Maxillary sinus elevation, followed by placement of a wide variety of grafting materials, has been the generally accepted surgical protocol for the development of bone in the sinus cavity. Over the years, various techniques have been proposed for maxillary sinus elevation, which differ in surgical approach, bone graft materials, and advanced technology application for hard tissue and soft tissue management.

Dr. Kao and a team of experts begin by discussing anatomy, radiographic image applications and limitations, and then provide step-by-step clinical procedures for the lateral window technique, including piezosurgery, and the trans-alveolar methods, including balloon and controlled hydrostatic sinus elevation. Also included are chapters on post-operative care and complication management.

**SPECIAL FEATURES**
- A decision tree for sinus elevation surgery
- Color photographs showing the steps of each procedure
- Survey of implant success and survival rates
- Chapters written by leaders in bone grafting and implantology

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Dr. Daniel W.K. Kao is the CEO of Washington Dental Group and also a clinical assistant professor of periodontics at University of Pennsylvania School of Dental Medicine. Dr. Kao is also a Diplomate of the American Board of Periodontology. His research interests include the clinical applications of growth factors (BMP, PDGF), the relationship of systemic disease and periodontal disease, and dental implant studies. Dr. Kao lectures at dentistry conferences both nationally and internationally.

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I would like to express special gratitude for my boss, Dr. Joseph Fiorellini, Chairperson at University of Pennsylvania Periodontal department. Dr. Fiorellini is not merely a boss. He is a mentor and a friend who has supported me in writing this book from the very beginning concept through to its completion. In fact, he’s been my solid sounding board whom I’ve bounced many new research ideas off him throughout my career. From my very first published paper when I was a resident, to now, my first text book, I consider myself extremely lucky to be able to grow professionally and personally by working for such an exceptional leader.

In addition, this book could not have been completed without the help of the following key contributors. Dr. Paul Levi’s encouragement in sharing his expertise and experience derived from his long and outstanding career. I relied on Dr. Levi’s expertise in periodontal and implant surgery, along with Dr. Eduardo Marcuschamer. Those 2 brilliant minds helped produce an excellent chapter titled avoiding and managing complications for the lateral window technique. I believe my readers will enjoy such a wealth of knowledge from such experts, as I have. Dr. Harold A. DeHaven and Dr. Gail Childers have also gracefully written anatomy and physiology of the maxillary sinus and postoperation managements of the transalveolar osteotome approach chapters. I know my readers will benefit greatly from their contributions. They’ve cheered me on and believed in me even before I made my own marks in Dentistry. To experience such kindness and support, I’m forever moved and humbled.

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My kids, Elizabeth, Christopher and Josephina. They have had to endure my absence during my long work hours. This book could never been completed without their unlimited love.
Many individuals with edentulous posterior maxilla present inadequate bone volume and vertical height between the floor of the sinus and the edentulous ridge, rendering it inadequate to accept a dental implant and achieve the degree of primary stability necessary for long-term success. The maxillary sinus, with all its variations, configurations, anomalies, and potential pathologies, has been a concern to dental implant surgeons. Over the past 30 years, creative surgeons have devised many different methods and protocols for entering the sinus cavity, elevating the Schneiderian membrane, and placing various grafting materials, with or without the addition of blood components, recombinant growth factors, and so forth. All efforts along these lines are, of course, aimed at inducing new bone formation in the space created between the bony walls of the sinus cavity and the elevated Schneiderian membrane, so that dental implants can be placed after adequate osteogenesis to allow for implant-supported restorations to be constructed.

The two main surgical approaches of sinus floor elevation are (Figure I.1): the external lateral window approach\textsuperscript{1,2} and the internal transalveolar approach\textsuperscript{3–6}. The environment of the lifted sinus membrane space inside the sinus cavity is beneficial for the bone formation. The elevation of the Schneiderian membrane for augmentation of the maxillary sinus was first presented by Tatum (1977) using autogenous bone from the iliac crest.\textsuperscript{1} However, to harvest bone graft from the second surgical site may affect the length of the surgical procedure, postsurgical morbidity, and patient comfort, although several bone replacement graft materials such as allografts, xenografts, alloplasts, and tissue engineering materials have been utilized.\textsuperscript{7–13} The lateral window surgical procedure is still relatively technique sensitive (Figures I.2 and I.3).

The internal approach is considered more conservative and less invasive than the external lateral window approach. The original concept of the internal transalveolar technique used a set of osteotomes of various diameters to create a “green-stick fracture” by hand tapping force in the vertical direction\textsuperscript{4} (Figure I.4). The following intrusion osteotomy procedure elevates the sinus membrane by a tapping motion to create a “tent.” Bone grafting materials, blood clot, and the dental implant may be inserted into the tented space through the osteotomy.
Figure I.1 Sinus elevation procedures. (a) Area for sinus elevation. (b) External approach. (c) Internal approach.

Figure I.2 (a–d) Sinus augmentation—lateral window approach.
opening. The osteotome technique is effective in certain cases, but the most sensitive aspect is the tapping force, which should be sufficient enough to infracture the sinus floor cortical bone but restrained enough to prevent the osteotome tip from traumatizing the Schneiderian membrane. Several surgical
techniques have been proposed to minimize the sinus membrane perforation rate by using a piezosurgical device, balloon, and hydrostatic pressure.\textsuperscript{16–19}

As treatment options of edentulous maxillary today may include dental implants, the practitioner must be familiar with various sinus lift surgical techniques in order to choose an ideal treatment option for the patient. The success of therapy is not only dependent on the success of the sinus

Figure I.5 (a) and (b) Unfavorable crown-implant ratio.

Figure I.6 The interarch relationship should be considered in order to achieve a successful surgical, restorative, and aesthetic outcome.

Table I.1 Surgical and restorative treatment options for vertical interarch discrepancy.

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<tr>
<th>Treatment Options for Each Classification</th>
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<td>Soft tissue augmentation</td>
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elevation and the integration of an implant but also the position and utilization of the implant(s) for function, health, and aesthetics. With widespread use of dental implants, evaluating alveolar bony ridge volume and dimensions should also incorporate the interarch relationship to achieve a successful surgical, restorative, and aesthetic outcome (Figures 1.5 and 1.6 and Table 1.1).

This book attempts to describe and elucidate the sinus-related subjects and to offer some developing consensus as to state-of-the-art thinking and practice. With the step-by-step clinical procedures, readers may use this book as a clinical manual for sinus elevation procedures.

References

Anatomy of the maxillary sinus

The maxillary sinus is the largest of the four bilateral air-filled cavities in the skull. It is located in the body of the maxilla and is a pyramidal-shaped structure having as its base the medial wall (the lateral nasal wall). This important complex structure will be discussed later in greater detail. The pyramid has three main processes or projections: (1) the alveolar process inferiorly (bounded by the alveolar ridge), (2) the zygomatic recess (bounded by the zygomatic bone), and (3) the infraorbital process pointing superiorly (bounded by the bony floor of the orbit, and below it, the canine fossa). The alveolar and palatine processes form the floor of the maxillary sinus, which after the age of 16 usually lies 1–1.2 cm below the floor of the nasal cavity (Figure 1.1). 1–3

Usually the maxillary sinus is separated from the roots of the molar dentition by a layer of cancellous bone, although occasionally significant bone volume is absent, allowing the apices of the molar teeth to be very near or project into the floor of the sinus cavity. This can provide a direct pathway for odontogenic infection to spread into the maxillary sinus (Figure 1.2). In such cases, tooth extraction may cause oro-antral fistula formation, with or without infection.

The zygomatic process or projection is largely unremarkable. Occasionally the maxillary sinus may be divided into two or even three separate compartments by bony septa. 4 These can usually be seen clearly on radiographic

Figure 1.1 Sinus anatomy. The maxillary sinus is the largest air-filled cavity in the skull.

Figure 1.2 Odontogenic infection may create a pathway to spread infection into the maxillary sinus.
Anatomy and Physiology of the Maxillary Sinus

examination, as well as by other diagnostic media. The four sinus cavities are all lined with pseudostratified, ciliated, columnar epithelium overlying a layer of periosteum in contact with the bony sinus walls. This bilaminar structure is known as the Schneiderian membrane, and its inner specialized epithelial lining is contiguous with the lining of the nasal cavity through an opening known as the natural ostium. The sinus linings, although similar in structure, are somewhat thinner than the lining of the nasal cavity.

Ostium

The natural ostium is located in an anteromedial position in the superior aspect of the medial sinus wall (lateral nasal wall), and its location makes sinus drainage by gravity impossible. It opens into the semilunar hiatus of the nasal cavity and is usually located in the posterior half of the ethmoid infundibulum behind the lower one-third of the uncinate process. The ostium size can vary from 1 to 17 mm and averages 2.4 mm. Because the superior location makes natural drainage impossible, drainage is dependent upon the wave-like motion or “beating” of the hair-like cilia. The ostium is much smaller than the actual bony opening, and mucosa fills most of the space and defines the ostium.

On the nasal aspect of the lateral nasal wall, the ostium is hidden behind the uncinate process in 88% of cases. Often there are accessory ostia present, usually located distal to the natural ostium in the area of the posterior fontanelle (Figure 1.3).

The medial sinus wall (lateral nasal wall) is a most significant structure, because the lateral wall presents a series of furrows and projections that can either facilitate maxillary sinus drainage through the ostium or, under certain circumstances, alter or impede sinus drainage. Small swellings of the pathways or the projections resulting from inflammation can be caused by infection, allergic rhinitis, or trauma, leading to impaired sinus drainage. When

Figure 1.3 The maxillary ostium (MO) enters the infundibulum, which is the space between the uncinate process (U) and the ethmoid bulla (*).