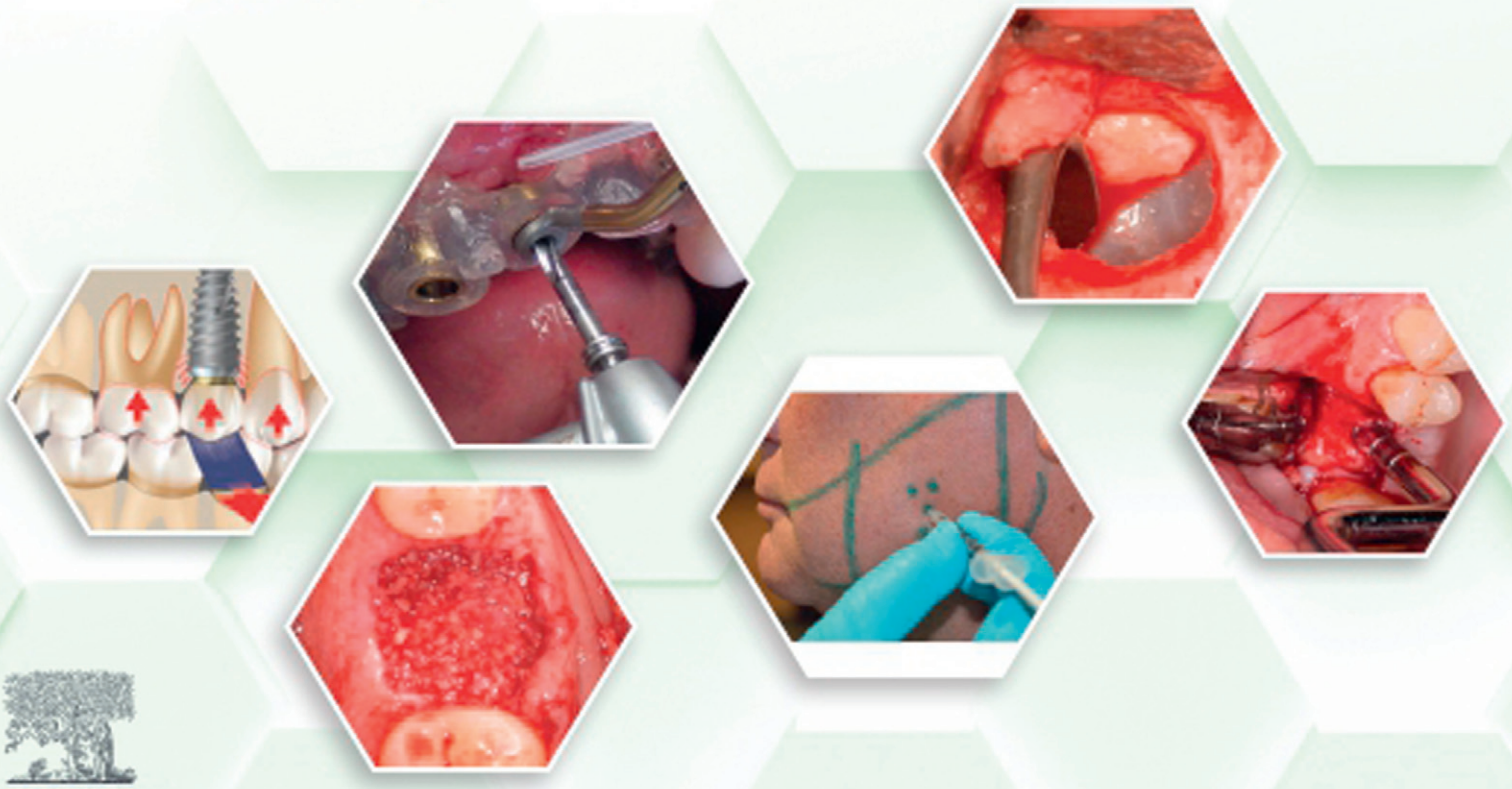
FOURTH EDITION

MISCH'S

CONTEMPORARY IMPLANT DENTISTRY

Randolph R. Resnik



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Foreword

After 50 years of involvement in dental implant evaluation and research and 47 years of clinical implant practice, I feel greatly honored as well as having a substantial professional responsibility to provide the Foreword to *Misch's Contemporary Implant Dentistry* authored by Dr. Randolph R. Resnik. Why? This book should, simply put, have an incalculable influence on dentistry for years to come.

Since 1972 I have also served continuously on the Executive Committee of the International Congress of Oral Implantologists (ICOI). Today, the ICOI is one of the largest implant societies in the world. For many years, Dr. Carl E. Misch and I were Co-Chairman of the ICOI. Since his death, I have acted as CEO. ICOI's mission has always been to promote worldwide dental implant education, research and international fraternity.

Having known Dr. Randy Resnik for many years, I can assure you that he is a shining example of a multi-talented individual who has pursued these goals and has dedicated his life to oral implantology/implant dentistry and expanding the impact of the Contemporary Implant Dentistry texts.

Because of his extensive teaching and mentoring background, he appreciates like few others the "gestalt" of oral implantology/implant dentistry. With the exponential growth of this field, fueled by exceptional professional acceptance and growing consumer awareness, Dr. Resnik has been able to thoughtfully identify the numerous sources of complications that can occur and propose many solutions. Further, he makes a strong case that dental implants are for the many, not just the privileged few. In this view several clinicians around the world are attempting to influence manufacturers to lower the price of implants or the required number of implants used in specific cases to increase their availability to patients and yet obtain satisfactory results.

Having spent many hours discussing the question with Dr. Resnik, I can assure you that he feels, as I do, that implants are the purview of generalists as well as specialists worldwide. What determines the elements of treatment that individual practitioners do should be determined by how well they train, by how much they are committed to lifelong education, and by how well they are influenced by mentors who are open, honest and caring, such as Dr. Resnik.

Several aspects of *Misch's Contemporary Implant Dentistry* have to be emphasized so that casual reading is not encouraged. There are eight sections with 42 chapters, all of which have been updated. Further, approximately 20 chapters are brand new and present in-depth multiple new topics. Dr. Resnik is very aware of how much and how fast the field of oral implantology/implant dentistry is changing. To this end, Dr. Resnik has asked multiple colleagues, researchers and specialists to contribute their knowledge.

Misch's Contemporary Implant Dentistry, authored by Dr. Randolph R. Resnik, is a classic guide for the student and the young practitioner and a valuable reference for well-experienced clinicians.

With great personal and professional respect,

Kenneth W. M. Judy, DDS, FAGD, FACD, MICD
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To my wife Diane, and children Christopher and Allison, for their patience and understanding along with enriching my life.

Carl E. Misch Dedication

The sign of a true genius is someone who has the innate ability to foresee what the future beholds. This is reflective of Dr. Carl E. Misch's life. Over 30 years ago, he was responsible for pioneering the foundation and protocols that are universally utilized today in the mainstream field of dental implantology. He had the unbelievable foresight to develop these concepts, usually against much resistance, to unprecedented perfection. When Carl, like other gifted geniuses, leave this life, the accomplishments they achieved reveal the true impact they have made on our daily lives.

Carl will always be known as one of the true "fathers" in implant dentistry, as most techniques and procedures today are based on his original principles and classifications. He had more to do with the inception, evolution and current theories of today's implant dentistry than any other practitioner in the field. He dedicated his life's work to the field of implant dentistry and worked painlessly every day to achieve these accomplishments.

Carl had a singular focus toward the understanding that if properly utilized, dental implants would have significant positive impacts on the health of the population at large. His passion was centered on perfecting the clinical outcomes of implant patients and his vision allowed implant dentistry to become a reality. He was a true innovator that has led to dental implants becoming the standard of care in dentistry even though he went against the odds and encountered much resistance.

Carl will be remembered as the consummate clinician, researcher, educator and father. He lived and taught what he believed, teaching right up to the end of his life. He was relentless and determined to further implant dentistry in the medical community. Not only did he continue teaching every one of us about dental implantology, he was also imparting further wisdom with his love for life. Carl was able to stimulate a renaissance in oral implantology that will continue to impact the field forever.

That is the beauty of life. Certain geniuses come along with great gifts. The best of these decide to dedicate their lives to sharing those gifts with others. That is a great description of Dr. Carl E. Misch, and I, as well as the rest of our profession, will never forget him. His legacy will live on in the clinicians he has educated, the teachers he has influenced, and the patients who will benefit from his tireless and profound work.

Carl, thank you for allowing me to continue your legacy. You are truly missed and you are in our thoughts every day. Rest in peace, my friend!

Preface

The use of dental implants in the field of dentistry has become a widely acceptable treatment modality to rehabilitate patients with edentulous sites. Dental implant clinicians and researchers continue to dedicate a significant amount of time and resources to the future development of the field. The global dental implant market continues to grow at an unprecedented rate, expected to exceed 7.0 billion by 2024. With an ever-increasing public awareness of the benefits of dental implantology, the popularity of dental implant rehabilitation will continue to increase for the future. A growing number of the population experience partial or complete edentulism, and the dental implant is now the preferred method of choice to replace a single, multiple, or completely edentulous sites. Therefore, it is imperative the dental implant clinician have a strong foundation of the accepted principles for treatment planning, radiographic evaluation, surgical procedures, prosthetic rehabilitation and postoperative care.

In the fourth edition of Contemporary Implant Dentistry, the underlying theme of past editions is clearly maintained with respect to the science-based concept of implant dentistry. This new edition is a comprehensive overview of all surgical aspects of implant dentistry, which include eight sections and 42 chapters. Each chapter in this book is specifically written to be related to all other chapters in the text with the concept of consistent and predictable care as the priority. The fourth edition has nearly tripled in size from the first edition written in the early 1990s. New chapters on treatment planning, implant surgery, pharmacology, medical evaluation, immediate placement and immediate loading, bone grafting techniques, Botox and dermal fillers, and the treatment of peri-implant disease have been added to this fourth edition.

The first part of the fourth edition Contemporary Implant Dentistry is related to the scientific basis for dental implants. It presents the rationale for the use of dental implants as inert replacements for missing teeth and why biomechanics play such a significant role in the treatment planning process. A comprehensive outline of the terminology is explained with clear and concise examples. Science based research is used as the basis for discussing implant design and biomaterials, along with the physiologic bone response to these materials.

The second part of this book discusses the biomechanical properties which relate to the dental implant process. The pioneering stress theorem concepts postulated by Dr. Carl Misch are the basis for these chapters as the various force factors which dental implants are exposed to are presented. The effects of these forces along with how different implant surfaces relate to the stresses are discussed in detail.

The third part of Contemporary Implant Dentistry provides information concerning the related basic sciences of oral implantology. The medical evaluation chapter details medical conditions and medications which have direct and indirect effects on the short and long-term success of dental implants. The radiographic evaluation chapter allows the reader to have a comprehensive understanding of normal anatomy as well as anatomic and pathologic variants related to dental implantology. An updated pharmacology chapter encompasses all prophylactic and therapeutic medications related to pre- and postoperative care of dental implants. And lastly, applied anatomy of the head and neck is discussed with an overview on possible infectious episodes that may result from dental implant treatment.

The fourth part of Contemporary Implant Dentistry is based upon all aspects of the treatment planning process. The pioneering classifications from Dr. Carl Misch including available bone, prosthetic options, key implant positions and bone density are updated. A new chapter added to this section details the use of interactive cone beam computerized tomography (CBCT) in the treatment planning process. Valuable treatment planning concepts are discussed with a generic protocol for the use of CBCT.

The fifth part of Contemporary Implant Dentistry discusses generalized treatment planning concepts related to anatomical regions within the oral cavity. Single , multiple, and fully edentulous treatment planning principles are presented according to anatomic areas in the anterior and posterior maxilla and mandible. The edentulous treatment planning process for fixed versus removable prostheses are compared with respect to anatomic areas in the maxilla and mandible.

The sixth part of Contemporary Implant Dentistry is dedicated to the implant surgery process. A new chapter related to surgical techniques entails basic surgical principles and protocols, as well as the armamentarium required in the field of oral implantology. Various surgical protocols are discussed related to the specific anatomy in the maxilla and mandible. In addition, a full array of possible complications of implant surgery with respect to etiology, management, and prevention is presented. And lastly, new classifications and protocols related to immediate implant placement surgery along with immediate loading techniques are explained in science- and research-based techniques.

The seventh part of Contemporary Implant Dentistry discusses all aspects of soft and hard tissue rehabilitation. A detailed chapter explains guidelines and techniques for atraumatic extraction and socket grafting. A new chapter specifically discussing the available bone substitutes and membranes, with advantages and disadvantages based on science and the latest research is presented. In addition, updated and comprehensive bone grafting chapters on guided tissue regeneration, maxillary sinus augmentation, intraoral bone grafts, and extraoral techniques are included in this part. And lastly, a new chapter related to the use of Botox and dermal fillers is added to this section which includes the use for esthetic and functional aspects of oral implantology.

The last section of Contemporary Implant Dentistry is related to the postoperative care, specifically the treatment of

peri-implant disease with an emphasis on treatment protocols. The last chapter includes a detailed protocol and treatment techniques on the maintenance of dental implants.

In summary, Contemporary Implant Dentistry has been used over the years as a textbook for dental schools, dental residents, postgraduate programs, lab technicians, general dentists, and dental specialists. The translations into many languages has shown the popularity and acceptance of this textbook in the field of oral implantology worldwide. The fourth edition of this textbook comprehensively updates the reader on all aspects of dental implantology with the goal of elevating the educational standards through a science-based approach.

Randolph R. Resnik, DMD, MDS

Acknowledgments

I would like to express my sincere gratitude for the many individuals who helped shape my career and provided the foundation for the writing of this book. First and foremost, I would never have had the ambition, aspiration, and discipline to write this book if not for the two mentors in my life, my late father, Dr. Rudolph Resnik, and the true pioneer in oral implantology, Dr. Carl E. Misch. My father was the perfect role model, educator, clinician, and a true pioneer in the field of fixed prosthetics. He was my hero and best friend, and the number one reason I am where I am today. His endless support and encouragement motivated me to give 100% to every endeavor that I ever pursued.

Secondly, Dr. Carl Misch was not only my mentor, but also a very close friend. His endless energy and ability to foresee the future of oral implantology and its impact on dentistry allowed me to be at the forefront of this challenging profession. His dedication and contributions to the field of oral implantology are unprecedented and will never be forgotten. The scientific basis for his classifications and principles will be an integral component in the field forever.

I would also like to acknowledge the thousands of doctors, whom over the past 30 years, have attended my various lectures, symposiums and especially the past graduates of the Misch International Implant Institute. It is through their inquisitiveness and ambition to learn that has empowered me to write the Fourth Edition of Contemporary Implant Dentistry. They have given me the determination and desire to raise the standard of care in our profession and elevate implant dentistry to the next level.

I am sincerely thankful to all the additional chapter authors for sharing their expertise with the writing of this book. Their dedication to implant dentistry, and especially their friendship and personal support to me, is greatly appreciated: Dean Jon Suzuki, Steven Caldwell, Robert Resnik, Christopher Resnik, David Datillo, Joseph Cillo, Neil Park, Grant Bullis, Mauri Kerr, Amanda Sheehan, Kevin Suzuki, Diana Bronstein, Ralph Powers, Francine Misch- Dietsh, and Mohamed Sharowry.

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At last but not least, I would like to thank my family, for their support and encouragement they gave me during this project, despite the sacrifice and burden it often imposed on them. My wife, Diane, who's unwavering support always gives me the strength to succeed. So proud of both of my children, Christopher, currently in a residency program at the University of Pittsburgh and soon to be third generation Prosthodontist and my beautiful daughter, Allison, who is currently in medical school at Georgetown University.

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PART I

Scientific Basis

1

Rationale for Dental Implants

RANDOLPH R. RESNIK AND
CARL E. MISCH

The goal of modern dentistry is to restore the patient to normal contour, function, comfort, esthetics, speech, and health by removing a disease process from a tooth or replacing teeth with a prosthesis. What makes implant dentistry unique is the ability to achieve this goal, regardless of the atrophy, disease, or injury of the stomatognathic system.[1] 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, advanced materials, and techniques, predictable success is now a reality for the rehabilitation of many challenging clinical situations.

The impact of dental implants has surely affected the field of dentistry in the United States. The number of dental implants placed in the United States has increased more than 10-fold from 1983 to 2002, and another fivefold from 2000 to 2005. More than 1 million dental implants are inserted each year and the industry is expected to be a $10 billion industry in 2020.[2,3] More than 90% of interfacing surgical specialty dentists currently provide dental implant treatment on a routine basis in their practices, 90% of prosthodontists restore implants routinely, and more than 80% of general dentists have used implants to support fixed and removable prostheses, compared with only 65% 15 years ago.[4-7]

Despite these figures demonstrating implants are incorporated into dentistry more than ever before, there is still a great deal of room for continued growth. Utilization of dental implants varies widely in different countries. For example, it is estimated that the number placed each year per 10,000 people is 230 for Israel (the greatest number); 180 for South Korea and Italy; 140 for Spain and Switzerland; 100 for Germany; 60 each for Brazil, the Netherlands, and the United States; 50 for Japan and France; 40 for Canada and Australia; and Taiwan and the United Kingdom, at 20 per year, use implants less often. The six countries with the greatest use of implants (five in Europe and South Korea) accounted for more than half the total market growth from 2002 to 2007. A long-term growth of 12% to 15% is expected in the future in most countries using implants at this time (Fig. 1.1).

The percentage of teeth replaced with an implant, rather than traditional fixed or removable prostheses, also dramatically varies by country. In countries such as Israel, Italy, and South Korea, 30% to 40% of teeth replaced incorporate a dental implant. In Spain, Switzerland, Germany, and Sweden, 20% to 26% of restorations to replace teeth are supported by an implant, whereas in Brazil and Belgium approximately 13% to 16% of restorations use an implant. Surprisingly, the United States, Japan, France, and Canada use implants in 10% or fewer of the teeth replaced, however this number is increasing (Fig. 1.2).[8]

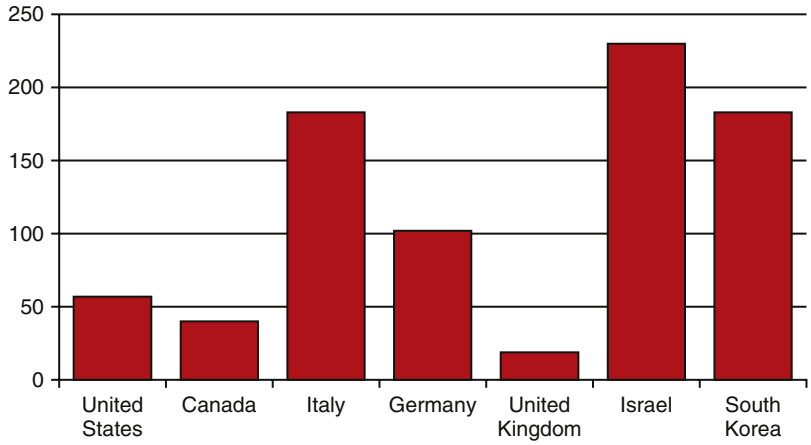
Increasing Demand for Dental Implants

The increased need and use of implant-related treatments result from the combined effect of several factors, including (1) patients living longer, (2) age-related tooth loss, (3) patients are more socially active and esthetic conscious, (4) a higher incidence of partial and complete edentulism, (5) conventional prosthesis complications, and (6) the inherent advantages of implant-supported restorations.

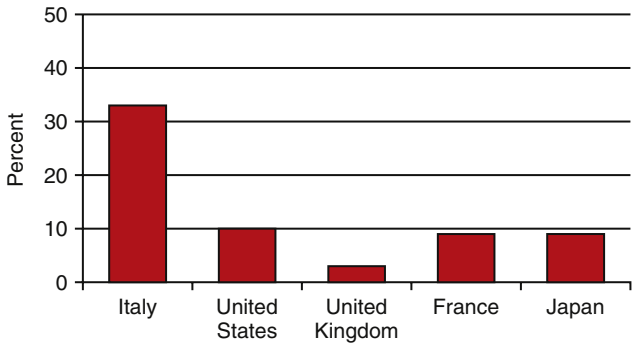
Patients Living Longer

According to the literature, age is directly related to every indicator of tooth loss[9,10]; therefore the aging population is an important factor to consider in implant dentistry. When Alexander the Great conquered the ancient world, he was only 17 years old. However, life expectancy at that time was only 22 years of age. From 1000 BCE to CE 1800, life span remained less than 30 years (Fig. 1.3). The latest statistics from the National Center for Health Statistics show that the average American life expectancy is approximately 78.6 years, with women (81.1 years) living approximately 5 years longer than men (76.1 years). The group older than age 65 is projected to increase from 12% in 2000 to more than 20% of the population before 2025 (Fig. 1.4).[11]

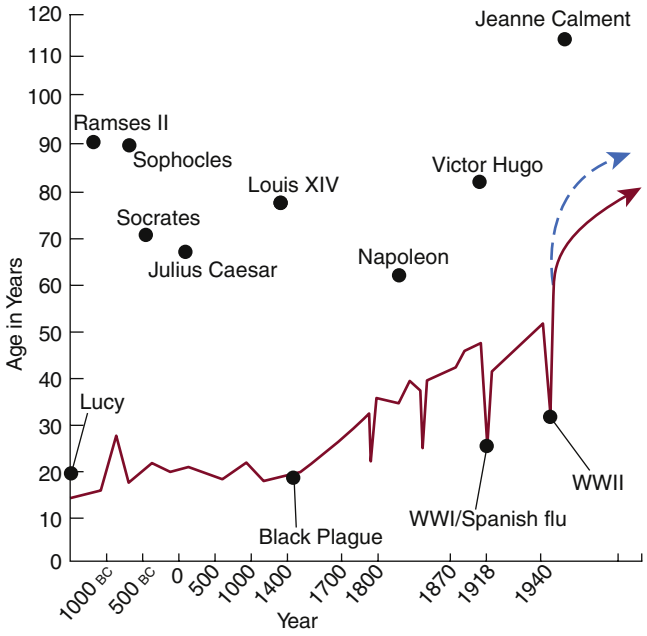
In addition, not only is the percentage of the population over 65 years increasing, but the overall population as a whole is increasing. The population in 2000 was 282 million and is projected to increase 49% to 420 million by 2050. Considering the effect of both a population increase and a greater percentage of that population being older than age 65, a dramatic overall increase in patient numbers can be expected. In 2003, 35 million people were older than age 65. This number is expected to increase 87% by 2025, resulting in almost 70 million people being older than age 65[9] (Fig. 1.5). Because older people are more likely to be missing teeth, the need for implant dentistry will dramatically increase over the next several decades.



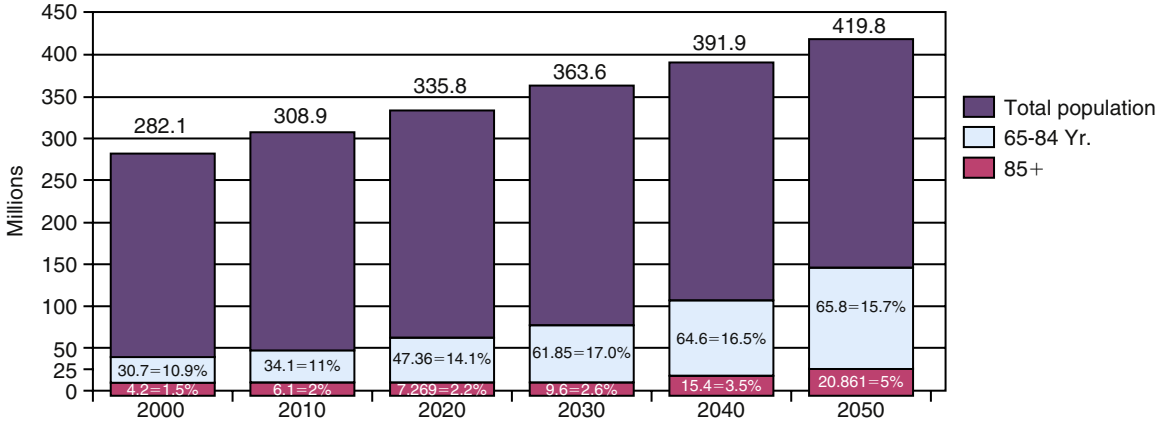
• **Fig. 1.1** Implant used to replace teeth varies by country. Estimated implant use per 10,000 people per year is greatest in Israel, South Korea, and Italy. (From Misch CE. Rationale for dental implants. In: Misch CE, ed. *Dental Implant Prosthetics*. 2nd ed. St Louis: Mosby; 2015.)



• **Fig. 1.2** Implant versus nonimplant tooth replacement (percentage) varies greatly by country. In the United States only 1 of every 10 teeth replaced incorporates an implant. (From Misch CE. Rationale for dental implants. In: Misch CE, ed. *Dental Implant Prosthetics*. 2nd ed. St Louis: Mosby; 2015.)



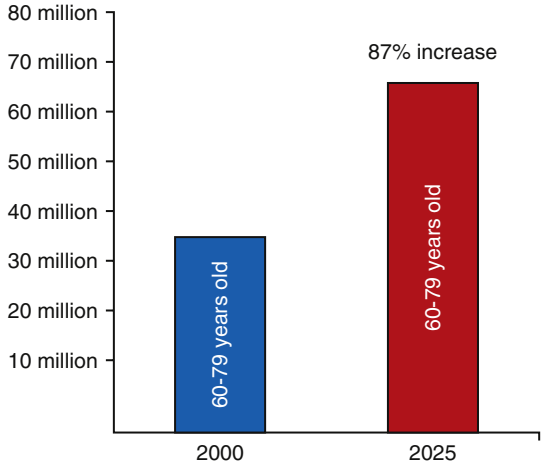
• **Fig. 1.3** Average life expectancy remained approximately 20 to 30 years for several hundred years of human civilization. Since the late 18th century, there has been a gradual increase in life span. (Redrawn from *Le Figaro Magazine*, Paris, 2004.)



• **Fig. 1.4** By 2050, 20.7% of the population will be older than age 65. In addition to the increasing percentage of 65 year olds, the population is also increasing. As a result, 34.9 million people were older than 65 in 2000, and 86.6 million people will reach this milestone by 2050.

Life expectancy has increased significantly past the age of retirement. A 65 year old person can now expect to live more than 20 additional years, and an 80-year-old person can expect to live 9.5 more years[10] (Fig. 1.6). Women represent two-thirds of the population older than age 65. It is not unusual for a 70-year-old patient to ask, "Is it worth it for me to spend a lot of money to repair my mouth at my age?" The response should be very positive because the patient's life expectancy will extend for two more decades on average, and his or her current oral situation will normally become worse if not corrected.

Over 69% of Americans between 35 and 44 years have at least one missing tooth. According to the National Center for Health Statistics, 91% of the people in the United States aged 20 to 64 had dental caries in their permanent teeth. The National Health and Nutrition Examination survey estimated that approximately 42% of the children aged 2 to 11 years have tooth caries, and over 23% are left untreated. The National Institute of Dental and Craniofacial Research has determined that tooth loss in American adults begins between the ages of 35 and 45, and more than 24% of adults older than 74 years are completely edentulous.[12]



● **Fig. 1.5** Adult population older than the age of 60 years will increase by 87% from the year 2000 to the year 2025. (From Misch CE. Rationale for dental implants. In: Misch CE, ed. *Dental Implant Prosthetics*. 2nd ed. St Louis: Mosby; 2015.)

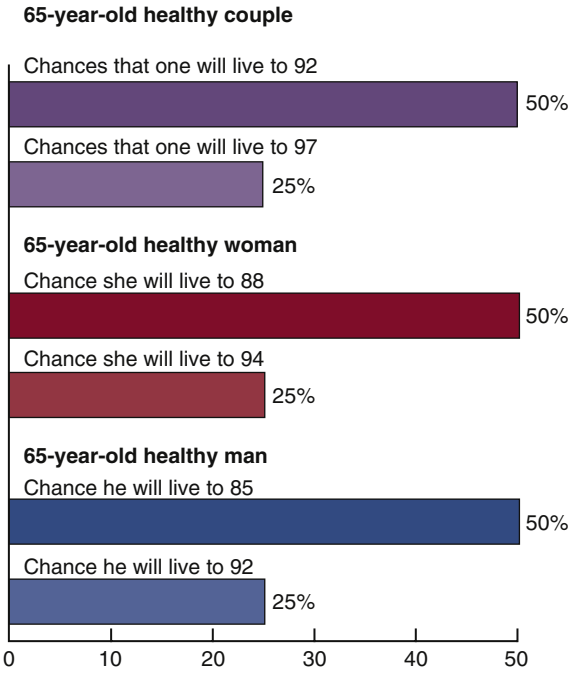
Age-Related Tooth Loss

The aging process directly affects the oral cavity with negative consequences. As the tooth enamel wears away, teeth become more vulnerable to disease processes and eventual tooth loss. Many medications directly affect the teeth, especially causing xerostomia. Xerostomia not only weakens the teeth, but also results in hard and soft tissue loss. Therefore, a direct correlation between the aging process and tooth loss exists.

The posterior regions of the oral cavity are the most common areas for single-tooth loss[13] (Fig. 1.7). 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).

The molar teeth are vitally important 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 very disparate results. The mean life span at failure has been reported as approximately 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 periodontal disease and endodontic therapy.[14] The tooth is at risk for extraction as a result of these complications, which are the leading causes of single posterior tooth loss in the adult (Fig. 1.8, Fig. 1.9).[15]

Researchers have found a direct correlation of tooth loss in the elderly population exhibiting physical and mental decline. The data showed that subjects who had lost all their natural teeth performed approximately 10% worse in both memory and mobility (walking) than counterparts with natural teeth. Usually, tooth loss is less with patients of higher socioeconomic status. However, in this study, the link between total tooth loss and mobility (slower walking speed) remained significant when all variables were taken into consideration.



● **Fig. 1.6** When a person reaches age 65 years, he or she may often feels an investment in health is less appropriate. A 65-year-old healthy woman will live 23 more years 50% of the time and 29 more years 25% of the time. Her present oral condition will become worse during this extended time frame if treatment is not rendered.

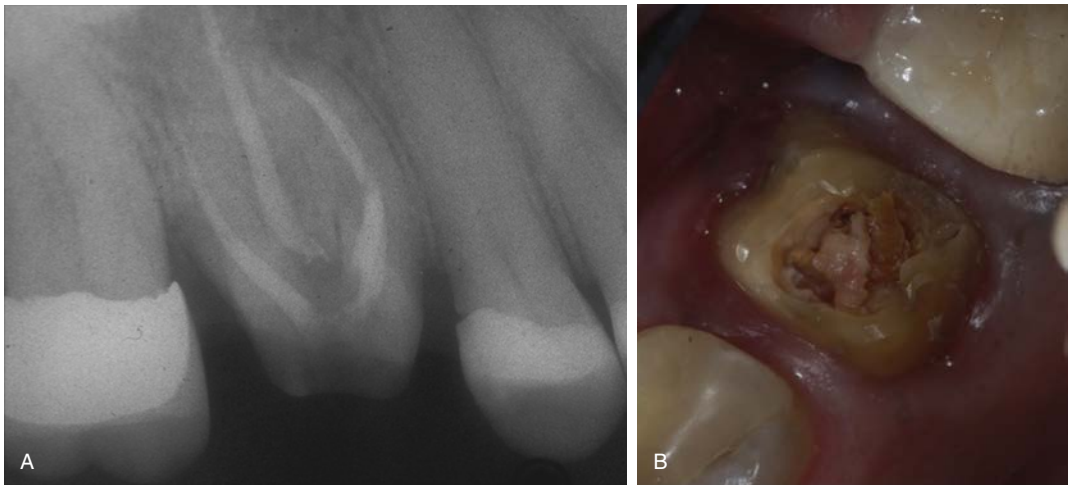
Patients More Socially Active and Esthetic Conscious

With patients living longer, their social pleasures, including dining and dating, are continuing into their elderly years. In the past, treatment of elderly patients emphasized nonsurgical approaches and palliative treatment. Today, the full scope of dental services for elderly patients is increasing in importance to both the public and the profession because of the increasing age of our society. Studies have shown that elderly patients that are more socially active will have a slower progression of health declines than elderly people who become less socially active. Engaging older people have been shown to be more motivated to maintain their health than their less-engaged peers. Therefore with patients living longer, patient education is vitally important as the demand for more comprehensive dental implant treatment will be most definitely increasing in the future to maintain social activity.

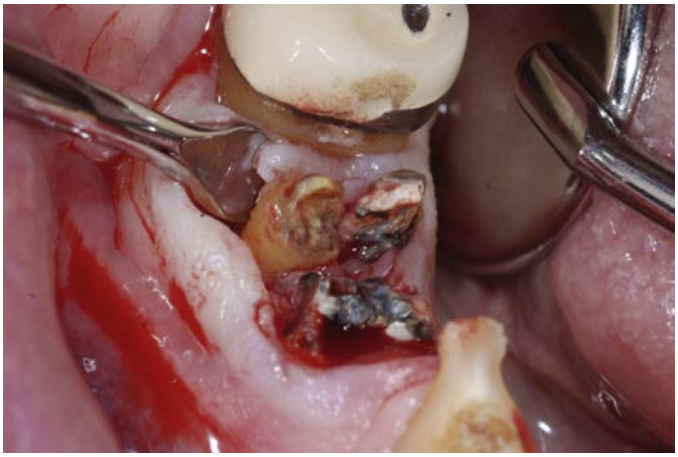
Higher Prevalence of Partial and Complete Edentulism

Partial Edentulism

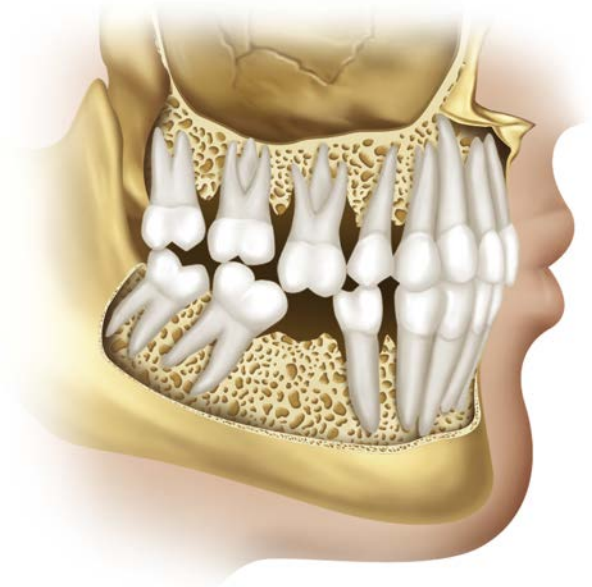
Currently, the prevalence of partial edentulism in the general population has resulted in an increased need for dental implants.



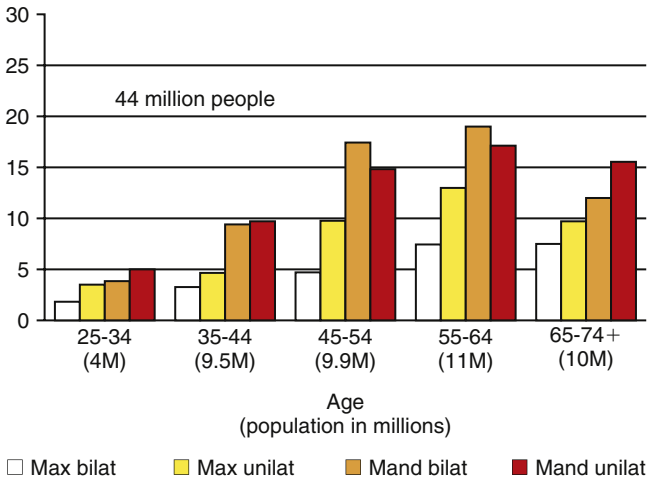
• **Fig. 1.7** (A and B) The most common tooth to be lost is the first molar. Approximately 80% of the time, the adjacent teeth are unrestored or have minimal restorations.



• **Fig. 1.8** Posterior molar tooth exhibiting caries and endodontic fracture, which are two of the most common complications leading to an unrestorable tooth.



• **Fig. 1.9** Posterior missing tooth is a frequent occurrence in a general practice. The most common single tooth missing is the first molar. which results in many dental arch complications. (From Misch CE. Rationale for dental implants. In: Misch CE, ed. *Dental Implant Prosthetics*. 2nd ed. St Louis: Mosby; 2015.)



• **Fig. 1.10** There are more than 44 million people in the United States missing at least one quadrant of posterior teeth (most often in the mandible). (From Misch CE. Rationale for dental implants. In: Misch CE, ed. *Dental Implant Prosthetics*. 2nd ed. St Louis: Mosby; 2015.)

Various studies have shown this pattern to be as high as 48% of the population. Many variables which have been associated this increase include gender, ethnicity, and chronic disease. In addition, adults exhibiting partial edentulism were 22.6% more likely to be from rural areas and 31.5% from depressed locations.[16]

As stated previously, the most common missing teeth are have been shown to be molars.[17] Partial free-end edentulism is of particular concern because in these patients, teeth are often replaced with removable partial prostheses. Implant placement in the posterior regions is often challenging because of the location of the maxillary sinus and the mandibular canal. Mandibular free-end edentulism frequency is greater than its maxillary counterpart in all age groups. Unilateral free-end edentulism is more common than bilateral edentulism in both maxillary and mandibular arches in the younger age groups (ages 25–44). About 13.5 million persons in these younger age groups have free-end edentulism in either arch (Fig. 1.10).

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. Approximately 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. 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, approximately 11 million individuals in this age group are potential candidates for implants. An additional 10 million show partial free-end edentulism at age 65 or older. Additional US survey studies have documented approximately 44 million people to have at least one quadrant of posterior missing teeth. For example, 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.[18-20]

Total Edentulism

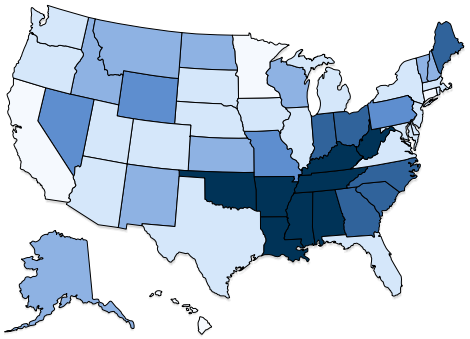
Although the percentage of patients with total edentulism is decreasing because of the baby-boomer population, the total number of patients exhibiting edentulism that will require treatment will increase in the future. In the past, full arch extractions were mainly indicated because of the combined pathologic processes of dental caries, periodontal disease, or as a method to reduce the costs associated with dental treatment. However, because of the high success rate of dental implants today, it is not uncommon for full-mouth extractions to be completed when teeth are questionable, especially in anticipation of future implant placement. Similar to other pathologic outcomes of disease, the occurrence of total loss of teeth is directly related to the age of the patient. The rate of edentulism increases approximately 4% per 10 years in early adult years and increases to more than 10% per decade after age 70.[21]

The average total edentulous rate worldwide is approximately 20% at age 60, although there is wide disparity between the countries with the highest and lowest rates. For example, in the 65- to 74-year age group, the total edentulous rate in Kenya and Nigeria was 0%, whereas the Netherlands and Iceland have a 65.4% and 71.5% rate, respectively. The edentulous Canadian rate was 47% at ages 65 to 69 and 58% from ages 70 to 98 (with Quebec at 67% for those older than age 65 compared with Ontario with a 41% rate). [22]

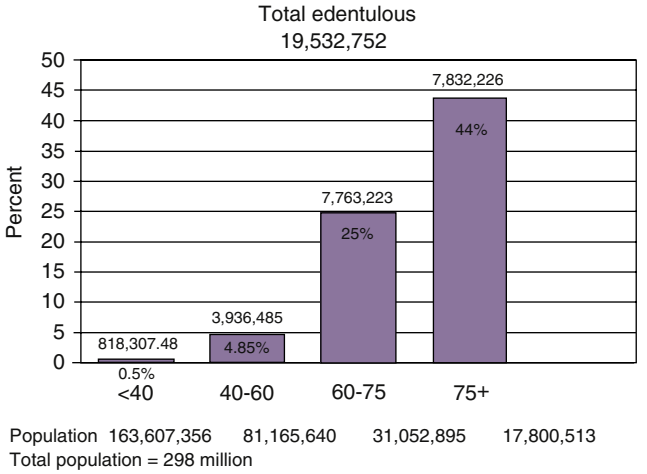
In the United States the comparison of edentulism from 1957 to 2012 decreased from 19% to 5%. Income is often related to education and may also play a role in the rate of edentulism in the United States from 1988 to 1994, studies reported an edentulous rate of 22% for those with less than 8 years of education, 12% for those with 9 to 11 years of school, 8% for those with 12 years of school, and 5% for individuals with more than 12 years of education.

Studies show that edentulism in the United States is rarely seen in high-income individuals. The level of education is inversely proportional to edentulism. Geographically, edentulism was found to be highest in states that are bordered by the Appalachian Mountains and the Mississippi Delta. The lowest prevalence was found in California, Connecticut, Hawaii, and Minnesota. The prevalence in southern states is nearly twice that in western states (Fig. 1.11).[23]

In the National Institute of Dental Research national surveys, the occurrence of total edentulism (absence of teeth) of a single arch (35 times more frequent in the maxilla) was slight in the 30- to 34-year-old age group, but it increased at around age 45 to 11% and then remained constant after 55 years at approximately 15% of the adult population. A total of approximately 12 million individuals in the United States have edentulism in one arch, representing 7% of the adult population overall. With the passing of generations born in the mid-20th century, the rate of decline in edentulism is projected to slow, reaching approximately 2.6% by the year 2050. This continuing decline, however will be offset by population aging.The projected number of edentulous people in 2050 will be approximately 8.6 million. This will be 30% lower than the 12.2 million edentulous people in 2010.[23]



● **Fig. 1.11** Age-standardized edentulism prevalence among adults aged ≥25 years in the United States in 2010. (From Slade GD, Akinkugbe AA, Sanders, AE. Projections of U.S. edentulism prevalence following 5 decades of decline. *J Dent Res.* 2014;93(10):959–965.)



● **Fig. 1.12** The US population completely edentulous rate ranges from 5% for 40 year olds to 44% for those older than age 75. As a result, 20 million people (10.5% of the population) in the United States have no teeth. An additional 12 million people (7% of the adult population) have no maxillary teeth opposing at least some mandibular teeth.

The present younger population is benefiting from today's advanced knowledge and restorative techniques. Edentulism has been noted in 5% of employed adults aged 40 to 44, gradually increasing to 26% at age 65, and almost 44% in seniors older than age 75 (Fig. 1.12).[24] As expected, older persons are more likely to be missing all their teeth. Gender was not found to be associated with tooth retention or tooth loss once adjustments were made for age. The percentages of one- or two-arch edentulism translate into more than 30 million people, or about 17% of the entire US adult population. To put these numbers in perspective, 30 million people represent approximately the entire US African American population, or the entire population of Canada. Although the edentulism rate is decreasing every decade, the elderly population is rising so rapidly that the adult population in need of one or two complete dentures will actually increase from 33.6 million adults in 1991 to 37.9 million adults in 2020. The total number of edentulous arches is estimated at 56.5 million in 2000, 59.3 million in 2010, and 61 million in 2020. Complete edentulism, therefore, remains a significant concern, and affected patients often

• BOX 1.1 Consequences of Complete Edentulism

- Continued bone loss of the maxilla and mandible
- Negative soft tissue changes of the face and jaws
- Negative facial esthetic changes
- Decreased masticatory function
- Increased Health Issues
- Negative dietary effects
- Psychological Issues
- Patients Less Socially Active

From Misch CE. Rationale for dental implants. In: Misch CE, ed. Dental Implant Prosthetics. *2nd ed. St Louis: Mosby; 2015.*

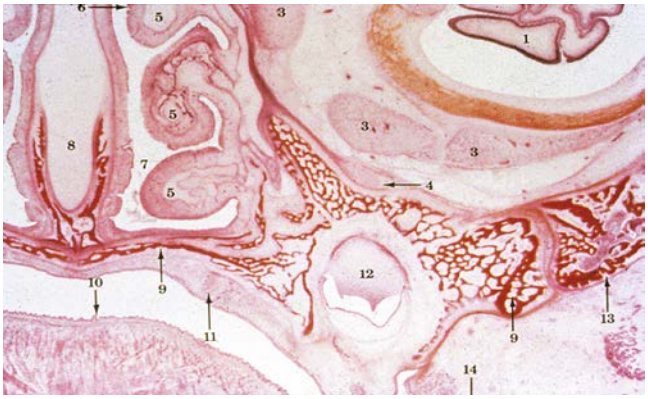
require dental implant treatment to solve several related problems. For example, to show the need for implant treatment with the edentulous group, if four implants were used to help support each complete edentulous arch in 2000, a total of 226 million implants would have been required. However, only approximately 1 million implants were inserted for all patient treatment (partially or completely edentulous) that year. Almost 70% of dentists spend less than 1% to 5% of their treatment time on edentulous patients, leaving a great unfulfilled need for implant dentistry.[25]

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

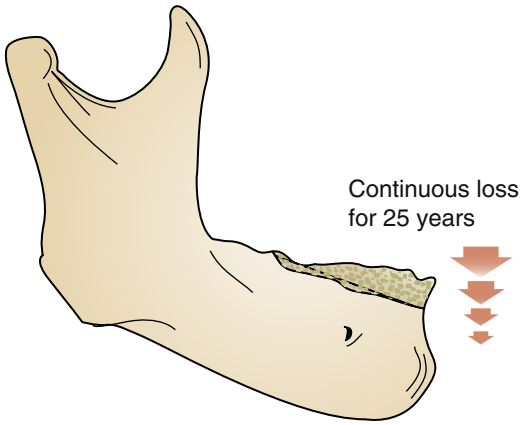
In the elderly population, tooth loss is more common. The baby-boomer population in the United States is the major purchaser of elective plastic surgery and antiaging procedures and medications. This generation is destined to be the most affluent older generation ever in the United States, and they will inherit the largest inflation-adjusted transfer of wealth in history at approximately $10 trillion.[26] This propensity for discretionary spending has fueled unprecedented growth in implant dentistry during the last decade, and it is expected to continue. The 65-year-plus population in the United States is expected to increase at annual rates of 1.5% to 3% from 2010 through 2035. The population of 65+ age group will increase from 12.4% of the population in 2000 to 20.6% in 2050.[27,28]

Anatomic Consequences Of Edentulism

Hard Tissue Loss. Basal bone forms the dental skeletal structure, contains most of the muscle attachments, and begins to form in the fetus before teeth develop (Box 1.1). Alveolar bone first appears when the Hertwig root sheath of the tooth bud evolves (Fig. 1.13). 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 (1892) stated that bone remodels in relationship to the forces applied. Every time the function of bone is modified, a definite change occurs in the internal architecture and external configuration.[29,30] In dentistry, the consequences of complete edentulous and remaining bone volume was noted by Misch in 1922, in which he described the skeletal structure of a 90-year-old woman without teeth for several decades.[31]



• Fig. 1.13 The alveolar bone forms as a result of the tooth root formation. When no tooth root is present, the alveolar process does not form (i.e., ectodermal dysplasia when partial or complete anodontia of both primary and secondary teeth occurs).



• Fig. 1.14 After the initial extraction of teeth, studies have shown the average first-year bone loss is more than 4 mm in height and 30% in crestal bone width. Although the rate of bone loss is slower after the first year, the bone loss is continuous throughout life.

Bone requires stimulation to maintain its form and density. Roberts and colleagues[32] reported 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. 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, then height, of the bone volume.[32] There is a 25% decrease in the width of bone during the first year after tooth loss and an overall 4-mm decrease in height during the first year after extractions for an immediate denture. In a pioneering longitudinal 25-year study, demonstrated continued bone loss during this time span; in comparing the bone loss of the maxilla to the mandible, a fourfold greater loss was observed in the mandible (Fig. 1.14).[33] Although, initially the mandibular bone height is twice that of the maxilla, maxillary bone loss is very significant in the long-term edentulous patient. In fact, maxillary implant placement and bone graft procedures may be more challenging in comparison to the mandible.

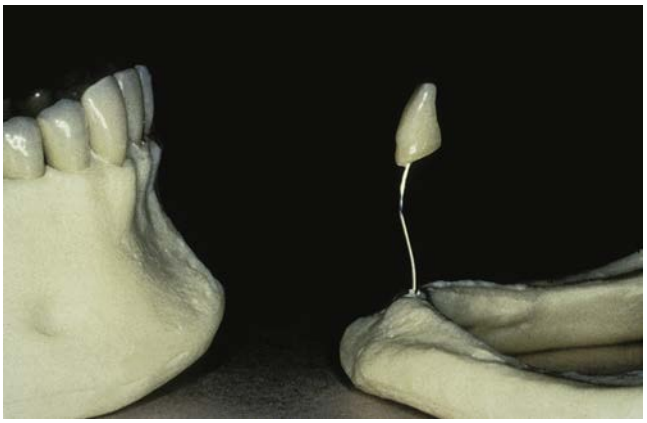
Prostheses also contribute to bone loss. In general, a tooth is necessary for the development of alveolar bone, and stimulation of this bone is required to maintain its density and volume. A removable denture (complete or partial) does not stimulate and maintain bone; rather, it accelerates bone loss. The load from

mastication is transferred to the bone surface only and not the entire bone. As a result, blood supply is reduced and total bone volume loss occurs. This issue, which is of utmost importance, has been observed but not addressed until recently in traditional dentistry. Most often dentists overlook the insidious bone loss that will occur after tooth extraction. Therefore, it is imperative patients be educated about the anatomic changes and the potential consequences of continued bone loss. The bone loss accelerates when the patient wears a poorly fitting soft tissue–borne prosthesis. Patients do not understand that bone is being lost over time and at a greater rate beneath poorly fitting dentures (Fig. 1.15). Patients infrequently return for follow-up visits for evaluation of their edentulous condition; instead, they will return for a repair of the prosthesis. Hence the traditional method of tooth replacement (e.g. removable prosthesis) often affects bone loss in a manner not sufficiently considered by the doctor and the patient. Bone loss has been shown to increase with the use of a poorly fitting soft tissue–borne prosthesis. Patients should be informed of periodic evaluations to reline or fabricate a new prosthesis (Fig. 1.16).

Preventive dentistry has traditionally emphasized methods to decrease tooth loss. No predictable therapy had been accepted by the profession to avoid the bone changes resulting from tooth loss. Today, the profession must consider the loss of both teeth and bone. The loss of teeth causes remodeling and resorption of the surrounding alveolar bone and eventually leads to atrophic edentulous ridges. The rate and amount of bone loss may be influenced by such things as gender, hormones, metabolism, parafunction, and ill-fitting dentures (Box 1.2). 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 accelerates bone loss. Nonetheless, studies have shown that approximately 80% of dentures are worn both day and night.[34] Atrophic edentulous ridges are associated with anatomic problems that often impair the predictable results of traditional dental therapy (Fig. 1.17; Box 1.3).

Loss of bone in the maxilla or mandible is not limited to alveolar bone; portions of the basal bone also may be resorbed, especially in the posterior aspect of the mandible in which severe resorption may result in catastrophic bone loss.[35] The contents of the mandibular canal or 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 nerve impairment of the areas supplied by the mandibular nerve are possible. The body of the mandible is also at increased risk of pathologic fracture, even under very low impact forces. The mandibular fracture causes the jaw to shift to one side and makes stabilization and an esthetic result most difficult to obtain during treatment of the fracture.

● **Fig. 1.15** Atwood described six different stages of resorption in the anterior mandible. Stage 1 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 in length of anterior residual bone.



● **Fig. 1.16** Loss of bone height in the mandible may be significant resulting in loss of function. This vertical bone loss has a large impact on restoring the patient back to dental health. The patient should understand that to restore the hard and soft tissue loss, more extensive treatment is usually indicated.

• BOX 1.2 Factors Effecting Rate and Amount of Bone Loss

- Gender
- Medications
- Hormones
- Age
- Metabolism
- Bone Quality
- Parafunction (Increased Biting Force)
- Ill-fitting prosthesis
- Facial type (brachiocephalic versus dolichocephalic)
- Time period dentures are worn
- Past History of Dental Disease

Modified from Misch CE. Rationale for dental implants. In: Misch CE, ed. Dental Implant Prosthetics. *2nd ed. St Louis: Mosby; 2015.*

● **Fig. 1.17** Maxillary and Mandibular edentulous arches depicting irregular bone resorption with varying degrees of quality soft tissue (i.e. attached tissue).

In the maxilla, extensive bone loss can also be problematic. In some cases, the complete anterior ridge and even the anterior nasal spine may be resorbed in the maxilla, causing pain and an increase in maxillary denture movement during function. Masticatory forces generated by short facial types (brachiocephalics) can be three to four times that of long facial types (dolichocephalics). Short facial–type patients are at increased risk for developing severe atrophy.

Many of these similar conditions exist in the partially edentulous patient wearing a removable soft tissue–borne prosthesis (e.g. removable partial denture) (Fig. 1.18). In addition, the natural abutment teeth, on which direct and indirect retainers are designed, experience significant lateral forces. Because these teeth are often compromised by deficient periodontal support or large restorations, the resultant forces may be damaging. These forces may result in an increase in mobility of the removable prosthesis and greater soft tissue support. These conditions often will lead to accelerated the bone loss in the edentulous regions (see Box 1.3).

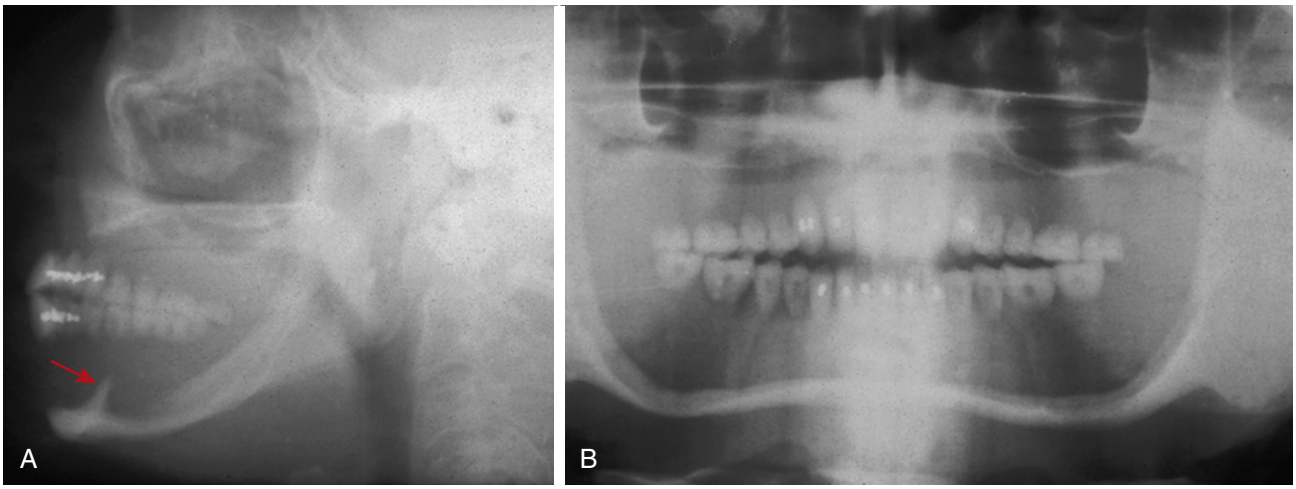
Soft Tissue Consequences. As bone loses width, then height, then width and height again, the attached gingiva gradually decreases. A very thin attached tissue usually lies over the advanced atrophic mandible or maxilla. The increased zones of nonkeratinized gingiva are prone to abrasions caused by the overlaying prosthesis. In addition, unfavorable high muscle attachments and hypermobile tissue often complicate the situation (Fig. 1.19).

As the bone resorbs from Division A to Division B, the resultant narrow residual ridge will often cause discomfort when pressure (from a prosthesis) is applied to the ridge. This often occurs in the posterior mandible, as atrophy may cause a prominent mylohyoid and internal oblique ridges covered by thin, movable, unattached mucosa. In severe atrophy cases the anterior residual alveolar process will continue to resorb, and the superior genial tubercles (which are approximately 20 mm below the crest of bone when teeth are present) eventually become the most superior aspect of the anterior mandibular ridge. This results in excessive movement of the prosthesis during function or speech. This condition is further compromised by the vertical movement of the distal aspect of the prosthesis during contraction of the mylohyoid and buccinator muscles and the anterior incline of the atrophic mandible compared with that of the maxilla.[36]

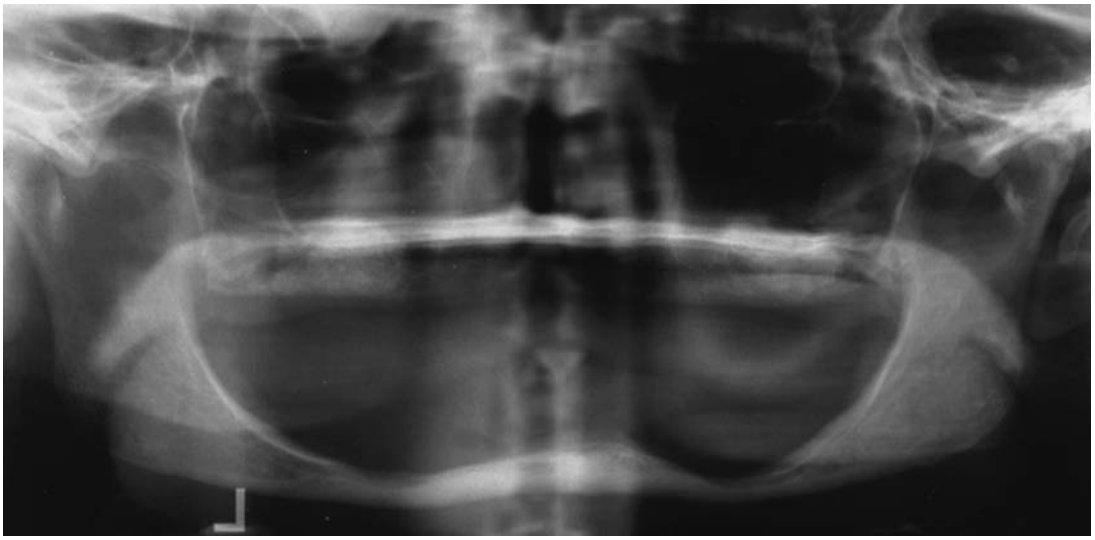
The thickness of the mucosa on the atrophic ridge is also related to the presence of systemic disease and the physiologic changes that accompany aging. Conditions such as hypertension, diabetes, anemia, and nutritional disorders have a deleterious effect on the vascular supply and soft tissue quality 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, the

• BOX 1.3 Edentulous Patient Complications

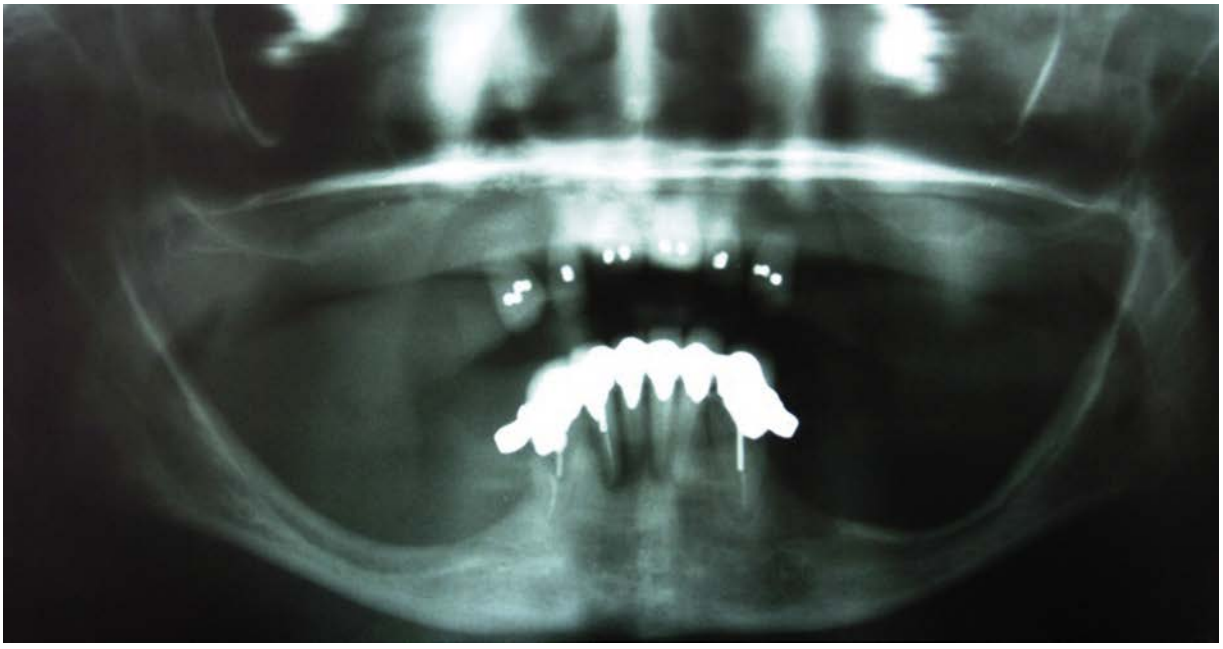
- Continued loss of supporting bone width
- Prominent mylohyoid and internal oblique ridges with increased sore spots
- Progressive decrease in keratinized mucosa surface
- Prominent superior genial tubercles with sore spots and increased denture movement
- Muscle attachment near crest of ridge
- Elevation of prosthesis with contraction of mylohyoid and buccinator muscles serving as posterior support
- Forward movement of prosthesis from anatomic inclination (angulation of mandible with moderate to advanced bone loss)
- Thinning of mucosa, with sensitivity to abrasion
- Loss of basal bone
- Possible Nerve Impairment from dehiscent mandibular neurovascular canal
- More active role of tongue in mastication
- Effect of bone loss on esthetic appearance of lower third of face
- Increased risk of mandibular body fracture from advanced bone loss
- Loss of anterior ridge and nasal spine, causing increased denture movement and sore spots during function



• **Fig. 1.18** (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 (red arrow) are positioned above the residual anterior ridge. The body of the mandible is only a few millimeters thick, and the mandibular canal is completely dehiscent. In the maxillary anterior ridge, only the nasal spine remains (not the original alveolar ridge), and the posterior maxillary bone is very 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 becoems pathologically thin.



• **Fig. 1.19** Resorption of an edentulous mandible may result in dehiscence of the mandibular canal and associated nerve impairment. In addition, a conventional removable prosthesis is often difficult to wear because of the associated discomfort from the exposed nerve. The soft tissue is often thin and is usually hypersensitive, especially if the patient is wearing a conventional removable prosthesis



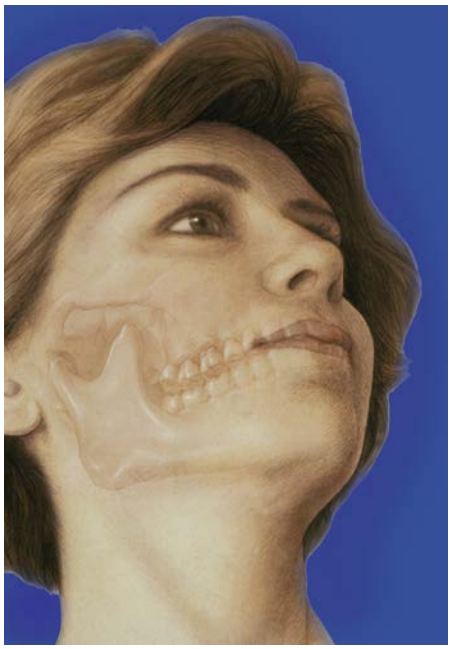
• **Fig. 1.20** Panoramic radiograph exhibiting extensive mandibular posterior atrophy. Note that the anterior teeth have maintained the bone in the anterior mandible and has resulted in the degradation of the premaxilla (Combination Syndrome). Wearing of a mandibular class I removable partial denture has escalated the posterior bone loss.

thickness of the surface tissues gradually decreases. Therefore, soft tissue irritation usually results.

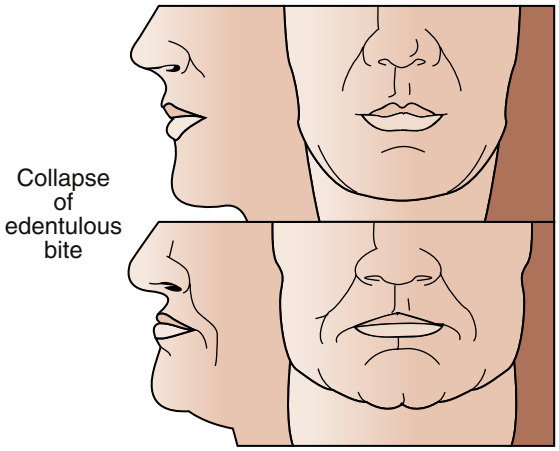
The tongue of the patient with edentulous ridges often enlarges to accommodate the increase in space formerly occupied by teeth. At the same time, the tongue is used to limit the movements of the removable prostheses and takes a more active role in the mastication process. As a result, the removable 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 task. The aged patient who recently became edentulous may lack the motor skills needed to adjust to the new conditions (Fig. 1.20; Box 1.4).

• BOX 1.4 Soft Tissue Consequences of Edentulism

- Attached, keratinized gingiva is lost as bone is lost
- Unattached mucosa for denture support causes increased soft spots
- Thickness of tissue decreases with age, and systemic disease causes more sore spots for dentures
- Tongue increases in size, which decreases denture stability
- Tongue has more active role in mastication, which decreases denture stability
- Decreased neuromuscular control of jaw in the elderly



● **Fig. 1.21** Esthetics of the inferior third of the face are related to the position of the teeth and include the muscles that attach to the bone.



● **Fig. 1.22** Long term denture use leads to many soft tissue changes. The loss of vertical dimension results in many changes, including a closed bite, a mandible that rotates forward, a receding maxilla, reverse smile line, increased number and depth of lines in the face, more acute angle between the nose and the face, loss of vermilion border in the lips, jowls, and witch's chin from loss of muscle attachment.

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. 1.21 and 1.22). A decrease in facial height from a collapsed vertical dimension results in several facial changes. The loss of the labiomental angle and deepening of vertical lines in the area create a harsh 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. 1.23). These conditions result in a decrease in the horizontal labial angle at the corner of the lips, and 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.

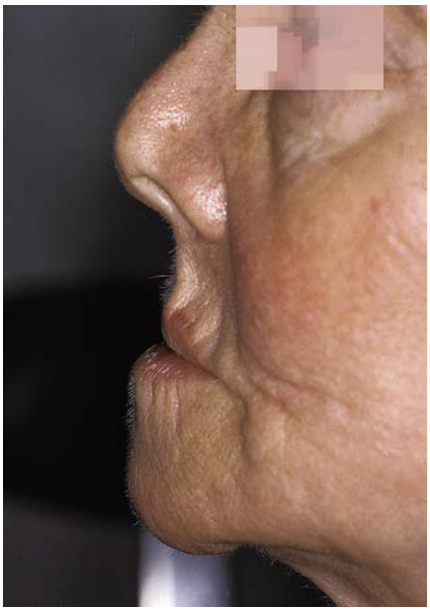
● **Fig. 1.23** Loss of bone height can lead to a closed bite with rotation of the chin anterior to the tip of the nose.

A thinning of the vermilion border of the lips results from the poor lip support provided by the prosthesis and the loss of muscle tone; its retruded position is related to the loss of premaxilla ridge and the loss of tonicity of the muscles involved in facial expression. Sutton et. al. evaluated 179 white patients at different stages of jaw atrophy, the collapse of the lips and circumoral musculature.[37] The contraction of the orbicularis oris and buccinator muscles in the patient with moderate to advanced bone atrophy displaces the modiolus and muscles of facial expression medially and posteriorly. As a result, a narrowing of the commissure, inversion of the lips, and hollowing of the cheeks are very characteristic findings (Fig. 1.24).[37] Women often use one of two techniques to hide this cosmetically undesirable appearance: either no lipstick and minimal makeup, so that little attention is brought to this area of the face, or lipstick drawn on the skin over the vermilion 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. This usually is accompanied by an increase in the columella-philtrum angle and can make the nose appear larger than if the lip had more support (Fig. 1.25). The maxillary lip naturally becomes longer with age as a result of gravity and loss of muscle tone, resulting in less of the anterior teeth shown when the lip is at rest. This 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. Loss of muscle tone is accelerated in the edentulous patient, and 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 by bone atrophy. 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 in which the muscles used to attach.

Patients usually are unaware the hard and soft tissue changes are from the loss of teeth. Studies have shown that 39% of denture

patients have have been wearing the same prosthesis for more than 10 years.[35] Therefore the consequences of tooth loss is a slow process and must be explained to the partially or completely edentulous patient during the early phases of treatment (Box 1.5).



● **Fig. 1.24** This patient has severe bone loss in the maxilla and mandible. Although she is wearing her 15-year-old dentures, the facial changes are significant. The loss of muscle attachments lead to ptosis of the chin (witch's chin), loss of vermilion border (lipstick is applied to the skin), reverse lip line (decrease in horizontal angles), increased vertical lines in the face and lips, increased lip angle under the nose, and a lack of body in the masseter and buccinator muscles.

Conventional Prosthesis Complications

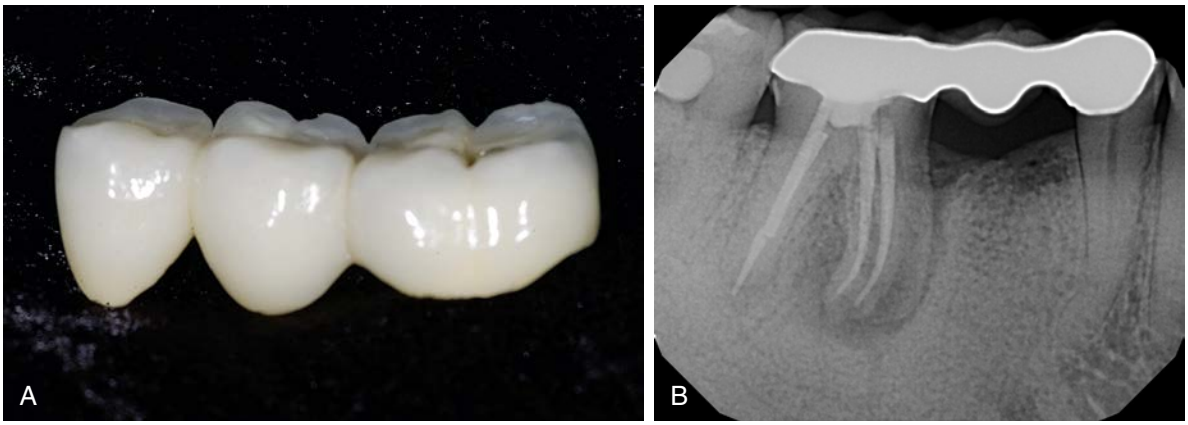
Fixed Partial Denture Morbidity

In the past, the most common treatment option to replace a posterior single tooth was a three-unit fixed partial denture (FPD). This type of restoration can be fabricated within a very short period of time and usually satisfies the criteria of normal contour, comfort, function, esthetics, speech, and health. Because of these benefits, a FPD has been the treatment of choice for the last 6 decades. This is a widely accepted procedure within the profession. Hard and soft tissue considerations in the missing site are minimal. Every dentist is familiar with the procedure, and it is widely accepted by the profession, patients, and dental insurance companies. In the United States, approximately 70% of the population is missing at least one tooth. Almost 30% of those aged 50 to 59 examined in a US National Survey exhibited either single or multiple edentulous

• BOX 1.5 Esthetic Consequences of Bone Loss

- Decreased facial height
- Loss of labiomental angle
- Deepening of vertical lines in lip and face
- Chin rotates forward giving a prognathic appearance
- Decreased horizontal labial angle of lip, which makes the patient look unhappy
- Loss of tone in muscles of facial expression
- Thinning of vermilion border of the lips from loss of muscle tone
- Deepening of nasolabial groove
- Increase in columella-philtrum angle
- Increased length of maxillary lip, so less teeth show at rest and smiling, which ages the smile
- Ptosis of buccinator muscle attachment, which leads to jowls at side of face
- Ptosis of mentalis muscle attachment, which leads to "witch's chin"

● **Fig. 1.25** (A) Panoramic radiograph of a 68-year-old female. The maxillary arch has severe atrophy and almost complete basal bone loss, including most of the nasal spine. The maxillary sinuses are completely pneumatized. The mandible exhibits severe atrophy with associated nerve dehiscence (B) Profile view. Note the maxillary bone loss effect: the lack of vermilion border of the lip, deep labial folds, and the columella-philtrum angle. The lower lip has a normal vermilion border and the muscles to the lower jaw are still attached, providing a normal contour.



• **Fig. 1.26** (A) Three-unit fixed partial denture is the most common method to replace missing teeth in the posterior regions of the jaws. (B) Three-unit fixed partial dentures have an increased possibility of recurrent decay or fracture with a poorer long-term success rate than an implant supported prosthesis.

spaces bordered by natural teeth.[38] However, there exist many inherent complications with FPDs. A three-unit FPD also presents survival limitations to the restoration and, more importantly, to the abutment teeth.[39] In an evaluation of 42 reports since 1970, Creugers and colleagues[15] calculated a 74% survival rate for FPDs for 15 years. The mean life spans of 9.6 to 10.3 years have been reported by Walton and colleagues[40] and Schwartz colleagues,[41] respectively. However, reports are very inconsistent, with as little as 3% loss over 23 years to 20% loss over 3 years. Caries and endodontic failure of the abutment teeth are the most common causes of prostheses failure. Up to 15% of abutment teeth for an FPD require endodontic therapy compared with 3% of nonabutment teeth that have crown preparations. The long-term periodontal health of the abutment teeth, including bone loss, may also be at greater risk.[39] Unfavorable outcomes of FPD failure include both the need to replace the failed prosthesis and the loss of an abutment and the need for additional pontics and abutment teeth in the replacement bridge. The abutment teeth of an FPD may be lost at rates as high as 30% within 14 years. Approximately 8% to 12% of the abutment teeth holding an FPD are lost within 10 years. The most common reason for single-tooth loss is endodontic failure or fracture of a tooth (usually after endodontic therapy).[42] Because 15% of abutment teeth require endodontics, and root canal therapy may be 90% successful at the 8-year mark, abutment teeth are at increased risk of loss. In addition, abutment teeth are more prone to caries when splinted together with an intermediary pontic. Individual crowns have decay rates below 2%; however, the risk of caries in abutment teeth is approximately 20%, mainly because the pontic region acts as a plaque reservoir. The carious lesion at the crown margin may cause structural failure, even if endodontic treatment is possible (Fig. 1.26). Almost 80% of abutments prepared for a three-unit FPD have no existing or only minimal restorations.[33] Rather than removing sound tooth structure and crowning two or more teeth, increasing the risk of decay and endodontic therapy (and splinting teeth together with pontics, which have the potential to cause additional tooth loss), a dental implant may replace the single tooth with a very high success rate (Box 1.6).

Therefore even though an FPD is an accepted treatment in dentistry, many inherent complications may develop. When evaluating partially edentulous spaces, a treatment option for replacement with a dental implant should always be included in the possible options presented to the patient.

• BOX 1.6 Single-Tooth Replacement—Fixed Partial Denture

- Estimated mean life span of FPD (50% survival) reported at 10 years
- Caries most common cause of FPD failure
- 15% of FPD abutments require endodontics
- Failure of abutment teeth of FPD 8% to 12% at 10 years and 30% at 15 years
- 80% of teeth adjacent to missing teeth have no or minimal restoration
- Possible esthetic issues

FPD, *Fixed partial denture.*

Removable Partial Denture Morbidity

Removable soft tissue–borne partial dentures (RPD's) have one of the lowest patient acceptance rates in dentistry. Half the patients with a removable partial denture chew better without the prosthesis. A 44-year Scandinavian 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.[43,44]

Wetherall et. al. reported a 60% tolerance and success in a 5-year distal extension RPD study. After 10 years, this was reduced to 35%[45] Wilding et. al. showed that very few partial dentures survived more than 6 years.[46] Although one of five US adults has had a removable prosthesis of some type, 60% reported at least one problem with it.[47] Reports of removable partial dentures indicate that the health of the remaining dentition and surrounding oral tissues often deteriorates. 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.[43,45] Those patients wearing the partial dentures often exhibit greater mobility of the abutment teeth, greater plaque retention, increased bleeding on probing, higher incidence of caries, speech inhibition, taste inhibition, and noncompliance of use. A report by Shugars and colleagues found abutment tooth loss for a removable partial denture may be as high as 23% within 5 years and 38% within 8 years.[39] Aquilino and colleagues reported a 44% abutment tooth loss within 10 years for a removable partial denture.[48] In addition, it should be noted that those patients wearing an RPD will accelerate bone loss

• BOX 1.7 Negative Effects of Removable Partial Dentures

- Low survival rate: 60% at 4 years
- Low survival rate: 35% at 10 years
- Morbidity of abutment teeth: 60% at 5 years and 80% at 10 years
- Increased mobility, plaque, bleeding on probing, and caries of abutment teeth
- 44% abutment tooth loss within 10 years
- Accelerated bone loss in edentulous region if wearing removable partial denture

in the soft tissue support regions. Therefore alternative therapies that improve oral conditions and maintain bone are often warranted (Box 1.7).

Complete Denture Morbidity

Masticatory function is an important factor when discussing complete denture function. 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 pounds per square inch (psi).[49] A patient who grinds or clenches the teeth may exert a force that approaches 1000 psi. The maximum occlusal force in the edentulous patient has been shown to be 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.[50]

As a result of decreased occlusal force and the instability of the denture, masticatory efficiency also decreases with tooth loss. Within the same 15-year time frame, 90% of the food chewed with natural teeth fits through a No. 12 sieve; this is reduced to 58% in the patient wearing complete dentures.[51] The 10-fold decrease in force and the 40% decrease in efficiency affects the patient's ability to chew. In persons with dentures, 29% are able to eat only soft or mashed foods,[52] 50% avoid many foods, and 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.[53] Lower intakes of fruits, vegetables, and vitamin A by women were noted in this group. These patients took significantly more medications (37%) compared with those with superior masticatory ability (20%), and 28% were taking medications for gastrointestinal disorders. The reduced consumption of high-fiber foods could induce gastrointestinal problems in edentulous patients with deficient masticatory performance. In addition, the coarser bolus may impair proper digestive and nutrient extraction functions.[54] There are systemic consequences from patients wearing conventional dentures. The literature includes several reports suggesting that a compromised dental function causes poor swallowing and masticatory performance, which in turn may influence systemic changes favoring illness, debilitation, and shortened life expectancy.[55-59] In a study evaluating the ability to eat fruit, vegetables, and other dietary fiber in edentulous subjects, 10% claimed difficulty, and blood tests demonstrated reduced levels of plasma ascorbate and plasma retinol compared with dentate subjects. These two blood tests are correlated with an increased risk of dermatologic and visual problems in aging adults.[60] In a study, the masticatory performance and efficiency in denture wearers were compared with dentate individuals. This report noted that when appropriate connections were made for different performance norms and levels, the chewing efficiency of a denture wearer was less than one-sixth of a person with teeth. Several reports in the literature correlate a patient's health and life span to dental health.[61] Poor chewing ability may be a cause of involuntary weight loss in old age, with an increase in mortality. In contrast, persons with a substantial number of missing teeth were more likely to be obese.[62] After conventional risk factors for strokes and heart attacks were accounted for, there was a significant relationship between dental disease and cardiovascular disease, with the latter still remaining as the major cause of death. It is logical to assume that restoring the stomatognathic system of these patients to a more normal function may indeed enhance the quality and length of their lives.[63-65]

When patients wear a removable prosthesis, there exists a significant psychological component to the associated drawbacks of the prosthesis. The psychological effects of total edentulism are complex and varied and range from very minimal to a state of neuroticism. Although complete dentures are able to satisfy the esthetic needs of many patients, there are those who feel their social life is significantly affected.[66] They are concerned with kissing and romantic situations, especially if a new partner in a relationship is unaware of their oral handicap. Fiske and colleagues,[66] in a study of interviews with edentulous subjects, found tooth loss was comparable to the death of a friend or loss of other important parts of a body in causing a reduction of self-confidence ending in a feeling of shame or bereavement.

One dental survey of edentulous patients found 66% were dissatisfied with their mandibular complete dentures. Primary reasons were discomfort and lack of retention causing pain and discomfort.[67] Past dental health surveys indicated that only 80% of the edentulous population are able to wear both removable prostheses all the time.[68] Some patients wear only one prosthesis, usually the maxillary, whereas 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 "oral invalids." They rarely leave their home environment and when they feel forced to venture out, the thought of meeting and talking to people when not wearing their teeth is unsettling.

A report of 104 completely edentulous patients seeking treatment was performed by Misch.[53] Of the patients studied, 88% claimed difficulty with speech, with one-fourth having great difficulty. As a consequence, it is easy to correlate the reported increase with concern relative to social activities. Awareness of movement of the mandibular denture was cited 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 (63.5%), and surprisingly, 16.5% of the patients stated they never wear the mandibular denture.

In comparison, the maxillary denture was uncomfortable half as often (32.6%), and only 0.9% were seldom able to wear the prosthesis. Function was the fourth most common problem reported by these 104 denture wearers. Half the patients avoided many foods, and 17% claimed they were able to masticate more effectively without the prostheses. The psychological effects of the inability to eat in public can be correlated with these findings. Other reports agree that the major motivating factors for patients to undergo treatment were related to the difficulties with eating, denture fit, and discomfort. The psychological need of the edentulous patient is expressed in many forms. For example, in 1970, Britons used approximately 88 tons of denture adhesive.[69] In 1982, more than 5 million Americans used denture adhesives (Ruskin Denture Research Associates: AIM study, unpublished

• BOX 1.8 Negative Effects of Conventional Denture Prostheses

- Bite force is decreased from approximately 200 to 50 psi
- 15-year denture wearers have reduced bite force to 6 psi
- Masticatory efficiency is decreased
- Lack of proprioception
- Higher incidence of gastrointestinal disorders
- Patients life span may be decreased
- Food selection is limited
- Psychological factors

psi, *Pounds per square inch.*

• BOX 1.9 Advantages of Implant-Supported Prostheses

- Maintain bone
- Restore and maintain occlusal vertical dimension
- Maintain facial esthetics (muscle tone)
- Improve esthetics (teeth positioned for appearance versus decreasing denture movement)
- Improve phonetics
- Improve occlusion
- Improve/regain oral proprioception (occlusal awareness)
- Increase prosthesis success
- Improve masticatory performance/maintain muscles of mastication and facial expression
- Reduce size of prosthesis (eliminate palate, flanges)
- Provide fixed versus removable prostheses
- Improve stability and retention of removable prostheses
- Increase survival times of prostheses
- No need to alter adjacent teeth
- More permanent replacement
- Improve psychological health
- Overall health improved

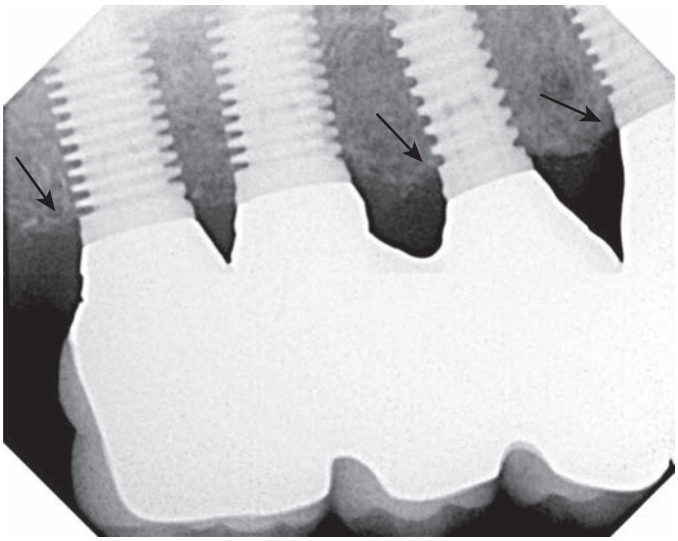
data, 1982), and a report shows that in the United States, more than $200 million is spent each year on denture adhesives, representing 55 million units sold.[70] The patient is often willing to accept the unpleasant taste, need for recurring application, inconsistent denture fit, embarrassing circumstances, and continued expense for the sole benefit of increased retention of the prosthesis. Clearly the lack of retention and psychological risk of embarrassment in the denture wearer with removable prostheses is a concern the dental profession must address (Box 1.8).

Advantages of Implant-Supported Prostheses

The use of dental implants to provide support for prostheses offers many advantages compared with the use of FPDs or removable soft tissue–borne restorations (Box 1.9).

Maintenance of Bone

A primary reason to consider dental implants to replace missing teeth is the maintenance of alveolar bone (Fig. 1.27). The dental implant placed into the bone serves both as an anchor for the prosthesis and as one of the effective maintenance procedures in dentistry. Stress and strain may be applied to the bone surrounding the implant. As a result, the decrease in trabeculation and loss of bone that occurs after tooth extraction is reversed. There is an



• **Fig. 1.27** Note the long term bone maintenance around the multiple splinted implants.

increase in bone trabeculae and density when the dental implant is inserted and functioning. The overall volume of bone is also maintained with a dental implant. Even grafts of iliac crest bone to the jaws, which usually resorb without dental implant insertion within 5 years, are instead stimulated and maintain overall bone volume and implant integration. An endosteal implant can maintain bone width and height as long as the implant remains healthy and stimulates the bone within physiologic limits.[71]

The benefit of bone maintenance is especially noteworthy in the maxillary edentulous arch. Rather than using implants only in the edentulous mandibular arch, because the main mechanical denture problems are in this arch, the maxillary arch should also be addressed. Once implant prostheses are placed to support and retain the mandibular restoration, the bone in the maxillary region continues to be lost and eventually the patient may complain of loss of retention and inability of the maxillary denture to function. The loss of facial esthetics is most often first noted in the maxillary arch, with the loss of vermilion border of the lip, increased length of the maxilla lip, and lack of facial bone support. Implants should be used to treat the continued bone loss and prevent the later complications found in the maxillary arch.

A mandibular denture often moves when the mylohyoid and buccinator muscles contract during speech or mastication. The teeth are often 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 closely related 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 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 occurs 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, which can occur with traditional dentures.

Occlusion Stability

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,[72,73] but an implant-supported restoration is stable. The patient can more consistently return to centric-relation occlusion rather than adopt variable positions dictated by the prosthesis' instability. 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. Patients with natural teeth can perceive a difference of 20 µm between the teeth, whereas implant patients can determine a 50-µm difference with rigid implant bridges compared with 100 µm in those with complete dentures (either uni- or bilateral).[74]

Occlusal Awareness

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

Masticatory Efficiency

In a randomized clinical trial by Kapur and colleagues, the implant group of patients demonstrated a higher level of eating enjoyment and improvement of speech, chewing ability, comfort, denture security, and overall satisfaction.[75] The ability to eat several different foods among complete denture versus mandibular overdenture patients was evaluated by Awad and Feine.[76] The implant overdenture was superior for eating not only harder foods, such as carrots and apples, but also softer foods, such as bread and cheese.[76] Geertman and colleagues evaluated complete denture wearers with severely resorbed mandibles before and after mandibular implant overdentures. The ability to eat hard or tough foods significantly improved.[77,78]

General Health

Researchers at McGill University in Montreal evaluated blood levels of complete denture patients and mandibular implant prostheses 6 months after treatment. Within this rather short period, implant patients had higher B_{12} hemoglobin (related to iron increase) and albumin levels (related to nutrition). These patients also had greater body fat in their shoulders and arms, with decreased body fat in their waists.[79]

Higher Success in Comparison To Other Treatments

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 approximately 75%.[42]

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 endodontic therapy, which are the most common causes of fixed prosthesis failure. A major advantage of the implant-supported prosthesis is that the abutments cannot decay and never require endodontics. The implant and related prosthesis can attain a 10-year survival of more than 90%.

Increased Biting Force

The maximum occlusal force of a traditional denture wearer ranges from 5 to 50 psi. Patients with an implant-supported fixed prosthesis may increase their maximum bite force by 85% within 2 months after the completion of treatment. After 3 years, the mean force may reach more 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 greatly improved compared with that of a soft tissue–borne restoration. The masticatory performance of dentures, overdentures, and natural dentition was evaluated by Rissin and colleagues.[51] The traditional denture showed a 30% decrease in chewing efficiency; other reports indicated a denture wearer has less than 60% of the function of people 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.

Nutrition

Beneficial effects such as a decrease in fat, cholesterol, and the carbohydrate food groups have been reported, as well as significant improvement in eating enjoyment and social life.[80,81] 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 is variable, depending on the number and position of implants, yet all treatment options demonstrate significant improvement to the patients health.[82,83]

Phonetics

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.[73] As a result, a patient in whom the vertical dimension is collapsed may still 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 or palates of the prostheses. This is 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 or fixed prosthesis.

Psychological Health

Patients treated with implant-supported prostheses judge their overall psychological health as improved by 80% compared with their previous state while wearing traditional, removable prosthodontic prostheses. This group perceived the implant-supported prosthesis

• BOX 1.10 Psychological Effects of Tooth Loss

- Range from minimal to neuroticism
- Romantic situations affected (especially in new relationships)
- "Oral invalids" unable to wear dentures
- 88% claim some difficulty with speech, and 25% claim significant problems
- More than $200 million each year spent on denture adhesive to decrease embarrassment
- Dissatisfaction with appearance, low self-esteem
- Avoidance of social contact

as an integral part of their body.[84] For example, Raghoebar and colleagues evaluated 90 edentulous patients in a randomized multicenter study.[85] Five years after treatment, a validated questionnaire targeted patient esthetic satisfaction, retention, comfort, and the ability to speak and eat with either a complete mandibular denture, complete mandibular denture with vestibuloplasty, or mandibular two-implant overdenture. Implant overdentures had significantly higher ratings, whereas no significant difference was found between the two complete-denture groups.[85] Geertman et al. reported similar results comparing chewing ability of conventional complete dentures with mandibular implant overdentures (Box 1.10).[78,86]

The Future of Implant Dentistry

The future of oral implantology is very positive and is expected to continue as one of the fastest and largest growth areas in medicine. The compound annual growth rate (CAGR) for dental implants is expected to grow at an annual rate of 9.7% through 2020, which is supported by improvement in techniques, technology, and materials.[87]

Techniques

Advancements in surgical procedures have had a significant impact on the field of oral implantology. Understanding bone density and modifications in surgical techniques has allowed an increase in success rates in poorer bone qualities. Modification of the bone using new techniques similar to osseodensification now can improve the quality of bone. With more biomechanically advantageous implant designs and the use of resonance frequency analysis (RFA), immediate implant placement and loading protocols have become more predictable. The RFA technology allows for the clinician to measure the bone-to-implant contact (Implant Stability Quotation), which is more accurate and predictable than subjective techniques. The use of better bone substitutes has allowed for predictable bone regeneration procedures to restore the hard and soft tissue loss from extractions. The ability to use bone growth factors (e.g., bone morphogenic proteins [BMPs]) increases the predictability of these procedures.

Technology

Technological advances have had a significant effect on the field of implant dentistry. The use of computerized tomography, mainly cone beam computerized tomography (CBCT), has changed the way clinicians plan and design implant cases. Faster, more efficient, low-radiation scanning machines allow the clinician to virtually plan the implant case with remarkable accuracy. New computer-aided design/computer-aided manufacturing (CAD/CAM) technology associated with CBCT scans allow clinicians to plan, design, and mill the entire case from provisionalization to the final prosthesis in the office setting.

The advent and accuracy of intraoral scanning technologies has risen to a level that has made conventional impression techniques almost obsolete. From a simple digital scan of the area of interest, the image data may be exported to a laboratory for fabrication and design of custom abutments, provisional restorations, and final restorations. Final casts or models may be fabricated via CAD/CAM milling or three-dimensional (3D) printing techniques. In-office 3D printers have given the clinician the luxury of printing models and prostheses in their offices, which is fast and simple.

Materials

One of the major advances in implant dentistry that will have a lasting effect on implant dentistry is the use of zirconia. This material allows the clinician to have a more predictable prosthetic option, which results in fewer and less maintenance and complication issues. The use of CAD/CAM to fabricate zirconia prostheses provides superior marginal integrity, fracture resistance, and flexural strength never seen in dentistry before. Zirconia is used for implant prosthetics and as a dental implant material. Major implant manufacturers are now creating zirconia implant options, showing a significant trend and a real presence of increased use of zirconia in the implant world.

Summary

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 prosthesis. The patient's function when wearing a denture may be reduced to one-sixth of that level formerly experienced with natural dentition; however, an implant prosthesis may return the function to near-normal limits. The esthetics of the edentulous patient are affected as a result of muscle and bone atrophy. Continued bone resorption leads to irreversible facial changes. An implant prosthesis allows normal muscle function, and the 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, as is often required for removable prostheses. 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 patients 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 is often compromised with soft tissue–borne prostheses because 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. An implant-supported prostheses offers a more predictable treatment course than traditional prosthetic restorations. The profession and the public are becoming increasingly aware of this dental discipline. Manufacturers' sales are increasing and expected to increase in the future at an alarming rate. Almost all professional dental journals now publish refereed reports on dental implants. All US dental schools now teach implant dentistry, and this discipline has become an integral part of most specialty programs. The future of implant dentistry is very exciting with unlimited expansion via technology and development. Implant dentistry has become the ideal and primary option for tooth replacement.

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