of the bone volume.49 The width of bone decreases by 25% during the first year after tooth loss and an overall 4 mm in height during this first year following extractions for an immediate denture.50 In a longitudinal, 25-year study of edentulous patients, lateral cephalograms demonstrated continued bone loss during this time span; a fourfold greater loss was
observed in the mandible (Figs. 1-6 and 1-7). However, because the mandible begins with twice the bone height of the maxilla, maxillary bone loss is also significant in the long-term edentulous patient.

A tooth is necessary for the development of alveolar bone, and stimulation of this bone is required to maintain its density and volume. A removable denture (complete or partial) does not stimulate and maintain bone; it accelerates the bone loss. The load from mastication is transferred to the bone surface only, not the whole bone. As a result, blood supply is reduced, and total bone volume loss occurs. This issue, of utmost importance, has been observed but not addressed in the past by traditional dentistry. Doctors most often overlook the insidious bone loss that occurs after tooth extraction. The patient often is not educated about the anatomical changes and the potential consequences of continued bone loss. The bone loss further accelerates when the patient wears a poorly fitting soft tissue-borne prosthesis. Yet patients do not understand that bone is lost over time and at a greater rate under poorly fitting dentures. Patients do not return for regular visits for evaluation of their condition, but only after several years when denture teeth are worn down or can no longer be tolerated.

Hence the traditional method of tooth replacement often affects bone loss in a manner not sufficiently considered by the doctor and the patient.

Preventive dentistry traditionally has emphasized methods to decrease tooth loss. No predictable therapy was accepted by the profession to avoid the bone changes resulting from tooth loss. Today the profession must consider not only the loss of teeth but also the loss of bone. The loss of teeth causes remodeling and resorption of the surrounding alveolar bone and eventually leads to atrophic edentulous ridges. Although the patient is often not aware of or informed of the potential consequences, over time consequences will occur. The rate and amount of bone loss may be influenced by sex, hormones, metabolism, parafunction, and ill-fitting dentures. Yet almost 40% of denture wearers have been wearing an ill-fitting prosthesis for more than 10 years. Patients wearing dentures day and night place greater forces on the hard and soft tissues, which accelerate bone loss. Yet 80% of dentures are worn day and night.

Atrophic edentulous ridges are associated with anatomical problems that often impair the predictable results of traditional dental therapy. Box 1-3 lists several of these anatomical problems. The loss of bone first causes decreased bone width. The remaining narrow residual ridge often causes discomfort when the thin overlying tissues are loaded under a soft tissue-borne removable prosthesis. The continued atrophy of the posterior mandible eventually causes prominent mylohyoid and internal oblique ridges covered by thin, movable, unattached mucosa. The anterior residual

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**Figure 1-6** After the initial loss of teeth the average first-year bone loss is more than 4 mm in height and 30% in width.

**Figure 1-7** Although the rate is slower, bone loss from tooth extraction continues throughout life.

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**BOX 1-3**

**Consequences of Bone Loss in Fully Edentulous Patients**

- Decreased width of supporting bone
- Decreased height of supporting bone
- Prominent mylohyoid and internal oblique ridges with increased sore spots
- Progressive decrease in keratinized mucosa surface
- Prominent superior genial tubercles, sore spots, and increased denture movement
- Muscle attachment near crest of ridge
- Elevation of prosthesis with contraction of mylohyoid and buccinator muscles serving as posterior support
- Forward movement of prosthesis from anatomical inclination (angulation of mandible with moderate to advanced bone loss)
- Thinning of mucosa, with sensitivity to abrasion
- Loss of basal bone
- Paresthesia from dehiscent mandibular neurovascular canal
- More active role of tongue in mastication
- Effect of bone loss on esthetic appearance of lower one third of face
- Increased risk of mandibular body fracture from advanced bone loss
- Increased denture movement and sore spots during function caused by loss of anterior ridge and nasal spine
Bone loss in the jaws does not stop with the original alveolar process but continues to include the basal bone. This bone loss is more dramatic than any osteoporotic bone loss observed in the hip or any other part of the skeleton.

Loss of bone in the maxilla or mandible is not limited to alveolar bone; portions of the basal bone may be resorbed also (Figs. 1-8 to 1-10), especially in the posterior aspect of the mandible where severe resorption may result in more than 80% bone loss. The contents of the mandibular canal and mental foramen eventually become dehiscent and serve as part of the support area of the prosthesis. As a result, acute pain and transient to permanent paresthesia of the areas supplied by the mandibular nerve are possible. The body of the mandible is also at increased risk of

**Figure 1-8** Bone loss in the jaws does not stop with the original alveolar process but continues to include the basal bone. This bone loss is more dramatic than any osteoporotic bone loss observed in the hip or any other part of the skeleton.

**Figure 1-9** Atwood described six different stages of resorption in the anterior mandible. Stage I represents the tooth and surrounding alveolar process and basal bone. Stages II and III illustrate the initial residual ridge after tooth loss. Stages IV to VI primarily describe a continuous loss of anterior residual bone in height.

**Figure 1-10** A, Lateral cephalogram of a patient demonstrates the restored vertical dimension of occlusion with a denture. However, because of the advanced basal bone loss in the mandible, the superior genial tubercles are twice the height of the residual anterior ridge. The body of the mandible is only a few millimeters thick, and the mandibular canal has been completely dehiscent for many years (one body is superimposed on top of the other in this view). In the maxillary anterior ridge, only the nasal spine remains (not the original alveolar ridge), and the posterior maxillary bone is paper thin because of basal bone loss at the crest and the pneumatization of the maxillary sinus. B, A denture may restore the vertical dimension of the face, but the bone loss of the jaws can continue until the basal bone is paper thin in the maxilla and the mandible becomes the size of a toothpick. (This is a different patient from the one in A.)
fracture, even under low-impact forces (Fig. 1-11). The mandibular fracture causes the jaw to shift to one side and makes stabilization and an esthetic result most difficult.

The complete anterior ridge and even the nasal spine may be resorbed in the maxilla, causing pain and an increase in maxillary denture movement during function\(^{53}\) (Fig. 1-12). Masticatory forces generated by short facial types (brachiocephalics) can be 3 or 4 times that of long facial types (dolichocephalics). The short facial type of patients are at increased risk to develop severe atrophy (Box 1-3).\(^{57,58}\)

Many of these similar conditions exist in the partially edentulous patient wearing a removable soft tissue-borne prosthesis. In addition, the natural abutment teeth, on which direct and indirect retainers are designed, must submit to additional lateral forces. Because these teeth often are compromised by deficient periodontal support, many partial dentures are designed to minimize the forces applied to them. The net result is an increase in mobility of the removable prosthesis and greater soft tissue support. These conditions protect the remaining teeth but accelerate the bone loss in the edentulous regions (Figs. 1-13 and 1-14).\(^{59}\)
Soft Tissue Consequences

As bone loses width, then height, then width, and then height again, the attached gingiva gradually decreases. A thin attached tissue usually lies over the advanced atrophic mandible or is absent entirely. The gingiva is prone to abrasions caused by the overlying prosthesis. In addition, unfavorable high muscle attachments and hypermobile tissue often complicate the situation. The thickness of the mucosa on the atrophic ridge also is related to the presence of systemic disease and physiologic changes accompanying aging. Conditions such as hypertension, diabetes, anemia, and nutritional disorders have a deleterious effect on the vascular supply and soft tissue quality under removable prostheses. These disorders result in a decreased oxygen tension to the basal cells of the epithelium. Surface cell loss occurs at the same rate, but the cell formation at the basal layer is slowed. As a result, thickness of the surface tissues gradually decreases. Therefore sore spots and uncomfortable removable prostheses result (Fig. 1-15).

The tongue of the patient with edentulous ridges often enlarges to accommodate the increase in space formerly occupied by teeth. At the same time, the tongue is used to limit the movements of the removable prostheses and takes a more active role in the mastication process. As a result, the removable prosthesis decreases in stability. The decrease
in neuromuscular control, often associated with aging, further compounds the problems of traditional removable prosthodontics. The ability to wear a denture successfully may be largely a learned, skilled performance. The aged patient who recently became edentulous may lack the motor skills needed to accommodate to the new conditions (Box 1-4).

**Esthetic Consequences**

The facial changes that naturally occur in relation to the aging process can be accelerated and potentiated by the loss of teeth. Several esthetic consequences result from the loss of alveolar bone (Figs. 1-16 and 1-17). A decrease in facial height from a collapsed vertical dimension causes several facial changes. The loss of labiomental angle and deepening of vertical lines in the area create a harsher appearance. As the vertical dimension progressively decreases, the occlusion evolves toward a pseudo-Class III malocclusion. As a result, the chin rotates forward and creates a prognathic facial appearance (Fig. 1-18). These conditions result in a decrease in the horizontal labial angle at the corner of the lips; the patient appears unhappy when the mouth is at rest. Short facial types suffer higher bite forces, greater bone loss, and more dramatic facial changes with edentulism compared with others.

A thinning of the vermillion border of the lips results from the poor lip support provided by the prosthesis and the loss of muscle tone; the retruded position of the border is related to the loss of premaxilla ridge and the loss of tonicity of the muscles involved in facial expression. Women often use one of two techniques to hide this cosmetically undesirable appearance: no lipstick and minimum makeup to bring as little attention as possible to this area of the face or lipstick drawn on the skin over the vermillion border to give the appearance of fuller lips. A deepening of the nasolabial groove and an increase in the depth of other vertical lines in the upper lip are related to normal aging but are accelerated with bone loss. An increase in the columella-philtrum angle usually accompanies these changes, which can make the nose appear larger than if the lip had more support. Men often grow a moustache to minimize this effect. The maxillary lip naturally becomes longer with age as a result of gravity and loss of muscle tone, resulting in less anterior teeth shown when the lip is at rest. This change has a tendency to "age" the smile, because the younger the patient, the more the teeth show in relation to the upper lip at rest or when smiling. The loss of muscle tone is accelerated in the edentulous patient, hence the lengthening of the lip occurs at a younger age.

The attachments of the mentalis and buccinator muscles to the body and symphysis of the mandible also are affected
Rationale for Dental Implants

The tissue sags, producing “jowls” or a “witch’s chin.” This effect is cumulative because of the loss in muscle tone with the loss of teeth, the associated decrease in bite force, and the loss of bone in the regions where the muscles formerly attached (Fig. 1-19).

Patients are unaware that these hard and soft tissue changes are from the loss of teeth. Regarding denture wearers, 39% have been wearing the same prosthesis for more than 10 years. Dentists are unable to evaluate patients unless they return for regular yearly visits. Therefore the dentist must explain the consequences of tooth loss to the partially or completely edentulous patient in the early phases of treatment (Box 1-5).

**DECREASED PERFORMANCE OF REMOVABLE PROSTHESSES**

The difference in maximum occlusal forces recorded in a person with natural teeth and one who is completely edentulous is dramatic. In the first molar region of a dentate person, the average force has been measured at 150 to 250 psi. A patient who grinds or clenches the teeth may exert a force that approaches 1000 psi. The maximum occlusal force in the edentulous patient is reduced to less than 50 psi. The longer patients are edentulous, the less force they are able to generate. Patients wearing complete dentures for more than 15 years may have a maximum occlusal force of 5.6 psi.

As a result of decreased occlusal force and the instability of the denture, masticatory efficiency also decreases with tooth loss. Within the same time frame, 90% of the food chewed with natural teeth fits through a No. 12 sieve; the percentage is 58% in the patient wearing complete dentures. The tenfold decrease in force and the 40% decrease in efficiency affect the patient’s ability to chew. In persons with dentures, 29% are able to eat only soft or mashed foods, and 50% avoid many foods; 17% claim they eat more efficiently without the prosthesis. A study of 367 denture wearers (158 men and 209 women) found that 47% exhibited a low masticatory performance. Lower intakes of fruits, vegetables, and vitamin A by women were noted in this group. These patients took significantly more drugs...
(37%) compared with those with superior masticatory ability (20%); 28% were taking medications for gastrointestinal disorders.

The reduced consumption of high-fiber foods therefore could induce gastrointestinal problems in edentulous patients with deficient masticatory performance. In addition, the coarser bolus may impair proper digestive and nutrient extraction functions.65-67 The literature provides several reports suggesting that a compromised dental function causes poor swallowing and mastication performance, which in turn may favor systemic changes favoring illness, debilitation, and shortened life expectancy (Box 1-6).68,69

Several reports in the literature correlate patients' health and life spans with their dental health.70-73 After conventional risk factors for strokes and heart attacks were accounted for, a significant relationship was found between dental disease and cardiovascular disease, the latter still being the major cause of death.65,67,72,74 One may assume logically that restoring the stomatognathic system of these patients to a more normal function may indeed enhance the quality and length of their lives.75-78

### CONSEQUENCES OF REMOVABLE PARTIAL DENTURES

Removable soft tissue-borne partial dentures have one of the lowest patient acceptance rates in dentistry. One half the number of persons with a removable partial denture chew better without the device. A Scandinavian 4-year study revealed that only 80% of patients were wearing such prostheses after 1 year. The number further decreased to only 60% of the free-end partial dentures worn by the patients after 4 years.79,80

A 5-year survival rate of partial dentures based on tolerance and use of the prostheses was about 60% for distal extension prostheses and 80% for tooth-borne prostheses.81-83 The survival rates were reduced to 35% and 60% at 10 years, respectively. In another study, few partial dentures survived more than 6 years.84 Although one of five U.S. adults has had a removable prosthesis of some type, 60% reported at least one problem with the prosthesis.85 Reports of removable partial dentures indicate that the health of the remaining dentition and surrounding oral tissues often deteriorates (Box 1-7).70,79,85

In a study that evaluated the need for repair of an abutment tooth as the indicator of failure, the survival rate of conventional removable partial dentures was 40% at 5 years and 20% at 10 years.81 Those patients wearing the partial dentures often exhibit greater mobility of the abutment teeth, greater plaque retention, increased bleeding on probing, more incidence of caries, and accelerated bone loss in the edentulous regions.82 Aquilino et al.86 reported a 44% abutment tooth loss within 10 years in patients wearing a removable partial denture. In addition, those patients wearing the device have accelerated bone loss in the soft tissue support regions. Therefore alternative therapies that improve oral conditions and maintain bone often are warranted.

#### PSYCHOLOGICAL ASPECTS OF TOOTH LOSS

The psychological effects of total edentulism are complex and varied and range from minimal to a state of neuroticism. Although complete dentures are able to satisfy the esthetic needs of many patients, some patients feel their social life is affected significantly. They are concerned with kissing and romantic situations, especially if a new friend is unaware of their oral handicap. Past dental health surveys indicate that only 80% of the edentulous population is able to wear both removable prostheses all of the time.19,20 Some patients wear only one prosthesis, usually the maxillary; others are able to wear their dentures for short periods only. In addition, approximately 7% of patients are not able to wear their dentures at all and become dental cripples or “oral invalids.” They rarely leave their home environment, and when they feel forced to venture out, the thought of meeting and talking to persons when not wearing their teeth is unsettling.

Misch and Misch64 reported on 104 completely edentulous patients seeking treatment. Of the patients studied, 88% claimed difficulty with speech, with one fourth having difficult problems. As a consequence, the reported increase can be correlated easily with concern relative to social activities. Awareness of movement of the mandibular denture was listed by 62.5% of these patients, although the maxillary prosthesis stayed in place most of the time at almost the same percentage. Mandibular discomfort was listed with equal frequency as movement and was 63.5%; surprisingly 16.5% of the patients stated they never wear the denture. In comparison, the maxillary denture was uncomfortable half as often (32%), and only 0.9% of persons were seldom able to wear the denture. Function was the fourth most common problem reported. Half of the patients avoided many foods,
 Psychological Effects of Tooth Loss

- Psychological effects range from minimal to neuroticism.
- Tooth loss affects romantic situations (especially in new relationship).
- “Oral invalids” are unable to wear dentures.
- Eighty-eight percent of patients claim some difficulty with speech, and 25% have significant problems.
- Patients spend more than $200 million each year on denture adhesive to decrease embarrassment.

ADVANTAGES OF IMPLANT-SUPPORTED PROSTHESSES

The use of dental implants to provide support for prostheses offers a multitude of advantages compared with the use of removable soft tissue–borne restorations. A primary reason to consider dental implants to replace missing teeth is the maintenance of alveolar bone. The dental implant placed into the bone serves not only as an anchor for the prosthetic device but also as one of the better preventive maintenance procedures in dentistry. Stress and strain may be applied to the bone surrounding the implant. As a result, the decrease in trabeculation of bone that occurs after tooth extraction is reversed. Bone trabeculae and density increase when the dental implant is inserted and functioning. The overall volume of bone also is maintained with a dental implant. Hence even grafts of iliac bone to the jaws, which usually resorb within 5 years, are instead stimulated and maintain overall volume and integration to support the implant. An endosteal implant can maintain bone width and height as long as the implant remains healthy. As with a tooth, periimplant bone loss may be measured in tenths of a millimeter and may represent more than a twentyfold decrease in lost structure compared with the resorption that occurs with removable prostheses.

A mandibular denture often moves when the mylohyoid and buccinator muscles contract during speech or mastication. The teeth often are positioned for denture stability rather than where natural teeth usually reside. With implants, the teeth may be positioned to enhance esthetics and phonetics rather than in the neutral zones dictated by traditional denture techniques to improve the stability of a prosthesis.

The features of the inferior third of the face are related closely to the supporting skeleton. When vertical bone is lost, the dentures only act as “oral wigs” to improve the contours of the face. The dentures become bulkier as the bone resorbs, making it more difficult to control function, stability, and retention. With implant-supported prostheses the vertical dimension may be restored, similar to that with natural teeth. In addition, the implant-supported prosthesis allows a cantilever of anterior teeth for ideal soft tissue and lip contour and improved appearance in all facial planes. This happens without the instability that usually occurs when an anterior cantilever is incorporated in a traditional denture. The facial profile may be enhanced for the long term with implants rather than deteriorating over the years, as can occur with traditional dentures.

Occlusion is difficult to establish and stabilize with a completely soft tissue–supported prosthesis. Because the mandibular prosthesis may move as much as 10 mm or more during function, proper occlusal contacts occur by chance, not by design. But an implant-supported restoration is stable. The patient can return more consistently to centric-relation occlusion rather than adopt variable positions dictated by the instability of the prosthesis. Proprioception is awareness of a structure in time and place. The receptors in the periodontal membrane of the natural tooth help determine its occlusal position. Although endosteal implants do not have a periodontal membrane, they provide greater occlusal awareness than complete dentures. Although patients with natural teeth can perceive a difference of 20 mm between the teeth, implant patients can determine 50-mm differences with rigid implant bridges compared with 100 mm in those with complete dentures (either one or two).

As a result of improved occlusal awareness the patient functions in a more consistent range of occlusion. With an implant-supported prosthesis, the restoring dentist controls the direction of the occlusal loads. Horizontal forces on removable prostheses accelerate bone loss, decrease prosthesis stability, and increase soft tissue abrasions. Therefore the decrease in horizontal forces applied to implant restorations improves the local parameters and helps preserve the underlying soft and hard tissues.

The success rate of implant prostheses varies, depending on a host of factors that change for each patient. However, compared with traditional methods of tooth replacement, the implant prosthesis offers increased longevity, improved function, bone preservation, and better psychological results. According to 10-year survival surveys of fixed prostheses on natural teeth, decay is indicated as the most frequent reason for replacement; survival rates are about 75%.
In the partially edentulous patient, independent tooth replacement with implants may preserve intact adjacent natural teeth as abutments, further limiting complications such as decay or porcelain fracture and poorer esthetics, which are the most common causes of fixed prosthesis failure.\textsuperscript{28} A major advantage of the implant-supported prosthesis is that the abutments cannot decay. The implant and related prosthesis can attain a 10-year survival of greater than 90%.

The maximal occlusal force of a traditional denture wearer ranges from 5 to 50 psi. Patients with an implant-supported fixed prosthesis may increase their maximal bite force by 85% within 2 months after completion of treatment. After 3 years the mean force may reach greater than 300% compared with pretreatment values. As a result an implant prosthesis wearer may demonstrate a force similar to that of a patient with a fixed restoration supported by natural teeth. Chewing efficiency with an implant prosthesis is improved greatly compared with that of a soft tissue–borne restoration. Rissin et al.\textsuperscript{62} evaluated the masticatory performance of dentures, overdentures, and natural dentition. The traditional denture showed a 30% decrease in chewing efficiency; other reports indicate that a denture wearer has less than 60% of the function of persons with natural teeth. The supported overdenture loses only 10% of chewing efficiency compared with natural teeth. These findings are similar with implant-supported overdentures. In addition, rigid, implant-supported fixed bridges may function the same as natural teeth.\textsuperscript{63} Beneficial effects such as a decrease in fat, cholesterol, and the carbohydrate food groups intake have been reported, as well as considerable improvement in eating enjoyment and social life.\textsuperscript{97-105}

The stability and retention of an implant-supported prosthesis are great improvements over soft tissue–borne dentures. Mechanical means of implant retention are far superior to the soft tissue retention provided by dentures or adhesives and cause fewer associated problems. The implant support of the final prosthesis varies, depending on the number and position of implants; yet all treatment options demonstrate significant improvement (Figs. 1-20 and 1-21).

Phonetics may be impaired by the instability of a conventional denture. The buccinator and mylohyoid muscles may flex and propel the posterior portion of the denture upward, causing clicking, regardless of the vertical dimension.\textsuperscript{95} As a result, a patient in whom the vertical dimension already has collapsed 10 to 20 mm still may produce clicking sounds during speech. Often the tongue of the denture wearer is flattened in the posterior areas to hold the denture in position. The anterior mandibular muscles of facial expression may be tightened to prevent the mandibular prosthesis from sliding forward. The implant prosthesis is stable and retentive and does not require these oral manipulations. The implant restoration allows reduced flanges and palates of the prostheses, which are of special benefit to the new denture wearer, who often reports discomfort with the bulk of the restoration. The extended soft tissue coverage also affects the taste of food, and the soft tissue may be tender in the extended regions. The palate of a maxillary prosthesis may cause gagging in some patients, which can be eliminated in an implant-supported overdenture (Box 1-9).

**Figure 1-20** Implant prostheses can maintain bone and reduce the bulk of the soft tissue–borne prostheses.
The goal of modern dentistry is to return patients to oral health in a predictable fashion. The partial and complete edentulous patient may be unable to recover normal function, esthetics, comfort, or speech with a traditional removable prosthesis.

The patient’s function when wearing a denture may be reduced to 60% compared with that formerly experienced with natural dentition; however, an implant prosthesis may return the function to near normal limits. The esthetics of the edentulous patient also are affected because of bone atrophy. Continued resorption leads to irreversible facial changes. An implant stimulates the bone and maintains its dimension in a manner similar to healthy natural teeth. As a result, the facial features are not compromised by lack of support. In addition, implant-supported restorations are positioned in relation to esthetics, function, and speech, not in neutral zones of soft tissue support. The soft tissues of the edentulous patient are tender from the effects of thinning mucosa, decreased salivary flow, and unstable or unretentive prostheses. The implant-retained restoration does not require soft tissue support and improves oral comfort. Speech and function are compromised with prostheses from the supporting structures during use. The tongue and perioral musculature may be compromised to limit the movement of the mandibular prosthesis. The implant prosthesis is stable and retentive without the efforts of the musculature.

Implant prostheses often offer a more predictable treatment course than traditional restorations. Thus the profession and the public are becoming increasingly aware of this dental discipline. Manufacturers’ sales have increased from a few million dollars to more than several hundred million dollars. Almost every professional journal and lay publication now carries advertisements for implants. Implant dentistry finally has been accepted by organized dentistry. All U.S. dental schools now teach some awareness of implant dentistry. The current trend to expand the use of implant dentistry will continue until every restorative practice uses this modality for abutment support of fixed and removable prostheses.\(^\text{106}\)

**References**


