Horizontal Alveolar Ridge Augmentation in Implant Dentistry
A Surgical Manual
This book is dedicated to my father, Alexander Tsipis. He would be very proud.
Horizontal Alveolar Ridge Augmentation in Implant Dentistry

A Surgical Manual

Edited by

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Preface

“Education is not a learning of facts, but training of the mind to think.”

Albert Einstein.

“Anatomy is destiny;”

Sigmund Freud.

Implant Dentistry (Oral Implantology) is a constantly evolving dental and surgical clinical practice and science. There are a variety of books that come out every year on different aspects of this surgical-/restorative discipline. Large hardcover textbooks with a name containing at least two words implant and dentistry heavily dominate shelves of medical/dental bookstores of many publishing companies and subsequently homes of many dentists who are happy to dedicate themselves to a lifelong learning. For different reasons, these expensive and authoritative books are often not top sellers. These books often become “shelf-bound”, collecting dust but more importantly providing little practical use in spite of their original intent.

During my professional dental graduate and oral and maxillofacial surgery postgraduate studies in three universities, I have always enjoyed more practical books – clinical manuals, These usually smaller medical, surgical, and dental books in a hard or soft cover were my mobile knowledge friends that I could take with me anywhere and study “on the go” in any setting. Arguably, these friendly manuals are preferred by most medical and dental students, residents, and doctors alike.

A good example of this type of clinically relevant practical book for me has always been Rapid Interpretation of EKG’s by Dale Dubin, MD. This is by far one of the most widely read and studied medical books by any medical or dental practitioner who had to learn about electrocardiography (EKG). This outstanding book is now in its successful 6th Edition and has always been a No.1 Best Seller. Why? I believe this is not only because it is a brilliantly written book accompanied by easy to follow photos, graphs, and tables, as well as quizzes and interactive courses, but also because of the book’s immense practicality and relevance for any health science student or practitioner or often a lay reader/learner.

The book that you are holding in your hands is an attempt to write this sort of book, a very clinically relevant surgical manual, a practical guide on the WHY and HOW of the alveolar bone augmentation in implant dentistry, a “take to the operative room” book full of clinically oriented chapters that can be easily understood and followed.

In the middle of writing this book, due to an enormous amount of accumulated techniques for the surgical alveolar ridge augmentation, Dr. Ole Jensen (whom I consider my mentor and who wrote an Introduction for this book) suggested that it would be an impossible and confusing task to demonstrate to doctors, residents, and students all these amazing surgical techniques in a single book volume. The size of this book would be enormous and practicality of having something very relevant with you and being able to “carry it around” would be a daunting task. That is how slowly the concept of two volumes (two books, really) evolved where horizontal and vertical ridge augmentation techniques in a style of a surgical manual-atlas full of case reports and illustrative photos are described in separate books.

The first book (Book I) contains multiple surgical techniques intended for mainly width-deficient alveolar ridges and thus the book is, in general, about the horizontal ridge augmentation; the second book, Vertical Alveolar Ridge Augmentation in Implant Dentistry: A Surgical Manual (Book II) contains a variety of surgical procedures designed for height (and volume) deficient alveolar ridges and therefore is about vertical and three-dimensional ridge augmentation. Both books do not claim to be a complete all-inclusive dissertation of all alveolar bone augmentation techniques. That would be impossible and impractical. Many surgical techniques are being proposed almost daily on the pages of peer-review oral surgical, periodontal, implant, and general dental journals and other publications. They are also often modified from the original versions with the discovery of new instrumentation and advances in computer technology. Two books approach was a logical (we thought) attempt to “split” the presented material into horizontal and vertical surgical techniques for the sake of learning.

Our goal with these two intrinsically linked books was to present a variety of commonly used and sometimes less known surgical techniques from a different point of view in a clear and concise manner with photographs and illustrations, and supplemented by case reports. Each book starts with the applied surgical anatomy and embryology of the jaws, move through diagnosis and treatment planning, which includes a team approach with restorative practitioner (prosthetic chapter) and often an orthodontic colleague (orthodontic implant side development chapter), and then move to a variety of hard (and even soft) tissue augmentation techniques. Each book ends with a glance into the future (quickly becoming a present-day reality), like tissue engineering, stem-cell technology, and organ regeneration. All these chapters were written by top-notch surgical specialists (surgeons–researchers–lecturers) from around the globe in the area of their particular expertise.

A reader of any skill or knowledge– a surgical resident or a new dental practitioner, an experienced periodontist or an oral and
maxillofacial surgeon- pay a special attention to the following three surgical concepts presented in these books:

1 Soft tissue versus hard tissue augmentation, or a combined hard-soft tissue augmentation approach that is often needed in the esthetic zone.

2 Static versus dynamic bone augmentation of the alveolar ridge (block graft versus distraction osteogenesis, or ridge-split versus orthodontic forced eruption, or guided bone regeneration (GBR) versus perioseal expansion osteogenesis).

3 Two-dimensional versus three-dimensional versus four-dimensional (predicting future bone changes associated with aging) bone augmentation.

As the editor and one of many contributors of these two surgical manuals, I hoped to accomplish the intended goal of these two books - to present a clinically relevant surgical material that would be read and re-read many times during your career and, therefore, would undoubtedly benefit your patients. If this will happen, I will consider myself a happy man.

Len Tolstunov
Acknowledgments

I would like to express my sincere gratitude to all 70 individuals from around the globe (from 10 countries) who became contributors to these two books (65 chapters in total) for their unselfish sharing of their knowledge, expertise, talent, and time. This was a volunteer army of top-notch professionals who sacrificed their own personal time to contribute to these books and thus to dental and medical education. In the process of book writing and production, many of them have become my friends and genuine collaborators whom I admire and look up to.

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Introduction

In modern implant-driven oral rehabilitation, alveolar bone deficiency is defined by what is necessary for successful dental implant osseointegration. This need for adequate quantity and quality of bone has led to the development of several innovative methods for alveolar ridge augmentation. At the same time, improved implant technology, like computer-guided implant placement methods, have lessened the need for complex augmentation procedures. The practitioner may ask what is needed for a specified treatment without regard to full regeneration of hard tissue. Where once large-scale reconstruction was considered, now minimally invasive surgical procedures are employed. The clinician then may ask what kind of minimally invasive procedures can and should be performed to support a restoratively driven implant treatment plan. This book will attempt to answer this question.

In addition to osseointegration, there are other factors to consider, including regaining alveolar form and associated esthetic gingival contour – effects termed orthoalveolar form. Orthoalveolar form, however, implies that the alveolar process and associated soft tissues are restored to ideal form and function with alveolar arches in functional occlusal relationship, including alveolar width and height and gingival drape essential for osseointegration and subsequent long-term function of dental implants. This means that the alveolus is not only restored to its original form but also often increased in bone mass and quality of soft tissue to accommodate dental implants. It is important to be familiar with a variety of surgical procedures in order to achieve an orthoalveolar form. This book will attempt to demonstrate these techniques.

Practitioners sometimes lose sight of what they need to accomplish. Completion of a surgical grafting procedure may not be needed for the prescribed implant procedure. Final restoratively driven surgical outcome according to a precise implant treatment plan helps to keep the whole dental team on track of what is needed to accomplish in each particular case. The surgeon must visualize where implant elements need to be placed, decide if the bone mass is needed there to support implants, and graft accordingly. This requires preprosthetic planning, which may include the use of surgical guide or navigation. The plan may prescribe staged or simultaneous grafting, even secondary grafting after implant placement. Whatever the plan, surgical efforts should attempt to gain added bone stock within the envelope of function, choosing a surgical method that has a biological basis for success. This book will attempt to illustrate these methods.

The surgical method of grafting is judged by early and late healing events but include the concepts of consolidation, functional remodeling, resistance to resorption, and bioactive capability for osseointegration. An ideal bone graft should therefore be well consolidated, undergo remodeling without significant resorption, and be well vascularized. Bone graft substitutes, like alloplasts, xenografts, and possibly allografts, may not fully integrate with native bone. Various forms of autografts, recombinant biomimetics, and autologous cell-based therapies may have an improved biological basis but require advanced surgical skills and technical support. This book will attempt to describe these therapies.

The quest for ideal bone graft is continuing. New techniques are constantly being introduced to simplify, improve, or expand indications for alveolar reconstruction. Currently, surgical techniques for implant-driven alveolar ridge augmentation can be classified into four broad categories. These would include: (1) guided tissue and bone regeneration (with or without titanium-reinforced devices), (2) block grafting (extraoral and intraoral), (3) ridge-split with formation of osteoperiosteal (pedicled) flaps, and (4) distraction osteogenesis. Alveolar ridge deficiency can also be classified according to defect morphology such as vertical defects, horizontal defects, combination defects, and complete absence of bone. Science and practice of alveolar ridge reconstruction is still a descriptive surgical discipline with numerous variables to consider, not the least of which is the “patient factor” that includes the patient’s general medical condition, patient’s wishes and desires (wants and needs), and patient’s cooperation. This book will attempt to address these factors of importance.

Another factor to consider in any surgery is the healing capacity of the host’s recipient site being grafted. In many cases, it can be more important than the type of material used for grafting. If the site is well vascularized and the grafting procedure is done well, complete incorporation of the bone graft may occur. Interestingly, in 1668, the very first bone graft (harvested from a dog) worked so well that it could not be removed when the patient asked for it to be removed for religious reasons at a later date. Failure of a bone graft, often attributed to the material used, probably happens more often due to host site healing deficiency or flawed surgical technique rather than the intrinsic property of the graft material per se.

One factor that has become extremely important is simplification of treatment, that is, economy of surgery, management, and expenditure. This means that the social contract between patient and physician has narrowed to favor minimally invasive procedures, shortened treatment times, simplified surgical management, and affordability. This is why an immediate function implant treatment has become so prevalent, even in the face of simultaneous bone grafting. The difficulty with simplification is proper diagnosis, comprehensive treatment planning, and adequate training. In addition, consensus on bone grafting and decision-making process are often limited to experience-based case report knowledge and lacking level I and II evidence-based controlled studies that are frequently difficult to find.

The purpose of this clinically oriented book in two volumes is to demonstrate the various techniques of implant-driven horizontal (Book I) and three-dimensional/vertical (Book II) alveolar bone augmentation treatment in use today in an easy to follow, step-by-step format. An international and multidisciplinary group of surgical specialists, well known in their own fields, will present various
surgical methods that will be illustrated graphically and supplemented by multiple intraoperative photographs. Benefits, risks, alternatives and complications of each technique will be demonstrated and scientific references will be provided, giving a reader a true insight into each surgical technique. This, hopefully, will help a reader to improve the knowledge of a selected technique as well as broaden the scope of surgical modalities that can be successfully employed in his or her practice. If you are a true learner, this book is for you.

Ole T. Jensen
SECTION I

Introduction
Brånemark’s discovery of osseointegration arguably became one of the most significant events in dentistry in the twentieth century [1,2]. It could be stated that this discovery divided dentistry into two periods: pre-implant era or era of symptomatic (symptom-driven) dentistry and an implant era or era of physiologic dentistry. In the first period, restorative dentistry had only two meaningful treatment options for failed teeth or edentulous jaws: removable dentures and fixed bridges. Both removable dentures and fixed bridges relied on support of adjacent teeth and underlying alveolar mucosa with little consideration for bone preservation.

For the last 50 years of the second and modern period of dentistry, restorative (reconstructive) dentistry has been utilizing physiologic treatment by replacing missing or failing teeth with bone-anchored (osseointegrated) endosseous implants that have an ability to maintain the alveolar bone in a similar manner to a natural dentition. A new principle of bone preservation was based on the concept of endosseous bone loading (EBL). Dental implants also removed an unnecessary load from adjacent teeth, thus decreasing and eliminating deteriorating effects of removable and fixed toothborne prostheses on natural dentition, strengthening masticatory function, and improving esthetics and patient’s comfort.

Initially surgically driven, implant dentistry was concerned mainly with an implant integration of dental implants. It was soon to become clear that in order to properly restore endosseously placed implants, they have to be inserted into the bone in a restoratively driven position, identical or close to where the natural teeth used to be, even if bone was no longer available in the area. Implant dentistry has emerged as a prosthetically driven surgical–restorative discipline.

In the last few decades, it became clear that success of implant dentistry and longevity of dental implants depend on three factors (“implant triangle”). These factors are: (1) a proper restoratively driven placement of implants, (2) the presence of a sufficient amount of bone stock, a foundation for the osseointegration, and (3) the presence of healthy peri-implant soft tissue for proper implant hygiene and maintenance. Missing any one component of the implant triangle tends to eventually result in compromise of implant health or longevity, and can often lead to implant failure.

The presence of bone atrophy or resorption due to tooth loss and trauma (among many other factors) has led to the development of a variety of implant-driven bone augmentation procedures in a single or staged fashion. This two-volume book is about bone augmentation techniques applicable to implant dentistry. A variety of bone augmentation procedures for the deficient (atrophyed) alveolar bone has been proposed in the literature [3–5] and are described in these two books. Each method has its indications and contraindications, its proponents and opponents. The following four alveolar ridge reconstruction techniques are frequently used in oral implantology and are described in this book:

1 Guided bone regeneration (GBR) with particulate bone graft [6,7].
2 Onlay (veneer) extraoral (hip, rib, calvarium) [8] and intraoral (chin, ramus, posterior mandible, zygomatic buttress, maxillary tuberosity) [9–11] block bone graft.
3 Ridge-split/bone graft and sandwich osteotomy [12–14].
4 Alveolar distraction osteogenesis [15,16].

To simplify learning of the surgical techniques, the editor (Tolstunov) of this book divided them roughly into two categories: horizontal augmentation and vertical (volumetric) augmentation. Book I inspects horizontal bone augmentation of alveolar ridges with bone width deficiency and Book II scrutinizes vertical bone augmentation of alveolar ridges with bone height loss. Both books do not claim to be a complete all-inclusive dissertation of all alveolar bone augmentation techniques. That would be impossible and impractical. Many surgical techniques are being proposed almost daily on the pages of peer-review oral surgical, periodontal, implant, and general dental journals and other publications. They are also often modified from the original versions with the discovery of new instrumentation and computer technology.

Classifications tend to simplify learning of a certain subject. They often give a reader a “bird’s-eye view” of the complex topic. There is a variety of different classifications of alveolar bone augmentation in implant dentistry. Table 1.1 demonstrates the editor’s classification. Based on years of teaching, practicing and in the process of writing this book, we offer the classification that can, hopefully, be well understood by students, surgical residents, and doctors, and be conceptually robust from the biologic point of view. Examine Table 1.1 after finishing this chapter.

The editor’s recommendation for readers of this two-volume book is to open the book on any chapter that seems clinically relevant at that particular moment and read/learn/study the technique thoroughly. Targeted (selective) reading is common and productive in medical literature. After finishing one chapter, you might want to come back later to the same chapter to re-think its content. Then, move on to another chapter on a different type of
(horizontal or vertical) augmentation for comparison, as well as read current literature on this subject. This might help you to eventually select the technique that suits you (feels best in your hands). Always remember the biologic rationale of each procedure when selecting the one to help your particular patient. For a novice dental surgeon or an experienced dental practitioner while studying surgical methods and techniques, I would suggest paying special attention to the following:

1. Soft tissue versus hard tissue augmentation: what is needed and what is the priority, especially in the esthetic zone.

2. Static versus dynamic bone augmentation techniques: block graft versus distraction osteogenesis, ridge-split versus orthodontic forced eruption, etc.

3. Two-dimensional (2D), three-dimensional (3D), and, finally, “four-dimensional” (4D) tissue augmentation: horizontal or vertical (2D) versus volumetric (3D) versus time-dependent bone and soft tissue grafting (considering the fourth dimension), with emphasis on aging changes that can be predicted and prevented by thoughtful augmentation techniques (especially, in the anterior maxilla).
Use this book as a surgical reference guide or manual at any locations – at the university, home, or in the operative room – and let us know what you liked or did not like, and what you would change, add, or delete in future editions of this book. We want each new edition to be better that the one before. Good luck on your learning journey for the benefit of your patients.

I. Particulate bone grafting
1 For INLAY grafts consider xenograft, possibly with autogenous bone (including bone morphogenetic protein (BMP)). Ideally, implant neck and apex are to be positioned in the native bone while the implant body is to be surrounded by the grafted bone. Primary implant stability in the native bone is important.
2 For ONLAY grafts consider mixed xeno-allograft, possibly with autogenous bone (including BMP). Implant neck is to be surrounded by the grafted bone, while the implant body is to be placed into the native bone with good primary stability (30 + Ncm) at the time of insertion.

Tenting procedures for the particulate graft
1 Cortical autogenous grafted. Detached free cortical bone block in width or height-deficient ridges is used for a 2D augmentation with a particulate graft positioned in between the cortical block and basal (native) bone as an INLAY graft. Separated cortical “tenting” free bone has no blood supply initially and 4-5 weeks later-some re-established periosteal source of revascularization only, which limits its survival and increases its impending resorption. Both endosteal and periosteal revascularization are provided for the particulate graft that has a good survival potential.
2 Ti-mesh tenting. Titanium mesh is used for 3D (volumetric) reconstruction of the collapsed ridge and functions as a scaffold protective device for the particulate graft underneath. The particulate graft is placed in ONLAY fashion on top of native bone. Endosteal revascularization is provided for the particulate graft that has a good survival potential.
3 Periosteal tenting
(a) Screw tenting: a soft tissue matrix is tented by metal screws for space creation for the particulate graft placed in ONLAY fashion on top of native bone. Both 2D and 3D ridge augmentations are possible (horizontally and vertically positioned screws). Endosteal and periosteal revascularizations are provided for the particulate graft that has a good survival potential.
(b) Implant tenting: a soft tissue envelope is tented by dental implants for space creation for the particulate graft placed in ONLAY fashion on top of native bone. A 2D ridge augmentation in height-deficient ridges is possible. Endosteal and periosteal revascularization are provided for the particulate graft that has a good survival potential.

II. Block bone grafting
Onlay or inlay, horizontal, vertical or combination (J-graft), fixation screws and plates. Secondary bone resorption often occurs.

III. Alveolar distraction osteogenesis
Horizontal or vertical, specific distractor devices.

IV. Free distant bone flap transfer with microvascular anastomosis
Vertical and horizontal, plates and screws.

Graft Revascularization implies bone healing (from angiogenesis to mineralization and ossification) from the particular vascular source:
1 Endosteal (central or centrifugal). Bone-to-bone healing (ossification) through angiogenesis. This applies to any onlay or inlay grafts and also for a gap osteotomy created by osteoperiosteal flaps (as in the ridge-split procedure). This is a dominant source of blood supply needed for free bone graft survival.
(a) Particulate graft: internal “coagulum” is converted into the woven bone; fast revascularization through bone formation.
(b) Block graft: plasmatic imbibition to block graft; slow revascularization through resorption.
2 Periosteal (peripheral or centripetal). Periosteal proximal angiogenesis to the grafted bone that is exposed to the juxtaposed periosteum (as in an onlay block graft). This is a supplementary source of blood supply needed for free bone graft survival.
3 Microvascular anastomosis. The best source of blood supply. Vascular free graft with hard and soft tissue transfer. The endosteal and periosteal sources are also established and are supplementary.

References


CHAPTER 2

Applied Surgical Anatomy of the Jaws

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Introduction

After extraction of teeth, the alveolar bone sockets heal and create an alveolar ridge. The new alveolar ridge is covered by thin cortex made up of compact bone overlying a core of cancellous bone and bone marrow. A full denture wearer’s bite force decreases from 200 psi to 50 psi. In fifteen years denture wearers have a reduced bite force of about 6 psi [1,2]. As a result, loss of alveolar bone ridge width and height occur in most patients and the dentures become loose. Many edentulous persons with or without dentures have lost a significant amount or complete loss of their alveolar bone (Figures 2.1 and 2.2). In some patients the mental neurovascular bundle is abnormally located on the crest of the atrophied jaw, causing pain and numbness of the chin in denture wearers (Figures 2.2 and 2.3) [3–6].

In rare cases, the incisive nerve and vessels are found under the mucosa covering the ridge (Figure 2.4). The loss of alveolar bone in the maxilla is more complicated due to the expansion of the maxillary sinuses in the posterior ridges (Figures 2.1 and 2.5). The facial appearance of these patients is significantly altered due to the reduction of the vertical dimension of the lower one third of the face. The most recent US health survey has reported that over 40 million people are edentulous. The ones with a significant or complete alveolar bone loss have been named dental cripples.

The advances in our knowledge of bone biology and physiology in the past two decades and the results of translational research and clinical trials has led to the development of clinical procedures aimed at the bioengineering of the structure and function of the atrophied edentulous ridges using bone grafts and implants. Such clinical procedures involve surgical access to the basal bones of the maxilla, maxillary sinuses, and mandible. Most of the surgical approaches extend beyond the fornice (mucobuccal fold) of the oral cavity and may harm the vital structures in the subcutaneous areas of the head subjected to surgical manipulation from the intraoral approach. To employ such bioengineering procedure the dentist and specialists must acquire knowledge of surgical anatomy in order to assure safe access to the jaw bone without harming muscles, vessels, and nerves. Such knowledge will also enable the operator to handle unexpected complications such as hemorrhage, airway obstruction, and nerve injury.

In this chapter we will consider the surgical anatomy of the maxilla and mandible as organs. To consider individual bone as organ we will deal with anatomical landmarks of surgical importance, muscle attachments, arterial supply with emphasis on vessels that may be injured during surgery, and on veins that may carry and spread infections. Lymphatic drainage from the maxilla and mandible will be discussed. The major sensory and motor innervation will be considered. The anatomy and physiology of the maxillary sinuses will be presented.

Maxilla, surgical anatomy [7]

In gross morphology (Figure 2.6) the maxilla is pyramidal in shape with the root of the zygoma as its apex. The latter can be palpated in the buccal vestibule of the oral cavity and represents an important surgical landmark; it divides the facial or lateral surface of the maxilla into anterior-lateral and posterior-lateral surfaces. The third surface of the maxilla is the orbital plate, which separates the orbit from the maxillary sinus. Facial trauma may lead to fracture of the orbital plate and the drooping of the eye in the direction of the maxillary sinus leading to a diplopia, a condition known as enophthalmia. The base of the maxilla is the lateral wall of the nose or the medial wall of the maxillary sinus. Puncture of this wall during a sinus lift procedure may lead to an antroanasal fistula. The latter heals fast with little or no complications when compared to the oroantral fistula.

The mucobuccal fold, also called the fornix, limits the intraoral part of the maxilla, which is covered by a mucous membrane. Above the fornix is the basal bone of the maxilla and is covered by the skin and subcutaneous tissue. At the molar region the buccinators muscle origin acts as a barrier between the buccal vestibule and the subcutaneous tissue of the buccal surgical space. There is no muscle barrier above the mucobuccal fold from canine to canine. The spread of infection from anterior teeth can spread to the facial space and spread to the lower and upper eyelids. The buccinators limit the spread of infection to the buccal vestibule. If the infection spreads above the origin of the buccinators, the infection will spread subcutaneously into the buccal surgical space (Figures 2.7 to 2.9).

The alveolar process of the maxilla related to the anterior-lateral wall carries the incisors, the canines and the premolars, whereas that of the posterior-lateral wall carries the molars and ends as the maxillary tuberosity. The anterior-lateral surface of the maxilla can be palpated under the skin. At the mid-line the anterior nasal spine projects anteriorly and carries the medial nasal septal cartilage. Excision of this process can lead to drooping of the nasal septum. Intraorally, it is possible to palpate the canine eminence and the
Bite force of full denture wearers decreases from 200 psi to 50 psi; by 15 years denture wearers have reduced the bite force to 6 psi. The decline in biomechanical force leads to progressive loss of alveolar bone. The maxillary sinus pneumatizes toward the alveolar bone and enhances the loss of alveolar bone in the posterior edentulous area. Progressive loss of alveolar bone of the mandible will bring the mental neurovascular bundle at the crest of the ridge.

Figure 2.1 Bite force of full denture wearers decreases from 200 psi to 50 psi; by 15 years denture wearers have reduced the bite force to 6 psi. The decline in biomechanical force leads to progressive loss of alveolar bone. The maxillary sinus pneumatizes toward the alveolar bone and enhances the loss of alveolar bone in the posterior edentulous area. Progressive loss of alveolar bone of the mandible will bring the mental neurovascular bundle at the crest of the ridge.

Figure 2.2 Loss of alveolar bone alters the anatomy of the floor of the mouth. Note the rise of the floor, by the mylohyoid muscles, above the posterior ridge. The genial tubercles are abnormally close to the crest of the ridge on the lingual side.

Figure 2.3 Total loss of the alveolar bone brought the mental neurovascular bundle lingual to the crest of the ridge. Note the loss of buccinators and mylohyoid attachments to the atrophied mandible.

Figure 2.4 Morbid anatomy of an atrophied mandible in a cadaver specimen. Note the hypertrophied superior genial tubercles (*), the mental neurovascular bundle at the crest of the ridge (arrow), and the exposure of the incisive neurovascular bundle (arrow).

Figure 2.5 Expansion of the maxillary sinus into the alveolar recess and close to complete loss of the alveolar bone (arrow).
canine fossa. The latter is located distal to the canine eminence and proximal to the root of the zygoma. It extends superiorly to the infraorbital foramen and inferiorly to the base of the alveolar process.

**Surgical access to the maxillary sinus**
(Figures 2.5 and 2.6)
The canine fossa is the site for facial access to the maxillary sinus. A vestibular incision between the canine eminence and the root of the zygoma and reflection of tissue above the fornx should reach the canine fossa subcutaneously and expose the bone for the purpose of creating a window into the anterior-lateral wall of the sinus. One has to be careful not to extend the reflection far superiorly to avoid detaching the levator anguli oris or caninus muscle and injuring the infraorbital neurovascular bundle (Figure 2.10). A vestibular incision at the buccal vestibule will cut the buccinator. Insertion of a periosteal elevator above the vestibular incision should access the posterior-lateral wall of the maxilla, which is also the anterior wall of the infratemporal fossa (Figure 2.6). At this site one should be careful not to sever the posterior superior alveolar nerve and artery. The posterior-lateral wall of the maxilla extends superiorly to the infraorbital fissure and posteriorly to the pterygomaxillary fissure. Surgical manipulation of the posterior-lateral wall to create a window into the maxillary sinus should avoid extending the instruments into these fissures to avoid injury to the maxillary artery and nerve.
The medial wall of the maxilla provides attachment to the inferior nasal concha and to the vertical plate of the palatine bone. The latter is the medial wall of the pterygopalatine fossa. At the superior border of the vertical plate of the palatine bone the sphenopalatine foramen is found and through which the sphenopalatine neurovascular bundle exits from the pterygopalatine fossa to the nasal cavity. Injection of local anesthetic by the incisive process of the pterygopalatine fossa for the purpose of blocking the maxillary nerve may pass through the sphenopalatine foramen to the nasal cavity and drip on the upper lip from the nose or reaches the oropharynx. The sphenopalatine nerves and vessels supply the walls of the nasal cavity and exit to the palate by passing through the incisive canals, which begin at two foramina located at the floor of the nose above the central incisors. The sphenopalatine neurovascular bundle exits to the palate by passing through the incisive foramen under the incisive papilla.

The opening of the maxillary sinus is actually a canal found in the medial wall of the maxilla, close to the floor of the orbit. The opening is reduced in diameter by the incisive process of the ethmoid bone. The latter provides the middle and superior nasal conchae. The middle meatus is located between the middle and inferior nasal conchae and is the site of the hiatus semilunaris. The maxillary sinus opens at the hiatus semilunaris. The roof of the maxillary sinus is the orbital plate of the maxilla. The infraorbital canal carries the infraorbital nerve and vessels and forms a bony ridge running along the roof of the sinus cavity.

The sinus space expands into the processes of the maxilla. It expands inferiorly toward the alveolar ridge (50% of all instances) as the alveolar recess, into the zygoma as the zygomatic recess (41.5%), frontal process (40.4%), and palatine process (1.75%). Palatal perforation leads into the floor of the nose and rarely into the sinus cavity. The sinus cavity is lined by a membrane approximately 1 mm in thickness, known as the Schneiderian membrane. The epithelial component of the membrane is made of pseudostratified ciliated epithelium with goblet mucous secreting cells. The subepithelial connective tissue layers contain blood vessels from anterior, middle, and posterior alveolar arteries and veins, as well as branches of anterior, middle, and posterior superior alveolar sensory nerves off the maxillary (V2) nerve, autonomic nerves, and seromucous glands. The cilia of the sinus epithelium beat toward the sinus canal and along with the mucous carry the foreign particles brought to the sinus by the breathed air toward the sinus opening. Smoking paralyzes the cilia and makes the patient more susceptible to sinusitis.

The bone surfaces at the floor of the sinus show few cells, which appear flat and do not resemble periosteal cells. The floor of the sinus is not flat but is divided into three fossae separated by bony septae. The anterior fossa is related to the premolars, the middle fossa is related to the two molars, and the distal fossa is related to the third molar. The septa may vary in heights from 2 mm to 6 mm. They can be detected as radiopaque lines on panoramic radiographs. During the sinus lift procedure for the purpose of augmenting the floor of the sinus with bone grafts, the operator should be aware of the presence of the bone septae in order to avoid perforating the sinus membrane.

Possible functions of maxillary sinus:
1. Resonance of voice.
2. Lightening of skull weight.
4. Secretion of bactericidal enzymes, which make the environment of healthy sinus sterile.
5. Warming of inspired air.

Normal sinus function requires patency of the sinus ostium, normal mucociliary function, and normal systemic and local immune function. Imaging of the sinuses using a panoramic view, Water’s view, a periapical radiogram, or tomography using computed tomography (CT) or cone beam computed tomography (CBCT) can show a healthy sinus cavity as radiolucent. Any turbidity caused by fluid, polyps or mucous cysts, thickening of the sinus membrane, etc., should indicate disease. Consulting an ear, nose, and throat (ENT) specialist is highly recommended before proceeding with the sinus lift procedure.

**Muscles attached to the maxilla of surgical importance** (Figures 2.10 and 2.11)

As the maxillary edentulous ridge resorbs, the crest of the atrophied ridge migrates toward the muscles that take origin from the basal bone of the maxilla. Therefore a vestibular incision or reflection of mucoperiosteal flap may detach these muscles and any surgical manipulation will be subcutaneous rather than intraoral and therefore has the potential of severing or injuring vital structures such as nerves, vessels, and muscles, as will be described below.

**levator labii superioris muscle**

It takes its origin from the infraorbital margin above the infraorbital foramen. The muscle covers the infraorbital neurovascular bundle. The muscle is penetrated during infraorbital nerve block anesthesia from a skin approach. The zygomatic branch of facial nerve innervates the muscle.

**levator anguli oris (Caninus)**

It originates in the maxilla below the infraorbital foramen. The infraorbital neurovascular bundle is therefore located between the caninus and levator labii superioris. In the atrophied edentulous maxilla the infraorbital neurovascular bundle is closer to the crest of the ridge. Reflection of the tissue following a vestibular incision to access the canine fossa in order to create a lateral window for sinus membrane lift and insertion of bone graft may detach the caninus muscle and injure the infraorbital neurovascular bundle leading to hematoma and subsequent paresthesia or anesthesia of the receptive
premaxilla between the canines, a mucoperiosteal flap reflection may detach the incisivus labii superioris. It may also detach the septalis and oblique fibers of the nasalis muscle. The first is attached to the skin of the nasal septum and the latter to the ala of the nose. These small muscles will reattach after placement of the flap. However, if the muscles were damaged, then drooping of the septum and flaring of the ala of the nose may result.

**Buccinator muscle**

The buccinator muscle originates from the base of the alveolar process opposite to the first, second, and third molars of both jaws. This muscle also takes origin from the pterygoid hamulus of the medial pterygoid plate of the sphenoid bone and therefore bridges the gap between the maxillary tuberosity anteriorly and the hamulus posteriorly. Extension of a subperiosteal frame design into the pterygoid plates may interfere with the fibers of these muscles without adding too much to the retention of the implants. The buccinator muscle crosses the retromolar triangle in order to reach the pterygoid hamulus (a process of the medial pterygoid plate of sphenoid) and pterygomandibular raphe. The latter links the superior constrictor muscle of the pharynx to the buccinator, which runs medial to the medial pterygoid muscle. The long buccal nerve and vessels reach the lateral surface of the buccinator by crossing the retromolar triangle deep to the buccinator muscle fibers. Incision at the retromolar pad that extend along the ramus in order to access more of the external oblique ridge during harvesting a ramus block for autologous ridge augmentation may sever the buccinator fibers and also sever the long buccal nerve and vessels. The buccal branches of the facial nerves innervate the buccinator.

**Sensory innervation of the maxilla** (Figure 2.12)

The maxillary nerve (V2) innervates the maxilla. The nerve leaves the middle cranial fossa by exiting through the foramen rotundum and crosses the pterygopalatine fossa (pterygopalatine portion). It then exits the fossa through the pterygopalatine fissure and appears at the infratemporal fossa (infratemporal portion). The nerve enters the orbit by passing through the infraorbital fissure and then runs into the infraorbital canal located at the floor of the orbit or the roof of the maxillary sinus (infraorbital portion). It then exits to the face by passing through the infraorbital foramen (facial portion).

**Pterygopalatine portion of the maxillary nerve**

This portion of the maxillary nerve gives rise to the descending palatine and sphenopalatine nerves. The descending palatine nerves

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**Figure 2.11** (A) Origin of the depressor septi muscle; (B) origin of the superior incisivus muscle; (C) origin of the nasalis muscle; (D) origin of the levator labii superioris muscle; (E) infraorbital foramen; (F) origin of the caninus muscle; (G) origin of the buccinator muscle; (H) insertion of the lateral tendon of the temporalis muscle; (I) insertion of the masseter muscle; (J) origin of the triangularis muscle; (K) insertion of the platysma muscle; (L) mental foramen; (M) origin of the inferior incisivus muscle; (N) origin of the depressor labii inferioris muscle; (O) origin of the mentalis muscle.

**Figure 2.12** Maxillary division of the trigeminal nerve as it exits the cranial cavity through the foramen rotundum and appears in the pterygopalatine fossa (I). This part of V2 supplies the descending palatine and sphenopalatine nerves and V2 then exits through the pterygomaxillary fissure to the infratemporal fossa (II). This portion supplies the zygomatic and posterior superior alveolar nerves. Then V2 enters the infraorbital fissure to become the infraorbital portion (III); it supplies the anterior and middle superior alveolar nerves and then V2 exits to the face through the infraorbital foramen (IV) and branches into the labial, nasal, and palpebral nerves.
descend through the descending palatine canal and branch into the greater palatine nerve, which supplies the mucosa of the hard palate and the lesser palatine nerves that supply the mucosa of the soft palate. These sensory nerves carry autonomic fibers from the sphenopalatine ganglion. Both sympathetic and parasympathetic nerves supply the mucous glands of the palate. The sphenopalatine nerve exits to the nasal cavity by passing through the sphenopalatine foramen. It supplies the nasal mucosa and terminates as the incisive nerve that supplies the mucosa covering the hard palate opposite the upper six anterior teeth. The sphenopalatine nerve carries autonomic nerves that supply the mucous glands and vessels of the nasal cavity. The infratemporal portion of the maxillary nerve gives rise to the zygomatic branch and posterior superior alveolar nerves. The zygomatic nerve divides into the zygomatico-facial and zygomatico-temporal cutaneous branches. The zygomatic nerve also carries autonomic fibers that supply the lacrimal gland in the orbit. The posterior superior alveolar nerve gives rise to a mucous branch that supplies the gingiva opposite the upper three molars and then enters the posterior wall of the maxillary sinus and contributes to the dental plexus that supplies the third molar, second molar and the mesio-buccal root of the first molar teeth and the surrounding bone. After teeth extraction most of the dental nerves degenerate. In some cases few dental branches remain within the alveolar ridge. Insertion of implants at this site may impinge on the residual nerves and cause phantom pain that the patient may feel as if the pain is originating from the extracted teeth. In some cases the severity of the pain may necessitate unscrewing the implant to relieve the pressure or removal of the implant.

Infraorbital portion of the maxillary nerve
It gives rise to the anterior and middle superior alveolar nerves. These nerves run in bony grooves in the facial wall of the maxillary sinus under the Schneiderian membrane. The nerves supply the sinus wall and roots of the premolars, the canine, lateral and central incisors on the same side, and also the central incisor at the contralateral side. The infraorbital facial portion of the maxillary nerve exits the infraorbital foramen and supplies cutaneous branches to the lower eyelid, side of the nose, and the upper lip. It also supplies the mucosa lining of the upper lip and the gingivae opposite the incisor and premolar teeth. V2 block anesthesia can be achieved by intraoral routes either via the descending palatine canal, via the greater palatine foramen, or via the pterygomaxillary fissure into the pterygopalatine fossa by following the slope of the posterior-lateral surface of the maxilla distal to the root of the zygoma.

Arterial supply to the maxilla (Figure 2.13)
The maxillary artery supplies the majority of arterial blood to the maxilla. It is one of the terminal branches of the external carotid artery. The maxillary artery starts deep to the neck of the mandibular condyle (mandibular portion) and then continues either superficially or deep to the lateral pterygoid muscle in the infratemporal fossa (pterygoid portion). It then reaches the pterygomaxillary fissure where it branches into one artery that enters the pterygopalatine fossa (pterygopalatine portion) and the infraorbital artery that enters the infraorbital fissure and then proceeds in the infraorbital canal (infraorbital portion) and exits on the face by passing through the infraorbital foramen.

Branches of the maxillary artery are as follows:
1. Mandibular portion: deep auricular, tympanic, meningeal, and inferior alveolar arteries.
2. Pterygoid portion: deep temporal, lateral pterygoid, median pterygoid, and massetric arteries.
3. Pterygopalatine portion: posterior superior alveolar artery, descending palatine and sphenopalatine arteries.
4. Infraorbital portion: anterior and middle superior alveolar, palpebral, nasal, and labial arteries.

The collateral or supplemental arterial blood supply reaches the maxilla via five arteries: two branches from the cervical portion of the facial artery (ascending palatine and tonsillar), two dorsal lingual arteries from the lingual artery, and the ascending pharyngeal branch from the external carotid artery. These arteries ascend in the head lateral to the lateral wall of the pharynx medial to the mandibular ramus. The operator of surgical osteotomy of the ramus needs to be aware of these parapharyngeal arteries. The latter arteries penetrate the lateral pharyngeal wall of the oropharynx and supply the palatine mucosa and the bone of the maxilla. During

![Figure 2.13 Arterial supply of the maxilla and mandible.](image)
orthognathic surgery the surgeon cuts the posterior, middle, and anterior superior alveolar arteries and occasionally the descending palatine arteries without compromising the blood supply to the maxilla because of the presence of the supplemental blood supply from the branches mentioned previously. Reflection of the palatine mucosa and the facial mucosa covering the maxilla during orthognathic surgery is contraindicated since it can lead to necrosis of the maxilla.

Venous drainage from the maxilla (Figure 2.14)
The maxillary vein provides venous drains from the maxilla. It is located in the infratemporal fossa and communicates freely with the pterygoid plexus of veins and then joins the superficial temporal vein to form the posterior facial vein within the parotid gland. Infection anywhere in the maxilla may follow the maxillary vein to the pterygoid plexus of veins. The latter communicate to the cavernous sinuses in the middle cranial fossa via emissary veins, causing infected cavernous thrombosis. An adequate arterial blood supply and healthy venous drainage are essential for bone regeneration and remodeling of bone grafts. Bilateral significant blockage of the carotid arteries may compromise the blood supply to the bone of the maxilla and cause a delay of healing after insertion of implants or bone grafting to the area.

Lymphatic drainage from the maxilla
The submandibular lymph nodes are the primary nodes that drain the maxilla including the maxillary sinuses. The most posterior portion of the maxilla drains into the deep facial nodes or retropharyngeal nodes, part of the deep cervical nodes. Normal nodes are not clinically palpable except the jugulo-digastric or tonsillar nodes and the jugulo-omohyoid or tongue nodes. Preoperative palpation of lymph nodes is an essential part of physical examination of the head and neck.

Mandible, surgical anatomy (Figure 2.15) [7]
The clinician should be familiar with the anatomical landmarks of the dentulous and edentulous mandibles, not only by

Figure 2.14 Venous drainage of the maxilla and mandible.

Figure 2.15 Anatomical landmarks of the facial and lingual view of the mandible.
radiographs but also by clinical examination. The mental eminence, inferior border premasseteric notch, gonial angle, lateral pole of the condyle, and coronoid process are all palpable under the skin. Intraoral palpable features of the mandible from the facial aspect are the external oblique ridge, coronoid process, and the boundaries of the retromolar triangle. The external oblique ridge forms its lateral boundary, the temporal crest forms the medial boundary, the retromolar alveolar bone forms its base, and the coronoid process forms the apex of the triangle. The mental foramen can be palpated at the interpupillary line at the apices of the premolars. In severely atrophied edentulous ridge the mental foramen along with the mental neurovascular bundle can be palpated at the crest of the ridge. Incision at the crest of the ridge should avoid injury to the mental neurovascular bundle. The cone beam CT imaging is helpful in confirming the location of the mental nerve prior to surgery. Vestibular facial incision at the symphyseal area will expose the mentalis muscles. Mucoperiosteal flap reflection at the molar region beyond the mucerubusal fold may sever the buccinator muscle attachment and periosteal reflection beyond this line will be subcutaneous. The operator needs to be aware of the presence of the facial artery, facial vein, and marginal branch of the facial nerve close to the premassetic notch of the mandible. Physical examination of the lingual side of the mandible should palpate the internal oblique ridge and the torus mandibularis in the premolar region, the temporal crest (site for insertion of the medial tendon of the temporalis muscle), and coronoid process of the ramus. In some cases of edentulous severely atrophied mandible the mylohyoid muscles push the sublingual salivary glands up to cover the crest of the ridge and the buccinator attachment in the molar regions may also reach the crest of the ridge and in some cases the muscle loses its attachment to the mandible. An abnormally enlarged superior genial tubercle can be palpated lingually at the mid-line in a severely atrophied edentulous mandible. The lingual nerve, which has a close relationship to the alveolar bone of the third molar in the dentulous mandible, may run close to the crest of the atrophied edentulous ridge and in some cases it may be found under the retromolar pad. The operator needs to be aware of the possibility of having the lingual nerve in the line of incision. Retromolar pad incision should be done buccally and in layers rather than down to the bone in order to avoid injury to the lingual nerve.

**Muscle attachment to the mandible of surgical importance to oral implantologists**

**Mylohyoid (Figure 2.16)**

The muscle takes its origin from the internal oblique ridge bilaterally. The most posterior fibers insert into the body of the hyoid bone while the rest of the fibers meet the mid-line from the mandible to the hyoid bone. The muscle forms the floor of the mouth. The structures above the mylohyoid are intraoral while the structures below the muscle are subcutaneous under the skin of the submandibular region. Atrophy of the edentulous mandibular ridge will bring the origin of the muscle close to the crest of the ridge. A crestal incision may injure the muscle and manipulation at this site may cause swelling and ecchymosis above the mylohyoid in the sublingual space or below the mylohyoid in the submandibular space. The mylohyoid depresses the mandible if the hyoid bone is fixed in position by the infrahyoid muscles and it can also raise the hyoid when the mandible is fixed in centric occlusion during swallowing. The nerves to the mylohyoid branch of V3 innervate the mylohyoid muscle.

**Genioglossus muscle**

The muscle takes its origin from the superior genial tubercle and inserts into the tongue from the tip to its base. Its posterior fibers insert into the body of the hyoid bone. The genioglossus muscles are the main protruders of the tongue. In the edentulous atrophied mandible the superior genial tubercles may become close to the crest of the ridge and in some cases are found at the same level as the crest of the anterior ridge (Figure 2.15). Surgical manipulation at this site should avoid severing the tendons of the genioglossus, which may lead to life threatening fall-back of the tongue, and obstruction of the airway. Branches of the hypoglossal nerves innervate the muscles. Paralysis of the genioglossus muscle on one side will lead to deviation of the tongue toward the affected side.

**Medial pterygoid muscle**

The majority of the muscle fibers take their origin from the medial surface of the lateral pterygoid plate of the sphenoid bone. A small slip of the muscle originates from the tuberosity of the maxilla (maxillary head). The muscle inserts on the medial surface of the angle of the mandible. The pterygomandibular surgical space is located between the medial pterygoid and the ramus of the mandible. This space contains the sphenomandibular ligament, the inferior alveolar nerve,

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**Figure 2.16** Lingual view of the mandible showing the lingual nerve at the pterygomandibular space (I) passing to the floor of the mouth at the edge of mylohyoid muscle (alveolar portion II), then runs in the floor of the mouth on the hyglossus muscle (III) and send branches to the tongue, lingual gingiva and mucosa of the floor of the mouth (IV). The pterygomandibular portion is the most commonly injured by the needle during inferior alveolar nerve block anesthesia while the alveolar portion is most susceptible to injury during complicated surgical removal of an impacted third molar tooth.