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

**ABOUT THE EDITOR**
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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EDITED BY

Daniel W.K. Kao
CEO Washington Dental Group
Clinical Assistant Professor of Periodontics
School of Dental Medicine
University of Pennsylvania
Philadelphia, Pennsylvania

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Wai S. Cheung

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Contributors

Curtis S.K. Chen, DDS, MSD, PhD
Professor and Director of Oral Radiology
Director of Advanced Specialty Program in OMF Radiology
Department of Oral Medicine
School of Dentistry
University of Washington
Seattle, Washington

Wai S. Cheung, DMD, MS
Associate Professor
Department of Periodontology
School of Dental Medicine
Tufts University
Boston, Massachusetts

Hua-Hong Chien, DDS, PhD
Clinical Associate Professor and Predoctoral Program Director
Division of Periodontology
College of Dentistry
Ohio State University
Columbus, Ohio

Gail G. Childers, DMD
Clinical Assistant Professor
School of Dental Medicine
University of Pennsylvania
Philadelphia, Pennsylvania

Daniel Kuan-te Ho, DMD, DMSc, MSc
Assistant Professor
Department of Periodontics
School of Dentistry
University of Texas Health Science Center at Houston
Houston, Texas

Daniel W.K. Kao, DDS, MS, DMD, DABP
CEO Washington Dental Group
Clinical Assistant Professor of Periodontics
School of Dental Medicine
University of Pennsylvania
Philadelphia, Pennsylvania

David Minjoon Kim, DDS, DMSc
Associate Professor
Director of the Advanced Graduate Education Program
Department of Oral Medicine, Infection, and Immunity
Division of Periodontology
Harvard School of Dental Medicine
Boston, Massachusetts

Paul A. Levi, DMD
Associate Clinical Professor
School of Dental Medicine
Tufts University
Boston, Massachusetts

Harold A. DeHaven, Jr., DDS
Clinical Professor
Department of Periodontics
School of Dental Medicine
University of Pennsylvania
Philadelphia, Pennsylvania

Eduardo Marcuschamer, DMD
Private practice
Denver, Colorado
Visiting Assistant Professor
Tufts University
Boston, Massachusetts
Mana K. Nejadi, DMD
Clinical Assistant Professor
School of Dental Medicine
University of Pennsylvania
Philadelphia, Pennsylvania

Chih-Jaan Tai, MD, MSc
Associate Professor
Department of Otorhinolaryngology
China Medical University and Hospital, Taiwan
Taichung, Taiwan

Dimitris N. Tataakis, DDS, PhD
Professor and Director of Postdoctoral Program
Division of Periodontology
College of Dentistry
Ohio State University
Columbus, Ohio

Elana E. Walker, DMD
Clinical Assistant Professor
School of Dental Medicine
University of Pennsylvania
Philadelphia, Pennsylvania
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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 and the internal transalveolar approach. 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. 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. 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 (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

Introduction
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. 14,15 Several surgical

**Figure I.3** Sinus augmentation—lateral window approach. (a) Day 0: sinus graft. (b) Wait 6–9 months for bone graft to heal, then place implant. (c) Wait another 6–9 months for osseointegration and implant restoration.

**Figure I.4** (a–d) Internal approach—osteotome technique.
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

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

<table>
<thead>
<tr>
<th>Treatment Options for Each Classification</th>
<th>Class II Interarch Discrepancy (vertical discrepancy)</th>
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</thead>
<tbody>
<tr>
<td>Surgical treatment options</td>
<td></td>
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<tr>
<td>Hard tissue augmentation</td>
<td>x</td>
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<tr>
<td>Soft tissue augmentation</td>
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<tr>
<td>Orthognathic surgery</td>
<td>x</td>
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<tr>
<td>Restorative treatment options</td>
<td></td>
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<tr>
<td>Pink porcelain/pink materials</td>
<td>x</td>
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<tr>
<td>Alter the vertical dimension</td>
<td>x</td>
</tr>
</tbody>
</table>

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.
Introduction

Introduction and the integration of an implant but also the position and utilization of the implant(s) for function, health, and aesthetics.\(^{20}\) 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 I.5 and I.6 and Table I.1).\(^{21}\)

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 and Physiology of the Maxillary Sinus

Harold A. DeHaven, Jr.

In this chapter, the reader will review anatomy landmarks of the maxillary sinus. In order to avoid/reduce some surgical complications, it is essential to understand the blood supply, nerve innervations, function, and physiology of the maxillary sinus.

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.
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.\textsuperscript{5,6}

**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.\textsuperscript{7} 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).\textsuperscript{8}

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

\textbf{Figure 1.3} The maxillary ostium (MO) enters the infundibulum, which is the space between the uncinate process (U) and the ethmoid bulla (*).
normal sinus drainage becomes altered or obstructed, this can lead to chronic sinusitis (Figure 1.4). The medial sinus wall remains relatively smooth during development, while the nasal side (lateral nasal wall) develops a series of projections and outgrowths into the nasal cavity. The lateral nasal wall develops as the medial wall of the maxillary sinus and includes portions of the ethmoid, the maxillary, the palatine, the lachrymal, the medial pterygoid plate of the sphenoid, the nasal, and the inferior turbinate bones. The lateral nasal wall gives rise to the following structures that become part of the ostiomeatal complex (OMC), a name given to the structures forming the projections of the lateral wall and their respective furrows, meatuses, and hiatuses, which become the drainage pathways from the sinuses.9

**Microscopic anatomy**

The microscopic anatomy of the sinuses reveals four basic cell types: namely, pseudostratified ciliated columnar epithelium, nonciliated columnar cells, goblet cells, and basal cells (Figure 1.5). The ciliated cells are by far the most prevalent cell type, and each cell has from 50 to 200 cilia. These cilia have been found to wave or “beat” at a rate of 700–800 times per minute and are capable of moving mucous at a rate of 9 mm per minute. They move mucous and serous secretions toward the ostium, and, due to its superior location, must overcome gravity in order to do so. Nonciliated cells are characterized by the presence of microvilli, which may serve to increase the surface area, helping to warm and humidify incoming air. The goblet cells produce glycoproteins that are responsible for the viscosity and elasticity of mucous. The function of the basal cells is unknown, but some speculate they may serve as a stem cell for differentiation. The maxillary sinus has the greatest concentration of goblet cells, although all of the sinuses have a paucity of goblet cells and submucosal cells compared to the nasal cavity.10
Nerves and blood vessels

Sensory innervation of the maxillary sinus is supplied by the maxillary division on the trigeminal nerve (V-2) and its branches (Figure 1.6): the posterior superior alveolar nerve, anterior superior alveolar nerve, infraorbital nerve, and greater palatine nerve. The middle superior alveolar nerve contributes to secondary mucosal innervation. The natural ostium receives its innervation via the greater palatine nerve, and the infundibulum is supplied by the anterior ethmoidal branch of V-1. The mucous membranes receive their postganglionic parasympathetic innervation for mucous secretion from the greater petrosal nerve (a branch of the facial nerve). Secretomotor fibers originate in the nervus intermedius, synapse at the pterygopalatine ganglion, and are carried piggyback to the sinus mucosa along with the sensory branches of V-2. Vasoconstrictor branches originate from the sympathetic carotid plexus.

The blood supply to the maxillary sinus is supplied by branches of the internal maxillary artery (Figure 1.7): the infraorbital orbital artery runs with the infraorbital nerve in the floor of the orbit, the lateral branches of the sphenopalatine and greater palatine arteries, and in the floor of the sinus, the posterior, middle, and anterior superior alveolar arteries. Venous drainage runs anteriorly into the facial vein and posteriorly into the maxillary vein, jugular vein, and dural sinus system.

Lymphatic drainage is accomplished through a network of lymphatic connections over the pterygopalatine plexus to the eustachian tube and nasopharynx. The primary lymphatic receptacles of the paranasal sinuses are the lateral cervical and retropharyngeal lymph nodes.
Figure 1.6 Sensory innervation of the maxillary sinus.

Figure 1.7 The blood supply to the maxillary sinus.
**Function and physiology of the maxillary sinus**¹,¹⁴

- Humidifying and warming inspired air
- Regulation of intranasal pressure
- Increasing surface area for olfaction
- Lightening of the skull mass
- Resonance
- Absorbing shock, helping to lessen brain trauma
- Contributing to facial growth
- Mucociliary propulsion of mucous and serous secretions toward the ostium

**Pathophysiology of the maxillary sinus**

Chronic or persistent maxillary sinusitis is a pathologic condition that must be recognized and treated before any anticipated sinus elevation procedure prior to bone grafting. The etiologic elements underlying a chronic (or acute) sinusitis can be (1) disruption in the mucociliary flow patterns, causing stagnation and failure of normal drainage through the ostium, (2) viral or bacterial infection of the upper respiratory tract, or (3) inflammatory swelling and blockage of the ostiomeatal pathways due to allergic reaction and/or infection.¹⁵ As with most disease processes, etiologies are usually multifactorial. In cases of chronic or acute sinusitis, referral to an appropriate ENT physician is essential.

**References**

CHAPTER 2

The Applications and Limitations of Conventional Radiographic Imaging Techniques

Hua-Hong Chien and Curtis S.K. Chen

This chapter will focus on the two most common traditional imaging modalities—periapical radiography and panoramic radiography—that have been reported as sources of radiographic imaging for dental implants.\(^1,2\) Full understanding of the strengths and limitations of a selected imaging modality is critical in the assessment of the maxillary sinus area for implant-site development and longitudinal evaluation of peri-implant conditions. Therefore, the applications and limitations of peri-apical and panoramic radiography, based on current published literature, are reviewed and discussed in this chapter.

Introduction

Currently, periapical and panoramic radiography are the most common initial dental radiographic examinations in implant dentistry. In general, the appropriate image for screening of maxillary sinus morphology and residual bone height is a panoramic radiograph. Periapical radiographs are commonly used to provide complementary information such as residual bone height and any adjacent pathoses. These two imaging modalities are not only able to provide mesio-distal (horizontal) and crestal-apical (vertical) measurements for implant size selection but also useful information on bone structure and density.

Periapical radiography

Among all the radiographic techniques available today, intraoral film-based periapical radiographs have the highest spatial resolution imaging (12–22 line pairs/mm) of teeth, potential associated pathology, and adjacent bone
structures. Periapical radiographs might meet the goal of maxillary sinus radiographic examinations by providing a low cost to the patient and following the as low as reasonably achievable (ALARA) principles. In addition, these images offer minimum distortion and magnification as long as a paralleling technique can be achieved. Also, the periapical imaging modality is inexpensive, readily available, and usually a patient-friendly radiographic method.

Periapical radiographs have been used preoperatively for the evaluation of sinus augmentation, examination of sinus proximity during indirect sinus augmentation, verification of implant osseointegration after implant placement, confirmation of implant-abutment seating before loading, and longitudinal assessment of peri-implant bone changes after loading. It should be noted that the bone height might not be the same on periapical as that on panoramic radiographs due to sinus floor configuration and the distortion rate of panoramic radiography.

**Clinical applications**

**Assessment of maxillary sinus augmentation**

Maxillary sinus augmentation is a highly predictable procedure for increasing the vertical bone height of the sinus floor to accommodate dental implants. Two different techniques used for the sinus grafting procedure are well documented in the literature: the lateral window technique and the osteotome technique. The osteotome technique was found to be suitable when a minimum of 5 mm residual bone height was present in the posterior maxilla; otherwise, the lateral window technique may be implemented to build up sufficient bone height for the placement of adequate implant length. Regardless of the surgical technique used for sinus augmentation, a presurgical clinical examination and radiological assessment should be performed for the planning of the surgery and implant placement. Periapical radiographs are usually selected to assess the residual bone height to determine whether to use a lateral window or osteotome technique (Figure 2.1). Periapical and panoramic radiography remain the dominant imaging strategies for the assessment of maxillary sinus augmentation due to their low cost and ready accessibility.

**Tip:** Periapical radiographs are usually selected to assess the residual bone height to determine whether to use a lateral window or osteotome technique.

**Examination of sinus proximity during indirect sinus augmentation**

During indirect sinus augmentation, the initial osteotomy is performed using a 2 mm twist drill drilling 1 mm shy of the sinus floor. At this point in the procedure, a periapical radiograph can be taken—with the direction indicator in place—to evaluate the sinus proximity. The smallest size osteotome is then
used for sinus floor infracture, once the apical end of the osteotomy is determined to be about 1 mm short of the sinus floor, as confirmed by a radiograph (Figure 2.2).

**Figure 2.1** A periapical radiograph depicting residual bone height of less than 5 mm, which suggests that a lateral window approach may be used for sinus grafting. (Courtesy of Dr. P.W. Dai, Taichung, Taiwan.)

**Figure 2.2** A periapical film demonstrating the position of the distal direction indicator being approximately 1 mm shy of the sinus floor.

**Verification of implant osseointegration after implant placement**
Periapical radiography can be used for the examination of implant osseointegration after healing because it has the best spatial resolution with lower cost and radiation dose. Failure to achieve osseointegration can be detected radiographically by the presence of peri-implant radiolucency along the entire length of the implant, and clinically based on implant mobility. An implant surrounded by fibrous connective tissue, a condition known as fibrointegration, typically presents with clinically discernible mobility.\(^{20}\)
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A periapical radiograph illustrating peri-implant radiolucency along the entire length of a nonosseointegrated implant is shown in Figure 2.3.

Assessment of implant-abutment seating during the procedure

Most implant systems contain two components: an implant body and a superstructure/abutment. It is critical to verify the proper seating of the implant abutment on the implant body, to allow for optimal transfer of occlusal forces to the implant. In other words, the abutment component must be firmly and passively seated on the implant body. Failure to fulfill these conditions may lead to uneven distribution of occlusal forces to the implant or implant overloading and to ensuing biological and biomechanical complications. The biological and biomechanical complications include implant fracture, screw loosening or fracture, prosthesis fracture, plaque accumulation, and loss of osseointegration.

It has been demonstrated that in in vitro conditions with central X-ray parallel to an implant-abutment gap, an opening as small as 21 μm was detectable using a periapical or bitewing imaging technique. However, as the angulation of the X-ray beam increases, the ability to recognize an implant-abutment gap significantly drops. The authors’ results confirmed that periapical radiography can be a sensitive imaging method for the assessment of implant-abutment interface as long as the vertical angulation of the tube is less than 5°, relative to the plane of the interface. Therefore, it is important to reject periapical radiographs with signs of significant X-ray beam angulation. It has been reported that the external implant threads start to blur.
on radiographs with an X-ray tube angulation of 13°. Very importantly, the blurring of implant threads on a periapical radiograph represents a sign of significant angulation, and such periapical films should not be used for verification of implant-abutment seating (Figure 2.4).

**Figure 2.4** Verification of the implant-abutment seating by periapical radiographs. (a) This periapical radiograph covers two fixtures. The anterior fixture was projected with the proper angle, while the posterior one has a more vertical angulation resulting in blurring of distal threads (white arrows), indicative of an unacceptable projection to evaluate implant-abutment interface of the posterior fixture. (b) A gap (white arrows) seen between the implant and the healing abutment indicates an open implant-abutment interface (improper abutment seating). (c) Adequate implant-abutment seating confirmed by a periapical radiograph of appropriate projection geometry.

**Longitudinal assessment of peri-implant bone change**
Implant success, as defined by Albrektsson et al. in 1986, includes the absence of peri-implant radiolucency on radiographs. The conventional periapical radiograph is the standard imaging method and most frequently used modality to evaluate the alveolar crestal bone height. Changes in peri-implant crestal bone height over time can be determined by using standardized and serial periapical radiographs. The method to obtain standardized periapical radiographs was described by Eggen in 1969 and has been widely used for longitudinal assessment of bone loss in patients with periodontal diseases. Moreover, an overview of the radiographic film holders for geometry standardization was provided by Dixon and Hildebolt in 2005.
The standardized periapical radiograph has been demonstrated to be a valuable noninvasive diagnostic tool to evaluate the success and survival of dental implants by assessing the crestal bone level and fixture integration.\textsuperscript{22,30,31} Matsuda et al. reported that both digital and conventional periapical radiographs perform well in detecting artificial intrabony defects adjacent to implants.\textsuperscript{32} Recently, the digital long-cone (paralleling) periapical technique has been found to have an excellent sensitivity and specificity in the detection of simulated peri-implant bone defects in fresh bovine ribs.\textsuperscript{33} The authors concluded that long-cone periapical radiography performs extensively better than cone beam computed tomography (CBCT) in detecting circumferential peri-implant bone defects. This may be due to periapical radiographs having better spatial resolution, contrast, and detail on bone quality than CBCT, as suggested by Vandenberghe et al.\textsuperscript{34} It is suggested that standardized periapical radiographs should be utilized as a reliable method for longitudinal assessment of marginal bone level around dental implants, because of the highest linear measurement precision combined with low-dose radiation.\textsuperscript{35} Therefore, the routine use of CBCT imaging in lieu of long-cone periapical radiography for the diagnosis of peri-implant bone loss is not recommended.

A longitudinal assessment of crestal bone loss around implants can be achieved by standardized periapical radiographs using XCP instruments (Rinn Corporation, Elgin, IL) and the long-cone technique\textsuperscript{36} without any further standardization attempt, such as bite impression as described by Larheim et al.\textsuperscript{37} A novel device known as a precision implant X-ray relator and locator (PIXRL) was recently developed by K.C. Lin and C.P. Wadhwani (personal communication) to monitor changes in bone architecture and prosthetic misfit predictably (Figure 2.5). The use of the PIXRL device allows for orthogonal radiographs to be made for an implant without having to remove the implant prosthesis. Moreover, it might also allow clinicians to monitor
crestal bone changes or prosthetic misfit around an implant accurately and consistently over time.

Linear measurement of bone change at the mesial and distal sides of an implant can be performed by calculating the vertical distance between the implant shoulder and the most coronal bone-to-implant contact using the implant length as an internal reference. However, the sensitivity is reduced as far as the lingual and buccal sides of peri-implant bone are concerned, compared to the interproximal sides. Nevertheless, earlier signs of crestal bone breakdown can be identified in implant patients during a maintenance program through the use of digital subtraction radiography (Figure 2.6). The advantages of using this technique are early detection of crestal bone breakdown and obtaining diagnostic information on subtle bony changes of the interproximal bone.

**Detection of residual cement**

Cementation of implant prostheses is a common practice. Excess cement in the gingival sulcus may harm the peri-implant tissues and can lead to peri-implantitis. Residual excess cement has been documented as an iatrogenic cause for significant peri-implant inflammation and crestal bone loss around

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**Figure 2.6** Digital image subtraction analysis. (a) Periapical film taken at the implant uncovering surgery (baseline) using an XCP film holder together with the bite registration. (b) Periapical film taken with the same customized bite block at 6 weeks after the implant uncovering surgery. (c) Digital subtraction imaging revealed no changes in the crestal bone level (blue arrows) between baseline and 6 weeks follow-up.
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restored dental implants.\textsuperscript{42-44} Intraoral dental radiographs (i.e., periapical films) were used to identify the residual excess cement around restored dental implants.\textsuperscript{45} Although radiographic examination can be used to identify and locate residual excess cement around dental implants, detection is affected by factors such as the composition of the cement (degree of radiopacity), the quantity of excess cement, and the site where cement is located.\textsuperscript{45, 46} Therefore, identification of excess cement may be possible with the use of periapical (Figure 2.7) or bitewing radiographs if the cement has sufficient radiopacity, is of sufficient quantity, and is located on—or extends to—the interproximal aspects of the dental implant.

Limitations

Although readily available and low cost for patients, periapical radiography has geometric and anatomic limitations. Periapical radiography also has disadvantages especially when there is lack of standardization between

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**Figure 2.7** (a) Periapical radiograph showing radiopacity consistent with presence of cement at the abutment/crown interface mesially and distally (white arrows), with no bone loss evident. (b) Periapical radiograph showing radiopacity consistent with presence of cement (white arrow) at the distal surface of the restoration with bone loss evident (yellow arrows). (c) Periapical radiograph taken after cement removal. [Figure 2.7(a) courtesy of Drs. R. Schuler and D.A. Rapoport, Tukwila, WA. Figures 2.7(b) and 2.7(c) courtesy of Dr. P.W. Dai, Taichung, Taiwan.]
serial radiographs, due to low reproducibility. Furthermore, periapical radiographs have practically no value in evaluation of the bucco-lingual width of the sinus or of the thickness of the buccal wall of the sinus, because they depict a 2-dimensional perspective of 3-dimensional anatomy. Areas of diagnostic interest may therefore be obscured, resulting in decreased diagnostic accuracy. Also, a periapical radiograph can only illustrate a small region of nearly three teeth. As a result, the use of periapical radiographs for assessment of sinus morphology is limited because it may lead to incomplete radiographic findings important for treatment planning of sinus grafting procedures. Consequently, periapical radiography alone is inappropriate for assessment of the maxillary sinus and must always be used in conjunction with other imaging modalities, such as panoramic radiography and/or CBCT.

Periapical radiography is essential for the assessment of implant component misfits. When verifying implant-abutment seating, it is difficult to confirm by the naked eye whether the angulation of the X-ray beam is less than 5° to the implant-abutment interface. Even the use of XCP instruments and the long-cone technique does not always guarantee that the angulation of the X-ray tube is smaller than 5°. A custom-made film-holding device, modified from XCP, has been demonstrated to direct the X-ray beam perpendicular to the implant and abutment (the angulation of the X-ray tube is 0°) for the production of a diagnostic radiograph to ensure accurate implant-abutment seating. Nevertheless, fabrication of this custom-made film-holding device is time consuming, which makes the device nonpractical.

When assessing a screw-type implant on a periapical radiograph taken during the implant integration phase, it is critical for the image to display sharp threads with no overlaps on either side of the implant in order to have an accurate assessment of the peri-implant bone conditions (Figure 2.8). It is

Figure 2.8 A periapical radiograph exhibiting sharp threads with no overlaps on either side of the implant, indicating that the image is adequate to be used for assessment of the peri-implant bone conditions.
difficult to define the most coronal bone-to-implant contact when an incorrect vertical projection angle is used, resulting in a blurred image around the implant threads. Therefore, an optimal projection angle in the vertical plane, where the radiation beam is directed perpendicular to the implant long axis, is crucial to achieve a periapical radiograph with high diagnostic value when assessing peri-implant bone loss. In addition, the evaluation of the peri-implant crestal bone level is limited to interproximal areas due to overlap of the implant with the buccal and lingual bones.

The ability of intraoral radiographs to detect residual cement is influenced by the material properties of the cement. Some types of cement commonly used for the cementation of implant-supported prostheses have poor radiodensity and thus may not be detectable during a radiographic examination. Therefore, it is recommended to use radio-detectable materials for cementation, because they will allow the early detection and removal of any residual excess cement, thus preventing development of cement-associated peri-implant disease.

**Tip:** It is recommended to use radio-detectable materials for cementation.

**Panoramic radiography**

Panoramic radiography is a popular radiographic modality because it is fast, convenient, and readily available. It usually serves as a survey image allowing for assessment of anatomic structures such as the maxillary sinus; the overview of the panoramic image may help indicate the need for subsequent periapical radiographs to visualize more details at questionable sites. Since it provides an excellent general overview of the maxillofacial area, including the maxillary sinuses with the adjacent dentition and bone structures, all dentoalveolar structures can be viewed in a single image with a small radiation dose less than the dose for a full mouth series. A survey of radiographic prescriptions for dental implant assessments showed that 63.8% of surveyed dentists prescribed only panoramic radiography. Panoramic radiography in combination with other imaging modalities such as periapical radiography, conventional tomography, and computed tomography was ordered by 28.9% of dentists responding to the survey. In fact, a consensus workshop organized by the European Association for Osseointegration in 2002 recommended the use of panoramic radiography for implant treatment planning on the upper jaw. Regardless of its popularity, panoramic radiography alone is usually not adequate to assess maxillary sinus structures in detail; therefore, it is commonly accompanied by other radiographic modalities, such as periapical radiography, conventional tomography, or CBCT, for detailed maxillary sinus assessment. In addition, limited sharpness and resolution in conjunction with different magnification in the horizontal and vertical planes can render a correct diagnosis difficult, if not impossible, and lead to inaccuracy of measurements.
Clinical applications
Assessment of the anatomic structures and morphology of the maxillary sinus
The ability of panoramic radiography to detect maxillary sinus septa has been reported in the literature.\textsuperscript{54-57} Identification of the maxillary sinus septa has gained increasing importance for sinus augmentation surgery because their presence may raise the risk of Schneiderian membrane perforation during sinus elevation surgery.\textsuperscript{58-60} The perforation of the Schneiderian membrane may be associated with the development of maxillary sinusitis.\textsuperscript{61,62} However, Krennmair et al. reported that the identification of sinus septa through panoramic radiography may lead to false diagnosis about 21.3\% of the time.\textsuperscript{59} The ability of panoramic radiography (Figure 2.9) to detect sinus septa has been well documented, and most of the studies reported a false-negative diagnostic value when using panoramic radiographs.

Assessment of maxillary sinus pathologic abnormalities and malignancies
Pathologic abnormalities of the maxillary sinus, such as sinus mucosa hyperplasia, mucosal thickening, antral pseudocyst, and mucous retention cyst, can be identified by panoramic radiography.\textsuperscript{63-71} A great interindividual variability of the thickness of the Schneiderian membrane has been documented in the literature.\textsuperscript{72,73} Mucosal thickening in the maxillary sinus (Figure 2.10) was the most commonly observed pathology reported in the literature.\textsuperscript{69,70,74} The presence of mucosal thickening is generally related to a pathologic irritation of odontogenic origin, including nonvital posterior maxillary teeth, periodontal abscesses, retained roots, embedded or impacted teeth, extensively carious teeth, and oro-antral fistulae.\textsuperscript{69} There is lack of agreement on the amount of mucosal thickening that is considered clinically abnormal, and the threshold used to define pathological radiographic mucosal thickening varies. Two mm of mucosal thickening was considered a threshold for pathological mucosal swelling in some reports, because the mucosa could be seen radiographically only at a thickness of 2 mm or above.\textsuperscript{69,73,75} Recent CBCT studies examining patients who needed implant therapy in the posterior maxilla showed mucosal thickening of greater than 2 mm in the majority of patients.\textsuperscript{72,76,77} It is clinically important to note that if the sinus membrane thickness is greater than 5 mm in CBCT or CT, an otorhinolaryngologist (ENT) consultation may be needed, due to the greater risk for ostium obstruction.\textsuperscript{77,78}

\textbf{Tip:} If the sinus membrane thickness is more than 5 mm in CBCT or CT, an ENT consultation may be needed due to the greater risk for ostium obstruction.
Figure 2.9 Sinus septa can be identified in (a) a periapical radiograph (white arrows) and (b) a panoramic radiograph (white arrow). A panoramic radiograph revealed the sinus septa in both the right (yellow arrow) and left sinus (white arrow). (c) The sinus septa were confirmed by CBCT scans in both panoramic (upper panel) and axial (lower right panel) views. Two distinct sinus cavities were noted in the axial view of the CBCT scans. Special caution must be used when evaluating the bone height in the CBCT sagittal view (lower left panel) for implant placement, as actual bone height may be less than the scan indicates.
Figure 2.10 A panoramic radiograph can be used to evaluate mucosal thickening in the maxillary sinus. (a) Mucosal thickening (white arrows) noted in the right maxillary sinus on a panoramic radiograph. Confirmation of mucosal thickening in right maxillary sinus by CBCT scans, seen in (b) axial (left panel) and cross-sectional (right panel) views, and (c) sagittal view.
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An antral pseudocyst, a pseudocyst, is a cyst-like change without epithelial lining. Radiographically, the antral pseudocyst frequently appears as a well-defined dome-shaped radiopacity with a rounded outline situated on the floor of the sinus (Figure 2.11). This type of lesion appears as a well-defined dome-shaped radiopacity with a rounded outline, situated on the floor of sinus. The panoramic radiograph also revealed a smaller mucosal antral cyst around the periapical region of tooth #2 in the right maxillary sinus.

![Figure 2.11](a) An antral pseudocyst can be recognized in (a) a panoramic radiograph (yellow arrows), and (b) a CBCT image (lesion indicated by yellow arrows in the panoramic view and white * in the axial and cross-sectional views). This type of lesion appears as a well-defined dome-shaped radiopacity with a rounded outline, situated on the floor of sinus. The panoramic radiograph also revealed a smaller mucosal antral cyst around the periapical region of tooth #2 in the right maxillary sinus.

An antral pseudocyst, a pseudocyst, is a cyst-like change without epithelial lining. Radiographically, the antral pseudocyst frequently appears as a well-defined dome-shaped uniform radiopacity with a rounded outline situated on the floor of the sinus (Figure 2.11). The dome-shaped opacity represents focal accumulation of inflammatory exudate that elevates the epithelial lining and the periosteum away from the underlying bone. On the other hand, the mucous retention cyst is the result of mucus accumulation due to the blockage and dilatation of ducts of the seromucinous glands. Seromucinous glands are generally located adjacent to the maxillary sinus ostium, and the mucous retention cyst could therefore originate near that region. Under prolonged infection of the maxillary sinus, the seromucinous
glands can proliferate markedly throughout the sinus lining to the sinus floor. As a result, they can give rise to a retention cyst on the sinus floor. Sometimes the retention cyst can become large enough to be evident radiographically and can have an appearance similar to the pseudocyst if it occurs on the antral floor. Under normal conditions, both lesions are generally asymptomatic and require no treatment because of spontaneous regression in most cases. Mucosal thickening and antral pseudocysts are the most common radiographic findings in the maxillary sinus. An incidence of 8.7% of pseudocysts was found in 1,080 patients by panoramic radiographs. Meanwhile, two retrospective studies using panoramic radiographs to identify the mucous retention cysts of the maxillary sinus reported a prevalence rate of 3.19% and 5.8%, respectively. Additionally, Ohba reported that panoramic radiography is superior to conventional head X-ray projections (Waters’ view) for the detection of maxillary sinus malignancy and cyst-like lesions close to the floor of the sinus. These studies suggested that the panoramic radiograph is a proper imaging modality for the detection of mucosal thickening and mucous cysts in the maxillary sinus.

The identification of mucosal thickening and mucous retention cysts has been demonstrated in elderly subjects over 76 years old through the use of panoramic radiographs. The authors reported that mucous retention cysts or diffuse mucosal thickenings were found in 12% of the subjects. In contrast, a study investigating maxillary sinus findings in elderly subjects above the age of 50 through the use of panoramic radiography found that 42% of the subjects had mucous cysts or diffuse mucosal thickenings. The large discrepancy in the aforementioned prevalence rate suggests that panoramic radiography may not be a good tool to assess mucous retention cysts or diffuse mucosal thickenings. Furthermore, a study comparing panoramic radiography with computed tomography on the assessment of radiographic signs of pathology found that only 1 (4.3%) out of the 23 sinuses that exhibited signs of pathology was correctly diagnosed by the panoramic radiograph.

It has been shown that panoramic radiographs can reveal maxillary sinus malignancies at the time of diagnosis in 90% of cases. Nevertheless, some individual case reports do show the failure to recognize the malignant features of the lesion when relying on panoramic radiographs alone. These observations suggest that panoramic radiography may have value in determining the need for further diagnostic procedures to confirm pathological findings in the maxillary sinus, and should be considered as a supplement to diagnostic radiography of the maxillary sinus and not as a substitute for conventional radiography.

**Limitations**

Panoramic radiography, a readily available and convenient image modality, offers a general overview of the dentoalveolar structures in one single image with both low cost and limited radiation dose. However, the image clarity
of panoramic radiographs is limited, especially in the anterior area.\textsuperscript{91,92} In addition, the different magnification in the horizontal plane according to object positioning, the magnification in the vertical plane, and the lack of 3-dimensional information are further limitations of panoramic radiography. Therefore, panoramic radiography in conjunction with periapical images is often recommended for the initial evaluation of an intended implant site.\textsuperscript{5}

Although capable of detecting maxillary sinus septa, panoramic radiography may lead to false-negative diagnosis of maxillary sinus septa due to low sensitivity and specificity.\textsuperscript{59} A 26.5\% rate of false-negative diagnosis (18 of 68 sinuses) regarding the presence or absence of sinus septa has been reported for panoramic radiographs.\textsuperscript{93} Collectively, these findings indicate that panoramic radiography alone is inadequate for the detection of maxillary sinus septa because of the difficulty in identifying overlapping anatomic structures. False-negative diagnosis of maxillary sinus septa by panoramic radiography may produce a less predictable outcome for sinus augmentation because the presence of septa may raise the risk of Schneiderian membrane perforation during sinus surgery.

Bone quantity can be readily evaluated after sinus grafting procedures through the use of panoramic radiography.\textsuperscript{94} However, the risk of overestimation of bone quantity was reported in the aforementioned study when only panoramic radiographs were used. The authors concluded that CBCT improved sinus graft diagnosis and thus increased the surgeon’s confidence in the treatment planning for sinus augmentation.

**Conclusion**

The conventional dental radiographic examination methods mentioned above, that is, periapical and panoramic radiographs, have specific indications, advantages, and limitations in relation to maxillary sinus diagnosis, treatment planning, and treatment. Recommendations for the radiographic examination of the maxillary sinus before sinus augmentation, in the course of implant placement, and during the follow-up evaluation period are summarized in Figure 2.12.

During the treatment planning phase, the maxillary sinus area is routinely clinically evaluated by visual examination and digital palpation, as well as radiographically assessed by panoramic radiographs to obtain an overview of sinus morphology and dental pathology, and by periapical radiographs to identify details of interest, as indicated. Periapical radiographs should be the first choice for the postoperative assessment of sinus grafting procedures with the adjunctive use of current tomographic approaches (i.e., CBCT) to confirm the suitability of available bone dimensions, in both the vertical (bone height) and horizontal (bone width) planes, for implant placement. Finally, periapical radiographs with properly controlled projection geometry should be used for dental implant
follow-up, which should include the longitudinal assessment of peri-implant bone changes and the evaluation of possible biomechanical complications.

In summary, each radiographic technique has its own indications and unique advantages and disadvantages. It is recommended that a combination of different imaging modalities be used in order to optimize the diagnostic outcome. However, the ALARA principle as well as the exposure dosage from imaging techniques should always govern the selection of the desired radiographic modalities if there is more than one technique suitable for a particular individual or situation. When planning the sinus augmentation procedures, clinicians should always choose the most favorable radiographic techniques rather than the one that is most convenient or readily available.

Figure 2.12 Recommendations for radiographic examination in the maxillary sinus. In general, guidelines for sinus evaluation, implant placement, and follow-up assessment are proposed (modified from Dula et al.). The thick black arrows represent procedures that are commonly used, while the thin black arrows represent procedures that are less commonly implemented.

References

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The Applications and Limitations of Conventional Radiographic Imaging Techniques


Introduction

The diagnostic radiographic modalities commonly used to assist dentists during implant treatment planning were limited to intraoral periapical and panoramic radiography until 2000. Traditional radiographic imaging techniques provide adequate 2-dimensional (2-D) information for the evaluation of the maxillary sinus; however, restricted film size, image distortion/magnification, and lack of a 3-dimensional (3-D) view may limit their usefulness in certain cases; the applications and limitations of conventional radiographic imaging techniques were reviewed in the previous chapter of this book (chapter 2, this volume).

Unlike the traditional 2-D dental radiographic imaging (i.e., periapical and panoramic radiographs), advanced radiographic techniques, that is, conventional cross-sectional tomography, medical-grade CT, and CBCT, offer essential 3-D information on dental and maxillofacial structures. A position paper regarding the role of radiographic imaging in dental-implant treatment planning was published in 2000 by the American Academy of Oral and Maxillofacial Radiology (AAOMR). In that article, some form of cross-sectional imaging was recommended for presurgical implant site assessment; at the time, the two available techniques that could provide cross-sectional information were the conventional cross-sectional tomography and medical-grade CT. Due to increased concerns regarding the commercialization and growing use of medical CT scans in implant dentistry, a consensus workshop organized by the European
Association for Osseointegration (EAO) was held in 2000 to establish guidelines for the use of diagnostic imaging in implant dentistry. These guidelines were published in 2002 and, again, some form of cross-sectional imaging was recommended for the treatment planning of implant cases. Nevertheless, the use of cross-sectional imaging should always be based on clearly recognizable needs and clinical requirements to ensure that the clinical benefits to the patient outweigh the risks associated with ionizing radiation.

Conventional cross-sectional tomography was the first method available to obtain cross-sectional information for dental implant patients, because of its moderate cost and relatively low amount of radiation exposure. Medical-grade CT scans were the next imaging modality available for 3-D assessment of the maxillary sinus, while CBCT is the most recently developed 3-D radiographic modality used in dental practice. It should be noted here that, in addition to the aforementioned radiographic techniques, cross-sectional information could also be obtained through magnetic resonance imaging (MRI), which does not use ionizing radiation, thus eliminating any radiation-associated risks. Although MRI may be used as a secondary imaging modality following CT/CBCT to help diagnose specific sinus diseases, MRI will not be reviewed in this chapter, as the properties of this imaging modality make it useful primarily for the assessment of soft tissues and not of bony structures. Ultrasound is another noninvasive imaging modality that does not involve ionizing radiation; although ultrasound imaging can provide cross-sectional or 3-D images, the clinical utility of ultrasound imaging in the field of implant dentistry and maxillary sinus assessment remains to be established.

**Conventional cross-sectional tomography**

In general, conventional tomography employs two types of tomographic movements: linear and multidirectional motion of the X-ray tube and the film. In conventional tomography, the X-ray beam and film move simultaneously with respect to each other, resulting in blurring of the anatomic structures outside the layer of interest. Generally, the more complex the tomographic motion, the more effective the blurring, which results in a clearer image of the area of interest. Conventional tomography offers cross-sectional information, thus expanding our ability to see anatomical structures at 3-D levels. Because of its relatively low cost and radiation dose, conventional tomography was the first method of choice to obtain cross-sectional information for patients receiving implants.

**Clinical application**

**Assessment of cross-sectional information on maxillary sinus anatomic structures and morphology**

Conventional tomography not only offers cross-sectional information with uniform magnification but also produces a far lower radiation dose than medical-grade CT scans if small edentulous regions are examined. As a general
rule, a panoramic radiograph will be taken with a reference marker (e.g., gutta-percha point or metal guide tube) incorporated into the radiographic stent to produce a tomographic image. Then the panoramic radiograph will be used as the initial scout image to select appropriate thin cross-sectional slices. The incorporation of a plastic stent with radiopaque markers offers an easy but efficient way to identify the anatomic structures of an area of interest.

Always bear in mind that there is no evidence to support the use of cross-sectional imaging to improve the overall success rate for a dental implant. In addition, conventional tomography, or any advanced radiographic imaging technique for that matter, should not be used without performing a comprehensive clinical examination. The use of conventional tomography must be justified on an individualized needs basis to ensure that the benefits to the patient outweigh the risk of cancer. In 2000, the AAOMR suggested that conventional tomography should be used as a supplemental diagnostic tool to periapical and panoramic radiography in patients receiving implant therapy. In other words, conventional tomography should be considered an optional radiographic modality after reviewing the periapical and panoramic imaging where cross-sectional information is required to assess the anatomical structures. An example of a series of spiral tomography of the left maxillary sinus is shown in Figure 3.1.

Limitations
Conventional tomography produces one cross-sectional image (limited to a narrow region) at a time, thus limiting the convenience of this image modality for the assessment of multiple jaw regions. Furthermore, the interpretation of a tomographic image is difficult because objects with dense radiopacity can appear to be in the image layer even when they are not actually in that layer. Therefore, radiographic training to develop the skills for good object recognition is mandatory for the interpretation of conventional tomographic images. These limitations, along with limited availability and the advent of newer modalities (i.e., CBCT), have made conventional tomography impractical, if not inadequate, for routine clinical use in the course of maxillary sinus-related dental implant treatment planning.

Medical-grade CT and CBCT
The efficacy of CT scans for evaluation of the maxillary sinus before installation of implants has been documented in the literature for decades. Indeed, the CT scan is regarded as the gold standard in medical imaging for the pathological-anatomical evaluation of the maxillary sinus because it provides clear visualization of the inflammatory changes in the sinus mucosa. CT scans also have the ability to visualize both bone and soft tissue in multiple views with thin sectioning. Unlike traditional 2-D dental radiographs and conventional tomography, a CT scan has the ability to measure bone density. Although CT scans were introduced into medical diagnostic imaging in the early 1970s, they were not available for dental application until 1987.
Furthermore, CT scans have been typically limited to certain complex cases in implant dentistry due to much higher costs and greater radiation exposure.\textsuperscript{20,21} The use of low-dose spiral CT techniques, such as the 32 or 64 multislice CTs, may allow a significant decrease in radiation dose; however, the size and cost of the machines and the lack of training among dentists have made them inappropriate for a dental office setting.\textsuperscript{22}

In the past decade, CBCT images have gained great popularity in oral and maxillofacial diagnosis. The advantages of CBCT, in comparison with CT, are its specific design for the dentomaxillofacial region and production of

\textbf{Figure 3.1} Cross-sectional spiral tomographic images of the maxilla sinus. Conventional spiral tomography was produced using a Cranex TOME multifunctional unit. (a) Panoramic scout image was used to select appropriate thin cross-sectional slices. (b) Conventional tomography consists of four slices, each 2 mm thick (exposure parameters of 60 kV, 56 seconds, and 1.6–2.0 mA). Note the relation of the radiopaque metal ball to the crestal bone. The tomographic image shows both the residual crestal bone height to the sinus floor and the thickness of the buccal bone.
good 3-D images in a much shorter scanning time, at a much lower radiation dose (50–90% reduction compared to medical-grade CT of the head), and at a significantly reduced cost to the patient.\textsuperscript{23, 24} The visualization quality of the maxillary sinus and bony structures in CBCT imaging is similar to that of CT scans; therefore, use of CBCT imaging instead of CT allows the practitioner to adhere to the ALARA principles by using a modality that employs significantly less ionizing radiation. Furthermore, CBCT allows the transfer of implant planning to the surgical site through the use of interactive treatment planning software, such as SimPlant (Materialise Dental, Glen Burnie, MD); the ability to perform interactive analyses and dimensional assessments adds significant functionality to CBCT scans and facilitates surgical and implant treatment planning. CBCT has been demonstrated to be an important diagnostic image modality in dentistry, thus the recognition of anatomic variations and lesions of the maxillary sinuses in CBCT is noteworthy in implant diagnosis.

**Clinical applications**

**Assessment of possible maxillary sinus pathology**

Appropriate preoperative assessment of the maxillary sinus is critical, because sinus disease and abnormalities are common among patients scheduled to undergo sinus augmentation,\textsuperscript{25} as well as among patients receiving CBCT images for reasons other than maxillary sinus symptoms or suspected sinus disease.\textsuperscript{26}

**Cystic lesions of maxillary sinus**

Maxillary sinus cysts are clinically benign lesions and generally divided into two categories: secretory and nonsecretory cysts.\textsuperscript{27} Secretory cysts include retention cysts and mucoceles. They are less common than nonsecretory ones. Retention cysts are mucoid-filled cysts and are caused by the obstruction of the seromucinous glands of the sinus mucosa. Mucus accumulation results in cystic dilatation of the glands.\textsuperscript{28} Retention cysts are mostly small and frequently encountered as an incidental finding in radiographs; compared to secretory cysts, which are completely lined by epithelium, nonsecretory cysts do not present epithelial lining and are thus referred to as pseudocysts since they are not real cysts.\textsuperscript{29} An antral pseudocyst is characterized by a very thin membrane with an inner layer of compressed connective tissue cells. They arise in the subepithelial connective tissue due to the accumulation of inflammatory exudate between the sinus bony wall and the periosteum, lifting it off the bone and the floor of the sinus to form the characteristic radiographic dome-shaped structure.\textsuperscript{30} Mucoceles are benign, expandable cyst-like lesions that are completely filled with mucus and lined with epithelium.\textsuperscript{31} They are generally rare, and the most common locations for mucoceles are the frontal and ethmoidal sinuses, although some may also be found in the maxillary and sphenoid sinuses.\textsuperscript{30, 32}
Mucoceles are invasive in nature and potentially destructive lesions. As mucus continues to accumulate, mucoceles slowly grow, progressively expanding and dilating the sinuses. The pressure generated from the mucus in the mucocele may eventually erode and remodel the bony walls of the sinuses. They can potentially destroy surrounding bone and expand into the adjacent structures, particularly into the cranium or orbit cavity. They are generally much larger in size than retention cysts and may fill the entire sinus cavities, thus creating symptoms.

Retention cysts are generally small and not evident, whether clinically or radiographically. When radiographically detectable, retention cysts frequently appear as homogeneous, well-defined, dome-shaped, or hemispheric radiopacities lying over the floor of the maxillary sinus (Figure 3.2). In contrast, pseudocysts may vary in size from a small dome-shaped lesion to a very large...

**Figure 3.2** Maxillary sinus pathology on CT scans. A small dome-shaped lesion (retention cyst) located on the floor of the right maxillary sinus (white arrows). Left maxillary sinus shows total opacity with a radiopaque lesion consistent with a foreign body on the sinus floor (black arrows), indicating left maxillary rhinosinusitis (opacification of sinus; indicated by white *) caused by sinus lift procedure. (a) Coronal view showing a normal right ostiomeatal complex and a blocked left ostiomeatal complex. (b) Representative axial image. (c) Representative sagittal image through the left sinus.
Mucoceles are frequently recognized by their radiographic features. The affected sinus is opacified by the entrapped mucus with displacement of all intrasinus air. CT findings of mucoceles appear as homogeneous opacification equal to the mucoid secretion.34 Both CT scans and MRI offer diagnostic value for sinus mucoceles. However, the primary imaging choice is CT scanning, because it not only makes a correct diagnosis possible but also provides the detailed evaluation of the involved structures required for surgical planning.35 Surgery for removal of retention cyst or pseudocyst is generally unnecessary because the lesions are benign and almost asymptomatic and do not result in sinonasal consequences.29, 36 However, the disease course of these cysts has been reported to be variant, from spontaneous disappearance, changeless, to significant enlargement.37 Surgical treatment should be considered only for patients with complaints.38 A pseudocyst might complicate the sinus augmentation procedure and possibly develop surgical complications. Therefore, ENT consultation is highly recommended for patients with symptomatic maxillary mucosal cysts. If surgery cannot be avoided, endoscopic removal of cysts via
the endonasal approach is the method of choice. Endoscopic sinus surgery with middle meatal antrostomy showed a high symptomatic improvement rate for symptomatic maxillary mucosal cysts. Unlike asymptomatic retention cysts or pseudocysts, a mucocele should be removed before sinus augmentation procedures due to its aggressive character and progressive size. Treatment of mucoceles by endoscopic approach has the advantage of being less invasive, with diminished morbidity and reduced operative time. Recently, endoscopic surgery has emerged as the first option of treatment for sinus mucoceles.

Rhinosinusitis of maxillary sinus

Rhinosinusitis, replacing the previous name of sinusitis, is defined as an inflammation of the mucosa of the nose and paranasal sinuses. Rhinosinusitis can be generally divided into acute and chronic forms, and their diagnosis is mainly based on symptoms. Acute rhinosinusitis (ARS) is usually infectious in nature, sudden in onset, and lasts less than 4 weeks, whereas chronic rhinosinusitis (CRS) is often more inflammatory, less clearly infectious, and has a minimal duration of 12 weeks. The four major symptoms of CRS include (1) mucopurulent nasal drainage, (2) nasal obstruction–blockage, (3) facial pain/pressure/fullness, and (4) loss or decreased sense of smell (anosmia or dysosmia). Two or more symptoms must be present to make a preliminary CRS diagnosis. Furthermore, objective confirmation with either nasal endoscopy or sinus CT examination is critical for making a definitive diagnosis of CRS. The importance of direct visualization of the sinus and the ostiomeatal complex by nasal endoscopy is beyond doubt. However, the accessibility of using endoscopy is not widely available to primary care providers, due to economic concerns and lack of professional training.

Conditions that directly or indirectly violate the Schneiderian membrane, such as periapical abscesses, periodontal disease, tooth extractions, dental trauma, dental implant placement, and sinus augmentation, are thought to increase the risk of maxillary sinusitis. Despite the growing popularity of sinus augmentation to support dental implant placement, the incidence of sinus augmentation–related CRS remains low. History of preoperative sinusitis and sinuses with mucosal thickenings were factors statistically significantly correlated with the occurrence of CRS after sinus augmentation. Membrane perforation in an unhealthy sinus might result in postoperative maxillary sinusitis. Interestingly, membrane perforation during sinus augmentation in patients with healthy sinuses was not related to the occurrence of postoperative CRS. However, membrane perforations greater than 5 mm must be repaired to avoid infectious complications or displacement of graft material in the sinus.

Detection of maxillary sinusitis based on conventional radiographs is usually difficult. In contrast, CT scans are useful for the diagnosis of maxillary sinusitis after sinus augmentation. CT scans have been shown to have good sensitivity and moderate specificity for the diagnosis of CRS, with good positive and negative predictive values. The CT imaging of ARS might present with air-fluid levels or
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Air bubbles within the opacification in maxillary sinus, while CRS is associated with thickening of the sinus membrane and opacification with higher attenuation than in acute disease (Figure 3.4).55 New bone formation, identical to osteitis, along the contours of the sinus cavity is a common CT finding associated with CRS.34

**Evaluation of maxillary sinus anatomical structures**

Presurgical assessments of the maxillary anatomical structures, such as sinus septa and vascular supply of the maxillary sinus, are crucial to avoid unnecessary complications during sinus augmentation surgery, regardless of the surgical approach used, that is, lateral window or crestal.56–58

**Assessment of maxillary sinus septa**

Maxillary septa are walls of cortical bone that arise from the inferior or lateral walls of the maxillary sinus, and they can divide the sinus into two or more cavities. Identification of the maxillary sinus septa is important for sinus augmentation using the lateral window approach because their presence may raise the risk of Schneiderian membrane perforation during sinus surgery.59–61 Moreover, the design of the lateral window during surgery is governed by the height of the maxillary sinus septa. The complication of the perforation of the sinus membrane, which has been reported to be associated with the development of maxillary sinusitis,62 can be prevented by thorough radiographic examination of the maxillary sinus. Sufficient information obtained from radiographic examinations may alter the surgical treatment plan and allow a more predictable outcome.

In reviewing the current literature on radiographic diagnosis of maxillary sinus septa, CT/CBCT scans have more sensitivity and specificity than panoramic scans.
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Radiographs because they provide 3-D information with greater accuracy.\textsuperscript{60,63–66} In addition, CT/CBCT scans are not only able to identify the presence of sinus septa (Figure 3.5) but also the location, height, and orientation of such septa.\textsuperscript{60,67} Although considered the “gold standard” for assessment of the maxillary sinus by otorhinolaryngologists,\textsuperscript{68,69} CT scans are not commonly used nowadays for the evaluation of maxillary sinus in dentistry due to the fairly high radiation dose\textsuperscript{70} and the other aforementioned disadvantages. Instead, CBCT is increasingly being used by dentists for assessment of the maxillary sinus because of its higher resolution and lower radiation dose.\textsuperscript{71} CBCT has been used to clarify the presence of septa in the maxillary sinus.\textsuperscript{72–74} Normally, septa with low height (less than 2 mm) do not require further attention because the membrane can usually be elevated without difficulty. In contrast, high septa with partial or complete separation of the sinus cavity may involve the preparation of two windows during sinus lift surgery.

The 16–33\% prevalence rate of maxillary sinus septa reported during the 1990s and based on conventional radiographic examinations\textsuperscript{60,63,75} is much lower than

\(\text{(a)}\)

\begin{figure}[h]
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\caption{Assessment of maxillary sinus anatomy on CT scans—maxillary sinus septa. (a) The location of bilateral septa (white arrows) on reformatted panoramic images. (b) The orientation of a septum (white arrow) on reconstructed cross-sectional images. (c) Axial images showing complete bilateral septa (white arrows) that divide each of the maxillary sinuses into two cavities. (Continued on p. 41)}
\end{figure}
the prevalence rate of more than 50% reported recently by CBCT examinations.\textsuperscript{73,74} This discrepancy in the prevalence rate could be attributed to the properties of the radiographic methods used to detect the septa. CBCT scans offer a thin slice interval of images (less than 1 mm in width) with sufficient resolution in all directions, increasing sensitivity and specificity in the detection of subtle septa.\textsuperscript{60} Therefore, CBCT is the recommended imaging modality for diagnostic preparation prior to sinus surgery.

Figure 3.5 Continued
Assessment of maxillary sinus intraosseous vessels

Knowledge and preoperative assessments of the blood supply of the sinus lateral wall is essential to avoid hemorrhage complications resulting from arterial injury during surgery. The arterial supply of the maxillary sinus wall and overlying Schneiderian membrane originates from the branches of the maxillary artery: the posterior superior alveolar artery (PSAA) and the infraorbital artery (IOA). With regard to the relationship with the bony lateral sinus wall, the anastomosis of the PSAA and IOA can occur intraosseously or partially intraosseously. In the partially intraosseous case, the anastomosis of the PSAA and IOA can be identified between the interior side of the bony wall and the Schneiderian membrane. Therefore, care should be taken not to tear the vessel when elevating the membrane. Several anatomical studies investigating the distribution of the maxillary artery on human cadavers reported that the intraosseous anastomosis between PSAA and IOA was found in 100% of the specimens. The average height from the alveolar crest to the intraosseous anastomosis has been reported to be 16–17 mm, putting this vessel in close proximity to the location of the lateral window osteotomy. Therefore, there may be a high probability of severing the vessel when preparing the bony window during the sinus surgery. It is suggested that 3-D radiographic assessments of the presence and location of the intraosseous artery in the bony lateral antral wall are essential before sinus lift surgery.

CT and CBCT scans have been established to identify the presence and location of the intraosseous artery in the sinus lateral wall (Figure 3.6). However, the intraosseous artery can be visualized only in about 50% of the CT/CBCT scans. This suggests that CT and CBCT scans may not be sensitive enough to detect the intraosseous artery due to its small diameter. A mean vessel diameter of 1.2–1.6 mm has been reported for the intraosseous artery in the aforementioned studies, with significantly smaller diameter reported in females. Fortunately, the bleeding caused by the transection of a small artery is

Figure 3.6 Assessment of maxillary sinus anatomy on CT scans. Maxillary sinus intraosseous artery (white arrow) in the lateral antral wall. (a) Representative axial image. (b) Representative coronal image. (c) Representative sagittal image.
not life threatening because it can be controlled by firm pressure with a moist
gauze pad, bone wax, direct ligation, or electrocautery.\textsuperscript{84} However, significant
bleeding in the surgical field may hamper the visualization of the sinus mem-
brane, making its elevation more difficult. Consequently, this may increase the
risk of tearing the membrane during elevation. It should be kept in mind that an
undetectable intraosseous artery in CT/CBCT imaging does not necessary
exclude its presence. However, information regarding the presence and location
of the intraosseous artery in CT/CBCT, when detectable, may help in prevent-
ing surgical hemorrhage by allowing the surgeon to alter his or her approach
during preparation of the lateral access window.

**Pre- and postoperative assessment of sinus grafting procedures**

CT/CBCT scans have been used to measure the remaining crestal bone height in
the posterior maxilla, to estimate the necessary bone graft volume needed for an
anticipated sinus lifting procedure, and also to assess the volume and density of
the grafted site after surgery (Figure 3.7).\textsuperscript{85,86} Graft height and volumetric changes
due to re-pneumatization of maxillary sinus after augmentation are well docu-
mented in the literature.\textsuperscript{87,88} Only 3-D imaging can offer precise measurement of
the volumetric changes after surgery for a long-term follow-up.\textsuperscript{89}

\begin{figure}[h!]
\centering
\includegraphics[width=\textwidth]{figure3_7.png}
\caption{Pre- and postoperative assessment for sinus augmentation procedure. CT and CBCT scans showing right maxillary sinus pseudocyst (white arrows) and augmentation procedure outcome. (a) Preoperative CT, and (b) postoperative CBCT scans 6 months following sinus augmentation procedure in coronal, axial, and sagittal views. Note also the prior augmentation (a) and subsequent implant placement (b) in the left maxillary sinus. (Continued on p. 44)}
\end{figure}
CBCT-guided implant surgery
CBCT-guided implant surgery has been well documented in the literature.\textsuperscript{2,}90–93 The CBCT data can be exported into digital imaging and communications in medicine (DICOM) files and subsequently transferred into an interactive treatment planning software. The clinician can then virtually create a treatment plan for the placement of implants into ideal positions based on the bone topography and the planned restoration. Once the digital treatment plan has been verified in all 3-D views, a surgical template is fabricated based on the simulated implant positions. Under the guidance of the surgical template, the osteotomy sites are prepared and implants are installed precisely in the same positions, depths, and angulations as was planned virtually. Although CBCT-guided implant surgery can be applied to a wide variety of clinical scenarios, including single tooth replacement, the full value of such an approach is fully realized in complex, multiple implant cases, such as the two types of cases reviewed below.

All-on-4 treatment of the completely edentulous maxilla
The All-on-4 technique for the rehabilitation of the edentulous maxilla has been described in detail in the literature.\textsuperscript{94–96} The All-on-4 full-arch restoration strategy for completely edentulous maxilla utilizes four dental implants that are equally distributed to improve prosthesis support. The two anterior
Applications and Limitations of Radiographic Imaging Techniques

(central) implants are placed straight up and parallel to each other, while the two posterior (distal) implants are positioned angled anteriorly at 30°, just missing the anterior wall of the sinus cavity. Tilting the distal implants in the maxilla can eliminate the need for sinus augmentation and obtain a more posterior implant position, eliminating the use of a cantilever prosthesis. In addition, implant anchorage can be enhanced by longer implant length and the support of the cortical bone from both the sinus wall and nasal fossae. Therefore, the All-on-4 technique as the treatment option for completely edentulous maxilla is commonly acceptable because it provides increased implant length and greater anterio-posterior spread and eliminates the need for sinus augmentation. The use of computer-guided flapless implant surgery for placement of All-on-4 implants has also been reported. Eighteen patients with completely edentulous maxilla were treated, and a 97.2% cumulative implant survival rate was reported at the 1-year follow-up. Within the limitations of this study, the authors concluded that the computer-guided All-on-4 treatment option is predictable with high implant survival rate for the treatment of patients with completely edentulous maxilla.

Despite its apparent advantages, popularity, and positive short-term outcomes, the All-on-4 technique lacks long-term (>5 years) follow-up data; additional clinical research, with larger cohorts and long term follow-up, is needed to substantiate the validity of this treatment modality.

An example of a CBCT-guided implant surgery using the All-on-4 technique for rehabilitation of an edentulous maxilla is illustrated in Figures 3.8–3.11. CBCT scan data, after conversion to DICOM format, were processed in commercially available implant simulation software to virtually plan the ideal implant position (Figure 3.8). Together with CAD/CAM (computer-aided design/computer-assisted manufacturing) technology, digital data from the surgical plan were used for the fabrication of a stereolithographic surgical template (Figure 3.9). The custom-made stereolithographic surgical template, containing metallic sleeves, was used together with the implant system-specific drilling instrumentation to guide the implant placement (Figure 3.10). Four implants were placed in upright (mesial-most) and tilted (distal-most) positions as shown in the panoramic radiograph (Figure 3.11), where the tilted implants were placed parallel to the anterior sinus wall (Figure 3.11a inset) to avoid the maxillary sinus.

Simultaneous transcrestal maxillary sinus floor elevation and implant placement for completely edentulous maxilla

Computer-guided implant surgery takes advantage of CT/CBCT technology and 3-D implant planning software to virtually place implants into their ideal position relative to the planned restoration and the underlying bony anatomy. The digital treatment plan data with the ideal implant position can be sent to the manufacturer for fabrication of a stereolithographic surgical guide using CAD/CAM technology. With the fabricated surgical guide and implant system-specific drilling instrumentation, the clinician can place the implants precisely in the positions, depths, and angulations as planned virtually.
Figure 3.8 CBCT-guided implant surgery using the All-on-4 technique for the rehabilitation of the edentulous maxilla. (a) Facilitate "virtual" treatment plan for implant positioning. (b) Four implants virtually placed in relation to the planned prosthesis (occlusal view). (c) Image without the surgical template, to better visualize implant positions in bone. The two mesial-most implants were planned in upright positions (yellow color) and the two distal-most implants were planned in tilted positions (blue color). (d) Image with virtual surgical template in place. (Courtesy of Drs. H. Leghuel, Columbus, OH, and A. Tsigarida, Philadelphia, PA.)

Figure 3.9 A bone-supported stereolithographic surgical template was fabricated following the virtual treatment plan in Figure 3.8.
Furthermore, transcrestal maxillary sinus floor elevation can be performed simultaneously with the computer-guided implant surgery for patients with completely edentulous maxilla who require indirect sinus augmentation.\textsuperscript{103} Implant placement under computer-guided surgery is then performed following maxillary sinus membrane elevation using the transcrestal approach (Figure 3.12).
Computer-assisted implant dentistry has been shown to have several clinical advantages, as it offers clinicians both accurate 3-D information on the bony anatomy and on the planned prosthesis outline; in this manner, ideal implant placement can be effectively implemented in a prosthetically driven manner. Furthermore, it is a safe and predictable surgical procedure, and with implants
placed flaplessly it results in less postoperative pain and discomfort than conventional implant surgery.\textsuperscript{106} The disadvantages of computer-assisted implant placement include increased costs (equipment, materials, guide fabrication, practitioner time), significant learning curve, and technical complexity.

**Limitations**

As the utilization of CT scans continues to increase in many countries, so have the questions related to the risk of scan-associated, radiation-induced cancer. The long-term carcinogenic effects of medical radiation exposure to the head and neck have been well established.\textsuperscript{107} Radiation exposure to the head and neck can result in tumors of the thyroid, salivary, and parathyroid glands, as well as the brain and central nervous system. Although the radiation-induced risk is relatively low for older men,\textsuperscript{108} recent epidemiological evidence suggests that the risk of CT scan-associated cancer is significant, especially for patients who undergo scans during childhood and adolescence.\textsuperscript{109} Therefore, the application of CT scans in dentistry should remain restricted to specific cases to ensure that the benefits always outweigh the risks.

When compared to medical CT, CBCT scans are more cost effective with less radiation exposure time and excellent spatial resolution. Moreover, several studies reported that CBCT is the most accurate radiographic method used in dentistry.\textsuperscript{110–112} CBCT is thus highly recommended as a routine presurgical procedure for sinus evaluation because the resulting images provide clinicians not only with an intuitive visualization of the sinus anatomy (e.g., septa, intraosseous artery) but also with identification of potential sinus pathology (e.g., mucosal thickening, pseudocysts, and mucoceles). It is generally agreed that the stochastic (chance) effects of ionizing radiation are considered to have no dose thresholds. Therefore, clinicians must follow the ALARA principle in protecting patients during the acquisition of CBCT images.

Despite their increasing popularity in implant dentistry, CBCT scans have several limitations.\textsuperscript{113} When compared with CT scans, the CBCT image modality demonstrates poor soft tissue contrast, making it unsuitable for diagnosis when soft tissue contrast is of great importance.\textsuperscript{114} As a result, tumors within the soft tissue cannot be adequately evaluated using CBCT. Furthermore, scatter streak and dark band artifacts can appear between two highly radiodense objects (e.g., metal crowns and dental implants) and thus deteriorate regional image quality significantly and affect diagnosis. Additionally, the spatial resolution for CBCT images (about 2 line pairs/mm) is fairly low as compared to the intraoral conventional radiographs (12–22 line pairs/mm).\textsuperscript{115}

A review conducted by D’Haese et al. found that computer-guided implant surgery is far from accurate on implant placement when using stereolithographical surgical guides.\textsuperscript{93} According to their study, it was suggested that a safety zone of at least 2 mm is essential to avoid critical anatomical structures. Furthermore, another systematic review concluded that the clinical demands on the surgeon were no less during computer-guided implant placement than during conventional placement.\textsuperscript{92} The clinician should bear in mind that there
Clinical Maxillary Sinus Elevation Surgery

is no obvious difference in the implant survival rate between conventional and computer-guided implant placement.

With the increased clinical application of CBCT scans in implant dentistry, incidental findings in CBCT have also increased. Incidental maxillary sinus findings in CBCT images, unrelated to the original purpose of the scan, have been reported to be as high as 46.8% in a group of 134 patients. Failure to recognize incidental lesions can have potential medico-legal ramifications. On the contrary, a potential false-positive diagnosis by untrained clinicians may add unnecessary costs to healthcare and cause significant anxiety to the patient and family. With the increasing application of CBCT imaging in dentistry, the need for a specialist radiologist report is strongly recommended in order to avoid medico-legal issues and to exclude any maxillofacial pathologic finding unrelated to implant therapy.

**Conclusion**

In spite of its increasing popularity as a diagnostic tool in oral and maxillofacial surgery, CBCT is recommended selectively (because of the relatively higher radiation) as an adjunct to conventional dental radiography. Clinicians should consider the benefit/risk ratio of a CBCT scan to minimize the risk of radiation-induced cancer for their patients. Although the chance of getting radiation-induced cancer may be fairly small, it is never negligible. In addition, clinicians must bear in mind that CBCT should be used as a complementary radiographic modality for a specific application, rather than a replacement for conventional 2-D imaging.

All CBCT examinations must be justified on a case-by-case basis as recommended by the International Congress of Oral Implantologists. In general, thorough medical and dental histories as well as comprehensive clinical examinations should be performed in conjunction with conventional radiography (periapical/panoramic). Currently, the CBCT examination is still not considered the standard of care in implant dentistry and should be used as an imaging alternative in particular cases where conventional radiography cannot provide satisfactory and adequate diagnostic information. These particular cases may include (1) confirmation of a possible sinus septum and identification of its location, orientation, and dimensions; (2) clarification of a potential sinus abnormality (e.g., sinus mucosa hyperplasia, mucosal antral cyst, sinusitis, etc.); and (3) validation of the bucco-lingual width of a maxillary sinus area that is impossible to assess by means of clinical examination and conventional tomography.

Computer-guided surgery should not be performed routinely and must be employed only when patient management can be improved. Periapical/panoramic radiographs should be the first choice for the postoperative assessment of sinus grafting procedures to confirm whether the vertical bone height is sufficient for implant placement.

The increased number of incidental findings that inevitably accompany the increased use of CBCT scans in dentistry require appropriate diagnosis, management, and follow-up to avoid improper or inadequate patient care.
and malpractice risks. Therefore, it is strongly suggested that CT/CBCT images are reviewed in their entirety by an oral maxillofacial radiologist or a dentist who has undergone specific training in this area.

References

Clinical Maxillary Sinus Elevation Surgery


Conventional Instruments Preparation and Preclinical Training of the Lateral Window Technique

Daniel W.K. Kao

This chapter will review the instruments and materials needed for the lateral window sinus lift technique. The reader will also learn how to use the hen’s egg and sinus model to practice the tactile sensation of grinding the hard tissue without harming the underlying soft membrane and will become familiar with the use of sinus lift hand instruments (various angulations/offsets).

Introduction to the lateral window technique

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. In the lateral window technique, an opening into the maxillary sinus is created to elevate the Schneiderian membrane from the floor of the sinus and to place a bone graft in the space immediately above the existing alveolar bone.

The lateral window sinus elevation is a widely used augmentation procedure that enables placement of an appropriate length implant in the posterior part of the maxilla where the bone quality is often poor. The initial step is to lift the full-thickness mucoperiostium flap at the maxilla. Then a high-speed round bur/piezosurgical diamond round tip can be used to create a bony window. The Schneiderian membrane must be carefully lifted to the desired height for bone grafting materials (Figures 4.1 and 4.2). A dental implant may be placed at the same time if the implant primary stability can be achieved. Depending on the amount of residual bone height present and the length of the dental implant to be placed, clinicians...
will determine whether or not the implant(s) can be placed at the same time as the sinus floor elevation procedure.

Lateral window sinus elevation requires clinicians to depend primarily on tactile sensations to perform lifting the sinus membrane. Therefore, preclinical training is essential in this type of medical procedure to reduce human error. This chapter will demonstrate some simple methods such as using a hen’s egg and sinus model for clinicians to familiarize themselves with these surgical procedures. Table 4.1 lists basic surgery instruments, and Table 4.2 lists lateral window sinus lift instruments. Basic surgery instruments are shown in Figure 4.3(a), and lateral window sinus lift instruments are shown in Figure 4.3(b).
Table 4.1 Basic surgery instruments list.

<table>
<thead>
<tr>
<th>Basic Surgical Set</th>
<th>Hu-Friedy Part Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oral mirror</td>
<td></td>
</tr>
<tr>
<td>Perio probe</td>
<td></td>
</tr>
<tr>
<td>Anesthetic aspirating syringe</td>
<td>30G short needle</td>
</tr>
<tr>
<td>#5 round scalpel handle</td>
<td>15 C and 15 blade</td>
</tr>
<tr>
<td>Prichard periosteal elevator</td>
<td></td>
</tr>
<tr>
<td>Periosteal elevator</td>
<td></td>
</tr>
<tr>
<td>Buser periosteal</td>
<td></td>
</tr>
<tr>
<td>#11 Kramer-Nevins DE knife</td>
<td></td>
</tr>
<tr>
<td>#7 Kramer-Nevins DE knife</td>
<td></td>
</tr>
<tr>
<td>Allen end-cutting intrasulcular knife</td>
<td></td>
</tr>
<tr>
<td>Curette/chisel</td>
<td></td>
</tr>
<tr>
<td>2/4 Molt surgical curette</td>
<td></td>
</tr>
<tr>
<td>Castroviejo round handle curved</td>
<td></td>
</tr>
<tr>
<td>Tissue plier</td>
<td></td>
</tr>
<tr>
<td>Corn suture plier</td>
<td></td>
</tr>
<tr>
<td>Cotton plier</td>
<td></td>
</tr>
<tr>
<td>Goldman-Fox scissors</td>
<td></td>
</tr>
<tr>
<td>Scissors</td>
<td>S14 SC</td>
</tr>
<tr>
<td>Minnesota retractor</td>
<td></td>
</tr>
</tbody>
</table>

Table 4.2 Lateral window sinus lift instruments list.

<table>
<thead>
<tr>
<th>Lateral Window Sinus Lift Instruments</th>
<th>Hu-Friedy Part Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sinus curette</td>
<td>PESIM16</td>
</tr>
<tr>
<td>Tarnow-Eskow sinus lift instrument</td>
<td>IMPSTE1/26</td>
</tr>
<tr>
<td>Sinus curette 2</td>
<td>SINC2</td>
</tr>
<tr>
<td>Sinus curette 1</td>
<td>SINC1</td>
</tr>
<tr>
<td>Kramer-Nevins sinus lift lg/sm, strong</td>
<td>IMP6577SC6</td>
</tr>
<tr>
<td>Kramer-Nevins sinus lift, lg/sm, 47°</td>
<td>IMP6576</td>
</tr>
<tr>
<td>#3006 sinus lift instrument</td>
<td>IMP 3006</td>
</tr>
<tr>
<td>#710 sinus elevator</td>
<td>IMP 6345 71 710</td>
</tr>
<tr>
<td>#1 sinus elevator</td>
<td>IMP SIM1</td>
</tr>
<tr>
<td>Palti sinus lift instrument</td>
<td>IMP 6523S 0311</td>
</tr>
<tr>
<td>Palti sinus lift instrument</td>
<td>IMP 6524S 0611</td>
</tr>
<tr>
<td>Bone packer</td>
<td>BPACK</td>
</tr>
<tr>
<td>Syringe bone grafting</td>
<td>SYBG</td>
</tr>
<tr>
<td>Bone tray bowl</td>
<td></td>
</tr>
</tbody>
</table>

Figure 4.3 (a) Basic surgery instruments. (b) Lateral window sinus lift instruments.
Suture materials and technique

4-0 Polyglycolic acid (PGA) suture with FS-2 needle with simple interrupted technique or continuous sutures technique may be used to achieve primary closure (Figure 4.4). It is recommended to demonstrate that passive flap adaptation is achieved before suturing. Using the horizontal mattress in the crestal line can also reduce the tension at the wound margins. The tension of the sutures should not compromise the vascularity of the flap, and the bites of the sutures should be located, if possible, approximately 3–5 mm away from the margins of the flaps to prevent flap tears and other postsurgical complications.

Monofilament sutures (Gore-Tex suture) with reverse cutting needles are also preferred for the closure of flaps. Monofilament sutures will retain minimal plaque, in particular when sutures are left in place for long periods of time. See Table 4.3 for suture materials and other instruments.

Tip: Thread size 4-0 is most commonly used in dentistry. Thread size 5-0 (smaller size) is used for a more delicate surgical area.

Tip: Chromic gut suture can be used at the vertical releasing site, especially at the mucosa area, to provide a more comfortable postoperative experience for the patient, because the mucosa tissue is extremely thin and may be very challenging for suture removal (Figure 4.5).

(a)  
(b)

Figure 4.4 (a) and (b) Continuous locking suture technique with 4-0 polyglycolic acid; FS-2 needle was used to achieve primary closure. (Courtesy of Dr. Kevin Ma.)

<table>
<thead>
<tr>
<th>Table 4.3</th>
<th>Suture materials and other instruments.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suture materials</td>
<td>4-0 polyglycolic acid (PGA) suture with FS-2 needle</td>
</tr>
<tr>
<td></td>
<td>4-0 chromic gut suture (Gore-Tex suture) with reverse cutting needles</td>
</tr>
<tr>
<td>Surgical high-speed and burs</td>
<td>No. 4, 6, 8 carbide and diamond round bur</td>
</tr>
<tr>
<td>Piezosurgical machine and inserts</td>
<td>are listed in chapter 7</td>
</tr>
</tbody>
</table>
The goal of preclinical training is to reduce the risk associated with human errors and increase patient safety by allowing the clinician to develop skills more efficiently in a shorter period of time.

Part I: preclinical training on a hen’s egg shell

The Schneiderian membrane is composed of periosteum covered by respiratory epithelium, which is thin, friable, and easy to perforate. Thus, the most frequent complication is the perforation of the membrane. Uncooked hen’s egg was proposed as a training model for clinicians to familiarize themselves with the sinus lift procedures, and especially to penetrate the hard tissue structure without harming the underlying soft tissue. The hard egg shell is comparable to the buccal maxillary cortical bone. The thin membrane lying between the egg shell and the egg white is similar to the Schneiderian membrane that lies underneath the cortical bone. Clinicians can develop a tactile sensation and acquire dexterity by using the egg model. Careful training on the egg could help practitioners to enter through the lateral window and elevate gently without damaging the Schneiderian membrane, which is the key factor of a successful sinus lifting procedure.

![Chromic Gut suture at mucosa](image)

*Figure 4.5 (a) and (b) Chromic gut suture. Chromic gut suture can be used at the vertical releasing site to provide a more comfortable postoperative experience for the patient.*
Preclinical training on the hen’s egg shell step-by-step
See Figures 4.6 and 4.7.
• The initial osteotomy can be prepared with a high-speed round diamond bur.
• The corners of the access are usually round. If they are too sharp, membrane perforation may occur during instrumentation.
• The osteotomy is done with a light touch, paintbrush stroke approach until the membrane is exposed and the window is free.
• Detach the transparent membrane lying between the egg shell and the egg white gently without tearing, using the inverted cone bur.
• This reduces membrane tension, facilitating further separation.

Figure 4.6 (a)–(c) Preclinical training on the hen’s egg shell. The initial osteotomy can be prepared with a high-speed round diamond bur. The osteotomy is done with a light touch and paintbrush stroke approach until the membrane is exposed

Figure 4.7 (a) and (b) Preclinical training on the hen’s egg shell. Detach the transparent membrane lying between the egg shell and the egg white gently without tearing, using the inverted cone bur (piezosurgical instrument).
Part II: preclinical training on a sinus model

See Figures 4.8 through 4.15.

By using a sinus model, trainees may be able to familiarize themselves with hand instruments such as Kramer-Nevins sinus lift instruments, a Tarnow-Eskow Sinus Lift Instrument, and a Palti Sinus Lift Instrument (Hu-Friedy).

- Instruments are introduced first along the floor of the sinus, then anterior, posterior, and superior aspects of 3–5 mm around the window to initially detach the sinus membrane (Figures 4.9–4.12).

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**Figure 4.8** (a) and (b) Sinus model. By using the sinus model, trainees may become familiar with hand instruments.

**Figure 4.9** (a) and (b) Sinus membrane detach—lower border. Gently release the sinus membrane with a hand instrument around the window about 3–5 mm.

**Figure 4.10** (a) and (b) Sinus membrane detach—mesial area.
Different instruments with variable angulations can then be used to further elevate the sinus membrane (Figures 4.13 and 4.14).

- The working end of the sinus hand instruments must always be kept in contact with the bone surface to avoid membrane perforation (Figure 4.15).
Figure 4.14 (a–d) After initial release of the lower border, mesial, distal aspect, and upper border of the sinus membrane about 3–5 mm, go farther from the lower aspect of the sinus cavity to separate all the way to the medial wall.

Figure 4.15 (a) and (b) Instruments must always be kept in contact with the bone surface to avoid membrane perforation. The left side shows the correct way to use the sinus membrane elevation instrument. The right side shows the wrong way to use the instrument.

**Tip:** Don’t let the working end of the hand instrument lean against the sinus membrane. (Leaning the working end against the sinus membrane will increase the chance of the sinus membrane tearing.)

### References


Anesthesia

Local infiltrative anesthesia in the buccal and palatal regions of the surgical area will usually suffice enough to perform the maxillary sinus lateral window procedure.

Incision (flap design)

A bevel horizontal incision (at 1–2 mm palatal to the alveolar crest and at least 4–6 mm away from the estimated border of the hard tissue outline “window”) provides the opportunity to perform simultaneous sinus elevation and implant placement. Buccal vertical releasing incisions are placed at the mesial and distal extension of the horizontal incision.

A full-thickness buccal flap is reflected from the crestal side all the way to 4–6 mm apically beyond the upper portion of the bony window outline. With the previous flap design, primary closure can be achieved without difficulty; even lateral bone augmentation can be performed concurrent with the sinus elevation procedure. (See Figure 5.1.)

Tip: 4–6 mm clearance provides a safe zone for suture materials. (The suture line will lie on the solid native bone, not the graft materials.)
Hard tissue management

Outline of the bony window
The window outline is prepared in the lateral aspect of the buccal alveolus. The size of the window is determined by the area to be grafted in the lateral aspect of the buccal alveolus. The osteotomy (window) can be oval or rectangular (Figure 5.2).

The inferior hard tissue outline of the window should be about 3–5 mm above the sinus floor (Figure 5.3).

The size of the upper window border is determined by the length of the implant. The mesial border can be extended as far as distal to canine, and the distal border can be extended to the tuberosity region in order to achieve a proper mesio-distal implant placement pathway.

Tip: For the upper border, be aware of the posterior superior alveolar artery [Figure 5.3(b)] and the level of the infraorbital nerve. The corners and sharp edges should be rounded to minimize the risk of tearing the sinus membrane.

Preparation of the bony window
A high-speed handpiece can be used depending upon the quality and thickness of buccal wall. The high speed has the advantage of saving time but is more technically sensitive (Table 5.1).

A No. 4, 6, or 8 diamond round bur with copious saline irrigation is utilized to outline the complete extension of the osteotomy (window) (Figure 5.4).
The osteotomy is deepened in smooth, light sweeping motions until the bone is thin and translucent enough to visualize the underlying gray/red color of the sinus membrane (Figure 5.5).
Figure 5.4  (a) Carbide and diamond round bur can be used to outline the bony window.  
(b) Piezosurgical round diamond tip.

Figure 5.5  (a) and (b) The osteotomy is deepened in sweeping motions until the bone is thin and translucent enough to see the underlying gray/red color of the sinus membrane.
Clinical Procedures of the Lateral Window Technique

Handle the bone island
Several techniques can be used to handle the “remaining bone island” (Table 5.2): 1. Tatum advocates infracture of the bone island and carefully elevating the sinus membrane so that the bone island will lie on top of the graft materials and form the roof of the sinus grafts1 [Figure 5.6(a)].
2. The wall-off technique involves removing the bony island completely from the surrounding wall with sinus lift elevators [Figure 5.6(b)].

Elevate the sinus membrane
Gently detach the membrane at the apical aspect of the sinus cavity and then the mesial and distal aspects. After initially releasing the lower border, mesial, distal aspect, and upper border of the sinus membrane about 3–5 mm, go farther from the lower aspect of the sinus cavity to separate all the way to the medial wall.

Please see chapter 4 for how to choose the proper offset/angulation sinus lift instruments for various conditions (Figures 5.7–5.11).

It is important to ensure that the membrane is lifted high enough to place the appropriate implant length (Figure 5.12).

Table 5.2 Advantages and disadvantages of techniques for bone island handling.

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infracture technique</td>
<td></td>
</tr>
<tr>
<td>Bone island can be used as a ceiling for graft materials and implant</td>
<td>The infracture bone island may increase the change to impinge the medial antral wall or to tear the sinus membrane</td>
</tr>
<tr>
<td>Wall-off technique</td>
<td>To provide more bone progenitor cell sources from the underlying sinus membrane</td>
</tr>
<tr>
<td>Bone island can be grinded into particles and used as bone graft materials</td>
<td>Removing the bone island may increase the chance of sinus membrane tearing</td>
</tr>
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Figure 5.6 (a) Infracture bone island. (b) Wall-off technique.
Figure 5.7 (a) and (b) The lower border of the Schneiderian membrane is lifted with a hand elevator.

Figure 5.8 (a) and (b) The mesial border of the Schneiderian membrane is lifted.

Figure 5.9 (a) and (b) The distal membrane is lifted.
Figure 5.10 (a) and (b) The upper border of the sinus membrane is lifted.

Figure 5.11 The medial wall sinus membrane is released. After initially releasing the sinus membrane, go farther from the lower aspect of the sinus cavity to separate all the way to the medial wall.

Figure 5.12 (a) and (b) Be sure the membrane is lifted high enough.
Bone graft materials and barrier membrane

There are several types of bone grafting materials used in maxillary sinus bone augmentation: freeze-dried bone allografts (FDBA), bovine xenograft (Endobon), equine xenograft (Equimatrix), combination of hydroxyapatite and $\beta$-tricalcium phosphate (OSTEON), and $\beta$-tricalcium phosphate and tissue engineering materials rhBMP-2 (Figure 5.14).

Osteoconductive bone grafting materials serve as a scaffold for new bone growth that is perpetuated by the native bone. Osteoblasts from the margin of the defect that is being grafted utilize the bone graft material as a framework upon which to spread and generate new bone. Osteoinductive bone grafting materials involve the stimulation of osteoprogenitor cells to differentiate into osteoblasts that then begin new bone formation. Osteoinductive bone graft materials can serve as a scaffold for currently existing osteoblasts and will also attract osteoblasts to form new bone. Properties of bone grafting materials are listed in Table 5.3.

The survival rates of implants placed in all types of particulate bony matrix materials, either used alone or in combination with other matrix materials, are very similar.$^{2,3}$

Clinicians can take the following factors into consideration: (1) incorporate xenografts for a slower resorption rate compared with allografts.

Tip: The extension of the sinus membrane reflection should include the medial wall in the horizontal direction and be superior enough for the desired amount of height for implant placement (see Figure 5.13—the sinus membrane is still not lifted in the medial wall).
(DFDBA/FDBA); (2) use xenografts or alloplasts if space maintenance of the matrix materials in the sinus is desired; and (3) possibly add to the matrix materials biologics if one desires enhancement of the quality of the bone formed in a shorter time period.

**Tip:** A recent study has shown the addition of rhBMP-2/ACS to Bio-Oss has a negative effect on bone formation.4

It is important to understand that the tight compaction of the graft material that was evident suggests an explanation for the decreased bone formation. Tight compaction of the scaffold leads to a decrease in space between the particles and a decrease in bone formation between the particles.

**Tip:** Collagen plug can be used to occupy the space where the implant will not be placed in order to reduce the use of bone graft materials (Figure 5.15).

### Table 5.3 Properties of various types of bone grafting materials.

<table>
<thead>
<tr>
<th></th>
<th>Osteoconductive</th>
<th>Osteoinductive</th>
<th>Osteogenic</th>
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<tbody>
<tr>
<td>Alloplast</td>
<td>+</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td>Xenograft</td>
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<tr>
<td>Tissue engineering materials</td>
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</table>
A barrier membrane can also be used to cover the window on the lateral wall of the maxilla (Figure 5.16). Several studies have shown that covering the window with barrier membrane can increase the implant success rate.2, 5

Tip: Care should be taken not to stenose the ostium draining into the middle meatus6 (Figure 5.17).
The suturing techniques utilized during flap closure after the lateral window technique for maxillary sinus augmentation are to passively approximate the margins of the flaps and help maintain flap closure during the initial stages of healing. These techniques should be achieved without creating additional trauma to the site. Please see the previous chapter for suturing materials and techniques.

**Tip:** Tension-free primary closure is the ultimate goal to prevent the chance of contamination of the grafts from the oral cavity environment. Removal of the sutures is recommended 2–3 weeks following the procedure, and it is important to remove all the sutures to avoid suture abscesses. Chromic gut suture can be used at the mucosa area to avoid suture removal.

**Tip:** If the patient has to wear a denture after the surgery, it may be necessary to do minor adjustments to allow the denture to fit properly.

**References**


Avoiding and Managing Complications for the Lateral Window Technique

Paul A. Levi and Eduardo Marcuschamer

Introduction

In spite of the high success and survival rates for implants placed in a grafted maxillary sinus, and regardless of the fact that the surgical technique of placement of an implant or implants is similar to implants placed in native bone, it is important to be aware that every surgical procedure has the potential risk for transoperative and postoperative complications. Prior to performing a maxillary sinus elevation using the lateral window technique, the anatomy and physiology of the maxillary sinus must be evaluated and understood. The surgeon must be knowledgeable about the potential for complications and their management should they occur. Understanding the normal anatomy of the maxillary sinus as well as its variations prior to performing a sinus elevation procedure will reduce the possibility of potential surgical and postsurgical complications. This requires a careful evaluation and selection of candidates for a sinus elevation procedure.

In this chapter we will consider the following presurgical findings: adjacent tooth pulpal pathology, blockage of osteum, cysts, malignant neoplasms, medical problems, mucoceles, preoperative medications, polyps, previous sinus surgery, septa, sinusitis, and a thickened sinus membrane.

In order to successfully complete any surgical procedure with a minimal chance for complications and failure, a thorough examination is absolutely essential in order to make a correct diagnosis and develop an appropriate treatment plan. A sinus augmentation using the lateral window technique
Clinical Maxillary Sinus Elevation Surgery

often is an integral part of a comprehensive treatment plan. Thus it is imperative that a thorough dental and periodontal examination be completed at the outset. This examination must include a thorough medical history and an understanding of past medical problems, previous surgical procedures, and medications that the patient is currently taking or has previously taken (see Appendix A). It also entails knowing the patient’s chief concern and desires for dental care and an appreciation of his or her tolerance for past dental procedures. In order to prevent postoperative complications, ascertaining a patient’s social history regarding alcohol, recreational drug use, and smoking is critically important information prior to a definitive treatment plan and certainly before undertaking any surgical treatment.

In addition to the medical and dental history, an inclusive clinical dental and periodontal examination is needed in order to rule out or diagnose all dental pathologies such as dental caries or other restorative problems, periapical pathology, oral hard or soft tissue pathology, occlusal problems, periodontitis, and mucogingival problems. An assessment of the edentulous ridges and the dental arch relationships, along with a prosthetic wax-up and evaluation, is needed for restorative treatment planning prior to implementing a lateral window sinus elevation. The success of therapy is not only dependent on the success of the sinus elevation and the integration of an implant but also on the position and utilization of the implant(s) for function, health, and aesthetics.1

In addition to the clinical examination, a complete radiographic examination will help to provide the clinician with knowledge of the anatomy and health of the sinuses. Parallel technique periapical radiographs of the area for the intended sinus elevation are the most minimal and basic images that are needed. A complete series of parallel technique periapical radiographs are central to a comprehensive dental and periodontal examination. A panoramic radiograph provides greater information on the sinuses and related structures than the periapical images. Three-dimensional imaging utilizing a CT scan will provide even more radiographic information than both the periapical and panoramic images and should be utilized to gain the most knowledge of the anatomy and health of the sinus (Figure 6.1). The CT scan can help to detect the presence of septa and the location of the ostium and can help to ascertain whether or not there is chronic sinus pathology2 (Figures 6.2–6.4). The use of MRI is not indicated to observe bony landmarks.3 Combining the evidence ascertained from the patient’s histories and the clinical examination, the diagnostic wax-up and radiographic imaging using a stent to show the location of the implants will provide the clinician with a great deal of information. These data are needed in order to make a correct diagnosis and determine whether additional consultations are indicated prior to implementing a lateral window sinus elevation. This will allow for excellent communication between the patient and the treating doctor(s), and it will provide the operating clinician with knowledge to guide the surgical procedure and minimize surprises.
Figure 6.1 The adequate patency of the semilunar hiatus (dotted red circle) allows proper drainage of the maxillary sinus mucous production into the middle meatus and assures a healthy maxillary sinus.

Figure 6.2 Healthy maxillary sinus. Note the radiolucency of a physiologically healthy maxillary sinus in a transverse cut of a CBCT.

Figure 6.3 (a) and (b) Chronic maxillary sinusitis. Note the thickening of the Schneiderian membrane (yellow arrow) in close relation to a periapical radiolucency (blue dotted line) on the apex of a nonvital maxillary left second premolar.
Problems to be avoided

Two common problems associated when performing the lateral window sinus elevation surgical technique are a Schneiderian membrane perforation and excessive bleeding. The additional complication of maxillary sinusitis is the most frequent postsinus elevation complication, although the reasons for a sinus infection are not always easily defined.\(^4\) Infection of the sinus graft, blocking the ostium, and augmenting or creating systemic disease are less commonly seen; however, they must be considered. Most of these complications can be prevented by a complete examination and knowledge of and understanding of the medical history. Radiographic imaging is extremely useful in understanding the specific sinus anatomy of a particular patient in order to be prepared to elevate the Schneiderian membrane with as little trauma as possible. The knowledge of a past history of sinus problems and/or surgeries that might affect a sinus, including apicoectomies or retrograde endodontic procedures in the affected area, is also significant information in preparation for the lateral window sinus elevation technique.

Tip: Schneiderian membrane perforation and excessive bleeding are two common complications.

The medical history

Medically, systemic diseases such as uncontrolled diabetes mellitus or other immunodeficient diseases that might interfere with wound healing and/or implant integration should be evaluated prior to proceeding with a lateral window sinus elevation. The physical and mental stability of the patient needs
to be assessed by the operating clinician and if needed by patient’s general physician. Knowledge of the patient’s present medical health and past history of disease is critical. If there is a history of using bisphosphonates, a medical consultation is critical to help prevent the possibility of osteonecrosis of the jaw (ONJ).\textsuperscript{5–7} It is also essential to ascertain from the patient’s physician if preoperative antibiotics are indicated. A history of an orthopedic joint prosthesis very well might require antibiotic premedication. Similarly, a cardiac valve replacement or heart transplant will require preoperative antibiotics. Other systemic conditions such as diabetes, chronic liver disease, a history of radiation therapy to the head or neck, or other conditions affecting the immunocompetence of the individual will necessitate a medical consultation prior to the surgical therapy.\textsuperscript{8} Radiation therapy to the head and neck could lead to osteoradionecrosis if surgical therapy is performed.\textsuperscript{9}

### Tip:
Antibiotic prophylaxis for total prosthetic orthopedic joint replacement is recommended by the American Academy of Orthopaedic Surgeons (2010). Amoxicillin 2 gm one hour prior to surgical procedure or 600 mg clindamycin one hour prior to surgical procedure.

As part of the medical history, a social history is important information to ascertain whether or not the patient uses tobacco products or recreational drugs and, if so, when, how often, and how much. In addition, the use of social drugs and in particular the use of cocaine is a potential problem due to its deleterious effects on the nasal passages and sinuses.\textsuperscript{3, 10} The knowledge of a patient’s alcohol intake is important for any surgical procedure. If the patient consumes heavy amounts of alcohol, there is the possibility of liver disease with the potential for excessive postsurgical hemorrhage. Additionally, the patient’s ability to comply with the postoperative instructions might be affected with alcohol abuse.

Utilizing the expertise of an otolaryngologist (ENT specialist) can be valuable in avoiding surgical and postsurgical complications. The specialist can diagnose, and if necessary treat, existing sinus disease, utilizing when needed functional endoscopic sinus surgery (FESS).\textsuperscript{9} In addition, the specialist can be on board to help assist in therapy should there be postsurgical problems. Eliminating smoking 1 week before the surgical procedure and continuing without smoking 8 weeks following the surgical procedure has been shown to reduce implant failures.\textsuperscript{11, 12}

### Tip:
Eliminating smoking 1 week before the surgical procedure and continuing without smoking 8 weeks after can reduce implant failures.

Avoiding dehydration and avoiding inhalation of pollutants are some of many measures that the patient can do to help prevent postsurgical complications. Exposure to low temperatures, dry air, and decongestants can also increase the chances for postsurgical problems.\textsuperscript{3} Considering the sinuses, it is important to take a careful history to identify previous or recurrent chronic naso-sinusal diseases, nasal trauma or surgery, or nasal respiratory obstruction.
that could affect the outcome of a sinus elevation in terms of postoperative complications. Pignatero et al. suggested that a “sinus compliance index” be established, as it has been shown that a sinus elevation procedure negatively affects the maxillary sinusal physiology and the normal sinusal homeostasis, which can cause a maxillary bacterial sinusitis. The healthier a sinus is presurgically and the less previous sinus disease, the less likely that sinusitis will be a postsurgical complication (Figures 6.1 and 6.2). The effect of sinus elevation on a preoperatively healthy sinus appears to be of no clinical significance.

**Radiographic examination**

Conventional radiographs are 73% reliable in the evaluating or demonstrating of maxillary sinus mucosal diseases. A basic parallel technique periapical radiograph will help to demonstrate the presence or absence of caries, bone loss, restorations, and periapical pathology. Periapical infection near to or into the sinus could lead to preoperative sinus disease and postoperative graft or sinus infection (Figure 6.3). In addition, one can assess the proximity of the sinus to the roots of the adjacent teeth and to the crest of the bone in the edentulous space (Figure 6.3). It can also suggest whether there is a septum, possible mucocele, polyp, thickened sinus membrane, fluid in the sinus, or any other radiopaque object within the sinus (Figures 6.4–6.6). Postoperative blockage of the ostium can be caused by the thickening of a cyst or mucocele or polyps (Figure 6.7). A panoramic radiograph will provide a more complete view of the area to be treated and the anatomical relationships. There is a degree of distortion by magnification of the image, and measuring distances on a panoramic image must be done taking this into consideration. The panoramic radiograph helps to show the approximate size of the sinus in two dimensions, mesially distally and superiorly inferiorly. The use of a Waters’ projection is also helpful in determining a clear sinus prior to augmentation therapy. Should this projection show opacity of the sinus, an endoscopic examination is indicated.

The result of extraction of a tooth in the proximity of the maxillary sinus can lead to enlargement of the sinus as a result of osteoclastic activity and bone resorption (pneumatization). A CT image will provide much greater information than a periapical radiograph or a panoramic radiograph regarding the shape and volume of the sinus and the crestal bone. In addition, the CT images will help to evaluate the OMC, which will aid the clinician in presurgical knowledge of the sinus and help prevent postsurgical complications. The CT image in conjunction with endoscopy can indicate the position and patency of the maxillary ostium and detect any associated middle-meatal anatomical alterations, which can be corrected prior to the lateral window sinus elevation. In addition, from an otolaryngological viewpoint, the CT image can detect chronic sinus disease, such as benign naso-sinusal neoplasms, mucous
cysts, cholesterinic granulomas, and choanal polyps, that can impair the maxillary drainage pathways before or could do so following the sinus elevation procedure. Removal of these lesions through FESS can restore naso-sinusal homeostasis and not damage the mucociliar transport system. Therefore, a CT scan will help to define the presence of lesions and allow for an accurate otolaryngological diagnosis and treatment if needed before proceeding with sinus elevation therapy.  

**Figure 6.5** Note the radiopacity of a clogged maxillary sinus in a transverse cut of a CBCT. Also note the loss of the external wall of the maxillary sinus.

**Figure 6.6** (a) and (b) A polyp in maxillary sinus should be evaluated by an ENT specialist to rule out a tumor, which is rare.
In addition to evaluating for preoperative sinus disease, the use of a CT scan to understand the anatomy of the sinus is most helpful in avoiding surgical or postsurgical problems. The mean height of the sinus is from 36 to 45 mm. The mean width mesiodistally is 25–35 mm and the facial-medial depth is 38–45 mm, providing the clinician with an average volume of the maxillary sinus. Therefore, it is essential to consider the dimensions and positioning of the sinus when planning surgical procedures to ensure patient safety and optimal outcomes.

Figure 6.7 A full view of the paranasal sinuses allows the clinician to perform a comprehensive evaluation prior to maxillary sinus surgery. Note the polyp on the right ethmoidal sinus (red arrow), a potential risk for complications following maxillary sinus surgery.

Figure 6.8 Note the space of the maxillary artery (yellow arrow) in the lateral wall of the maxillary sinus. In some instances the maxillary artery runs inside the bone. (Courtesy of Dr. Michael Kulianos, Athens, Greece.)
An understanding of the dimensions of the ostium, a 7–11 mm long and 2–6 mm wide elliptical opening located on the superior aspect of the medial wall of the maxillary sinus superior to the first molar, can prevent overfilling of the sinus and blocking the ostium during and following the lateral window sinus elevation surgery. Uchida found that on average the distance from the floor of the sinus to the ostium averages 28.5 mm. Should the ostium be blocked as a result of a lateral window sinus elevation, chronic sinusitis could develop, which could compromise the success of the sinus graft, the implant, and the patient’s general health and well-being. Additionally, the position of large blood vessels can be determined with CT imaging (Figure 6.8).

**Septa**

Septa, bony protrusions into the maxillary sinus cavity, have been reported in 20–58% of patients and can complicate sinus elevation by hampering bone plate inversion and lifting. The risk of a Schneiderian membrane perforation increases with the presence of maxillary sinus septa. Underwood stated that the formation of septa relates to the different eruption phases of the teeth. Others have different embryological reasons for septa. There are diverse variations in sinus septa in prevalence, location, and size. Bony septa (Figure 6.9) in the maxillary sinus occur commonly between the second premolar and the first molar. In evaluating 66 sinuses, 18 (27.3%) were located anteriorly, 33 (50%) were in the middle of the sinus, and 15 (22.7%) were seen posteriorly. Primary and secondary septa were defined, with primary septa arising developmentally and secondary septa caused by the pneumatization of the sinus. It has been suggested that

![Figure 6.9](image) (a) and (b) Bony septa in the maxillary sinus are common abnormalities and can be depicted by axial with coronal CT scans.
septa be removed to enable the bone graft to cover the entire sinus floor. As septa tend to enlarge medially, it is recommended that the Schneiderian membrane be elevated laterally to medially to help avoid membrane perforation. Boyne and James recommended their removal by cutting them with a narrow chisel and removing them with a hemostat, thus enabling the bone graft to be placed over the entire antral floor. Boyne and James recommended their removal by cutting them with a narrow chisel and removing them with a hemostat, thus enabling the bone graft to be placed over the entire antral floor. Studying sinus morphology, by means of CT scans, provides valuable information. A CT scan can preoperatively detect the presence of a narrow maxillary sinus, which might be difficult to negotiate when elevating the Schneiderian membrane.

**Tip:** Septa can be removed to enable the bone graft to cover the entire sinus floor. Another option is to modify the design of the window so that it follows the contour of the sinus floor and septum, hence making a W-shaped bony window or two windows where membrane is elevated and both windows are infractured.

### Prevention of hemorrhage

Excessive bleeding during the lateral window sinus elevation procedure may be prevented or anticipated by prior knowledge of the location of intraosseous arteries in the lateral wall of the sinus. Intraosseous arteries are found <16 mm from the crest of the ridge in 20% of patients. With CT image visualization the lateral window can be adjusted to avoid the artery, or if not possible, the clinician should be prepared to control the hemorrhage by clamping and crushing the bone, cautery, the use of bone wax, sutures, or other procedures (Figure 6.10).

**Figure 6.10** Note the ligation of the maxillary artery with 5–0 chromic gut suture, after the window osteotomy and membrane elevation. The black arrow shows the dissected maxillary artery on the distal portion of the sinus. (Courtesy of Dr. Michael Kulianos, Athens, Greece.)
Summary, presurgical prevention of complications

Maintain a checklist of diagnostic assessments.

a. Be sure that an accurate and complete medical, dental, and social history is taken.

b. Complete a thorough dental, prosthetic, periodontal, and radiographic examination.

c. Obtain additional medical or dental consultations as needed and complete medical therapy if indicated.

d. Thoroughly discuss the procedures and their possible complications with the patient.

e. Review the pre- and postoperative instructions and explain post- and preoperative medications at the time of the consultation prior to implementing surgical therapy. (See Appendix B.)

f. Be certain that all supplies and instruments are present and that the equipment is working prior to the surgery. Have backup supplies and equipment available. For example: anesthesia, lidocaine 2% 1:50,000 to control hemorrhage and eliminate pain, a backup set of sinus membrane elevators, a complete set of surgical burs, extra surgical blades, a periodontal surgical kit, extra bone grafting material, additional membranes and extra suture material, and any other instruments that might become dull or contaminated and that you feel are important to the success of your therapy.

Complications during the surgical procedure

Flap care

Maintaining the integrity of a surgical flap increases the possibilities of achieving primary closure at the time of surgery and preserving this wound closure throughout the course of healing. Manipulating the flap gently during the surgical procedure is essential for any bone grafting procedure and helps to avoid postsurgical complications, such as flap necrosis, oro-antral fistula formation, graft infection and loss, postoperative pain, and so forth. Atraumatic techniques need to be utilized during flap elevation, flap retraction, periosteal releasing incisions, and suturing in order to help maintain the integrity of the flap.

Trauma during retraction

Trauma during flap retraction can be a significant surgical complication when performing a lateral window technique for a maxillary sinus augmentation. The risk of trauma during retraction is increased when the procedure is performed in the molar region, the window is located superiorly to the crest of the ridge, teeth are present mesial to the surgical site, the posterior maxilla is extremely resorbed, and the patient presents with reduced mouth opening. Flap trauma during retraction can induce a wide variety of postsurgical complications causing necrosis of the flap, wound opening, wound infection, or infection of the bone graft. In addition, trauma to the infraorbital nerve has
been reported during flap retraction and flap elevation, generating reversible or at times irreversible paresthesia.\textsuperscript{27,31,32}

To reduce the amount of trauma during retraction it is important to evaluate the patient’s opening of his or her mouth in order to design a flap that will not be compromised during therapy. The window design must allow good visibility and access, and the exposure of the bone with the flap retracted should allow at least 3 mm of bone exposed surrounding the window. This will permit the suturing of the flap over bone and not over the grafted window. The horizontal crestal incision should be mesio-distally wide enough to allow good vascularity to the flap. The width is also important to help avoid tension during retraction, which could strangulate the vascularity and also traumatize the soft tissue. Creating vertical incisions of adequate length can reduce trauma during retraction of the flap without tension and positioning the flap for maximum visibility of the window. During the procedure the assistant and the clinician must be cognizant that the edge of the periosteal elevator must always contact bone, which helps to avoid physically crushing the soft tissue along with compromising the vascularity. In addition, it is important to constantly irrigate the surgical area with normal saline to maintain hydration of the flap.

Additional trauma to the flap can be produced when vertical and/or lateral ridge augmentation procedures are performed simultaneously with the lateral window technique for sinus elevation. This additional trauma can be a result of incisions made into the periosteum in order to achieve flap advancement. When periosteal releasing incisions are needed, trauma to the flaps can be minimized by maintaining the incisions as superficial and as coronal as possible to help to avoid severing blood vessels of large caliber and thus compromising the vascularity.\textsuperscript{33} Incisions made in the gingiva will not leave a scar, and a scar is also most unlikely in the alveolar mucosa. Careful and complete suturing of an incision without tension is also very important to prevent a scar.

**Inadvertent tears/perforations of the flap**

An inadvertent tear or perforation of the flap is a surgical problem that can compromise the success of the procedure, in particular when utilizing a lateral window technique. The risk of postsurgical difficulties increases when the tear or perforation is located over the sinus window. The lack of vascularity along the edges of the tear or perforation of the flap, when they do not lie over vital bone, can create additional complications. These problems can include graft contamination, oro-antral fistula, wound infection, graft infection, and graft and implant failure.

Flap tears and perforations can be the consequence of inadvertent penetration of the flap with the initial incisions, traumatic flap retraction, aggressive flap elevation especially in the presence of exostoses and/or scar tissue, presence of previous pathologies such as a former sinus tracts, and deep periosteal incisions for flap advancement.\textsuperscript{34}
If a flap perforation or tear is identified, it is important to elevate and free the flap along the borders of the tear or perforation to prevent the spread of the tear or perforation and greater damage to the flap. If the borders of the tear or perforation lie over vital bone, the margins of the tear or perforation can be coapted with a resorbable suture of a thin caliber. If the margins of the tear or perforation are located over grafted bone, depending on the size, the margins can be sutured; but if the clinician believes that the procedure will be compromised, the procedure should be aborted.

**Schneiderian membrane tear or perforation**

In 2004 Devorah Schwartz-Arad et al. evaluated 70 patients who underwent 81 external sinus elevation procedures and placed 212 screw-shaped implant fixtures; transoperative and postoperative complications were thoroughly documented. They found that the perforation of the Schneiderian membrane was the most significant transoperative complication found with 36 of the sinus elevation surgeries (44%); these results are consistent with the findings of others.\(^{35}\) Even though a statistical significance was not found between the presence of septa and membrane perforations, out of the 23 sinuses in which the presence of septa was recorded, 12 perforations of the Schneiderian membrane occurred. Even though most perforations of the Schneiderian membrane can be repaired, the clinician must utilize judgment in order to decide when the procedure should be aborted.\(^{35}\) Usually perforations are created during the preparation of the window or during the elevation of the Schneiderian membrane. Specifically, if sharp edges and ridges like Underwood’s septa and spines are present, they are likely to be involved with membrane tears\(^ {27}\) (Figure 6.11). Nonetheless, perforations can also be created during graft condensation and osteotomy preparation for simultaneous implant placement.

The integrity of the Schneiderian membrane will increase the stability of the graft by allowing adequate vascularization during initial healing.\(^ {36}\) Membrane perforations are strongly associated with the occurrence of postoperative complications such as acute or chronic sinus infection, swelling, bleeding, wound dehiscence, and loss of the graft material.\(^ {27,37,38}\)

To reduce the probabilities of a perforation of the Schneiderian membrane, it is important to do a thorough preoperative evaluation of the anatomy of the sinus. Applying gentle pressure while performing the lateral window osteotomy, creating the outline of the lateral window as close as possible with the anterior wall and floor of the sinus, and maintaining the sinus elevators continuously in contact with the bone are techniques to lessen the likelihood of a sinus membrane perforation. Also, utilizing a piezoelectric surgical device for window preparation will reduce the probability of tearing the Schneiderian membrane.\(^ {36}\) A thick Schneiderian membrane observed with CT scan imaging is commonly a sequelae of previous sinus pathology (Figure 6.12). Interestingly, thick Schneiderian membranes tend to be easier to manipulate and are more resistant to perforations and/or tears during lateral window approach sinus augmentation than thin membranes.
Figure 6.11  (a) Small Schneiderian membrane perforation following complete osteotomy for lateral window technique for maxillary sinus augmentation. (b) Two Large Schneiderian membrane perforations following complete osteotomy for lateral window technique for maxillary sinus augmentation. (c) A resorbable collagen membrane was placed to cover both Schneiderian membrane perforations. Note how the membrane extends beyond the outline of the perforations.

Figure 6.12 Thickenining of the Schneiderian membrane on a smoker.
Despite efforts to avoid Schneiderian membrane perforations, the clinician must be prepared to manage them. Schneiderian membrane perforations vary in size and location and may be managed with various techniques. Some Schneiderian membrane perforations are large enough to be appreciated by the operator, others are of a smaller diameter or located on areas not easy to visualize or not visible because the surgical site contains blood. The Valsalva test (blocking the patient’s nostrils and asking the patient to blow through his or her nose) will help to identify the presence of perforations not seen with direct vision.

If a Schneiderian membrane perforation is encountered, it is recommended that the clinician stop the procedure, evaluate the perforation(s), and determine how to or if to proceed. In order to proceed, it is essential that the margins of the perforated Schneiderian membrane are detached from the bony walls of the sinus. Additional bone removal with a rotary instrument and/or piezoelectric device can facilitate this process. In discussing sinus membrane repair, authors have recommended the use of sutures, membranes, and/or bone plates depending on the size and location of the tear.

Resorbable membranes are the most commonly utilized materials to repair Schneiderian membrane perforations. It is important that the membrane overlaps by 3–5 mm the periphery of the perforation to assure the stability of the membrane and the subsequent bone graft. Following the membrane repair and complete membrane elevation, graft material should be adapted very gently without any excessive pressure to assure the stability of the repaired membrane. If the membrane perforation cannot be repaired or controlled, the procedure should be aborted and reentered after 6–8 weeks to allow for the regeneration of the Schneiderian membrane.

When attempting a lateral window technique with simultaneous implant placement, special care needs to be taken in order that the operator does not perforate the Schneiderian membrane while drilling the osteotomy for placing the implant. Some clinicians insert a periosteal elevator into the sinus cavity while drilling to protect the elevated Schneiderian membrane from the implant drills; however, it is preferable to fill the sinus with bone graft material prior to the implant drilling, even if some graft material will be removed during the process of placing the implant. This assures a complete fill of the created cavity. Also, it is particularly important to fill the sinus prior to implant drilling when a sinus membrane perforation was encountered during lateral window preparation or Schneiderian membrane elevation.

**Grafting material into sinus**
The introduction of graft particles into the sinus cavity can be the result of a defective Schneiderian membrane repair, nondiagnosed Schneiderian membrane perforation, perforation of the Schneiderian membrane due to excessive forces at the time of graft packing, and overfilling of the graft causing necrosis of the Schneiderian membrane.

The presence of graft particles in the sinus cavity can create a variety of postoperative complications. A frequent concern and complaint from patients
who have been treated with a lateral window sinus augmentation is the presence of blood and graft particles being expelled through the nose. Even though graft particles are smaller than the semilunar hiatus and even though sinus drainage is not impaired, there is a high risk of a blockage of the semilunar hiatus and subsequent impediment of the sinus drainage. This problem can create a variety of more serious complications such as chronic sinusitis, infection of the graft, and in some instances damage to the eye and/or thrombosis of the cavernous sinus.

**Tip:** If the clinician suspects that graft particles have been dislodged into the sinus cavity, the patient must be monitored very closely to avoid potential complications mentioned above. Prescribing antibiotics, anti-inflammatory medications, and nasal decongestants may not be sufficient. If symptoms do not subside, a reentry of the site to clean the sinus complex by either an experienced clinician or an ENT specialist is recommended.

![Figure 6.13](image)

Figure 6.13  (a)–(c) During the placement of an implant, the implant was inadvertently pushed into the maxillary sinus.
Dislodgement of an implant into the sinus
The inadvertent dislodgement of an implant fixture into the augmented sinus during lateral window sinus augmentation with simultaneous implant placement can occur as a result of inadequate apico-coronal height of the residual ridge, poor bone quality of the residual ridge, widening of the implant osteotomy from overdrilling, positioning the implant in an unnecessary apical position, and applying excessive pressure during implant installation (Figures 6.13). If the dislodgement of an implant fixture is encountered during lateral window sinus elevation, locate the implant fixture with a CT scan, and if a CT scan is not available utilize a panoramic or a periapical radiograph. Depending on the location of the implant fixture and the skill of the operator, the graft material should be removed along with the implant fixture. If the Schneiderian membrane perforation is still manageable and the graft can be contained, the sinus augmentation procedure may proceed. The implants should be maintained unloaded until the grafted area has healed completely. If the Schneiderian membrane perforation is not manageable after retrieving the implant fixture, the procedure should be aborted and reentered after the site has completely healed no sooner than in 3 months.

Contamination of site or graft material
The introduction of pathogenic bacteria into the surgical site or into sterile graft material represents a risk for potential postoperative complications and major postoperative sinus infections. The surgical team should execute careful sterile surgical techniques to avoid the contamination of sterile instruments, graft, and surgical site from nonsterile components, extra oral tissues, and saliva.

Trauma to adjacent teeth with disruption of apical blood supply
During the process of bone remodeling following tooth extraction and sinus pneumatization, the residual alveolar bone surrounding the remaining teeth can be very thin and many times nonexistent. When there is no bone surrounding the apices, there can be an incorporation of the blood vessels and nerves of the involved teeth into the Schneiderian membrane. In particular, the lateral window sinus elevation has a potential risk of damaging the vascularity of neighboring teeth. When present in an extremely pneumatized sinus, if the elevation of the Schneiderian membrane is performed at the apices of the neighboring teeth, a disruption of the vascularity of the neighboring teeth can create a potential postoperative complication of pulpal necrosis.31

In order to reduce this potential risk, a CT scan will aid the clinician in identifying the presence of alveolar bone surrounding the apices of the neighboring teeth. When the alveolar bone surrounding the apices is extremely thin or nonexistent, the clinician should remain at least 3–5 mm away from the apices of the neighboring teeth, which many times will limit the extent of the lift.
Excessive bleeding

The vascular supply to the maxillary sinus is mainly derived from three arteries: the infraorbital artery, the posterior superior alveolar artery, and the greater palatine artery. In 2005, Elian et al. analyzed 50 CT scans and found that the maxillary artery could only be visualized in 53% of the cases. This is because at times the maxillary artery is found to run intraosseously and other times it is found extraosseously, attached to the Schneiderian membrane. In that same study Elian et al. found the average height of the maxillary artery was 16 mm superior to the alveolar crest. Commonly the osteotomy for the lateral window technique is located inferiorly to the location of the maxillary artery. When due to extreme resorption of the alveolar ridge the distance from the crest of the bone to the maxillary artery interferes with the location of the lateral window, complications of bleeding are more common. In addition, intraosseous arteries are more difficult to dissect and can be easily damaged.

When the path and location of the maxillary artery are identified, efforts to modify the location and shape of the lateral window should be done. If modifying the shape and location of the lateral window does not avoid the pathway of the maxillary artery, utilizing a crestal approach for maxillary sinus augmentation can be performed. With the introduction of piezoelectric surgery the risks of damaging the artery have been reduced even in those cases when the maxillary artery runs along the outline of the lateral window.

To avoid complications it is recommended to locate the position of the maxillary artery with the use of a CT scan, even though it can only be seen half of the time (Figure 6.8). If during the lateral window osteotomy the maxillary artery is visualized, it is important to dissect the artery from the bone to avoid injuries.

Although a hemorrhage during sinus grafting is not common, depending on the caliber of the vessel and the extent of the damage, more serious complications can arise. If arterial bleeding occurs, pressure can be applied with gauze soaked with anesthetic containing epinephrine 1:50,000. Caution needs to be taken not to damage the Schneiderian membrane. If bleeding cannot be controlled, the blood vessel can be cauterized using electrocautery or laser. Otherwise, the artery should be dissected and ligated with a resorbable suture (Figure 6.10). Excessive bleeding can also arise from traumatizing the flaps during retraction or creating very deep periosteal incisions for flap advancement. Intraosseous bleeding hemorrhage can be controlled by the use of bone wax or crushing the bone surrounding the orifice of the vessel.

Incomplete elevation of the sinus membrane

Grafting the sinus if an incomplete elevation of the Schneiderian membrane was performed can create abnormal compartments on the new sinus anatomy (Figures 6.14 and 6.15). If there is insufficient drainage of those compartments, there can be an accumulation of sinus fluid production that can become easily infected.
The most common areas of incomplete elevation of the Schneiderian membrane are the anterior and medial walls of the maxillary sinus (Figure 6.15). In order to avoid incomplete elevation of the Schneiderian membrane from the anterior wall of the sinus, it is recommended to design the lateral window as close as possible to the anterior wall of the sinus in order to have direct access to manage and visualize the membrane. Drying the surgical area with gauze strips will help visualize the lateral wall of the sinus cavity and avoid incomplete elevation of the membrane. It is important to evaluate the medial-lateral distance of the sinus and take care to elevate the medial wall completely so as not to leave a narrow space between the membrane and the lateral wall. Knowledge of the width from the lateral wall to the medial wall also helps to define the amount of grafting material that will be needed and
more importantly to allow adequate time for new bone to form. The greater the volume of the grafted sinus, the more time is needed for graft maturation.\textsuperscript{45}

**Postoperative instructions to help avoid postoperative complications**

In order to help prevent postoperative problems (see Table 6.1), it is very important that the patient be thoroughly aware of the procedure to be performed well prior to doing the sinus elevation with the lateral window technique. We recommend that the clinician discuss the procedure in detail with the patient several days prior to the therapy and provide the patient with a list of preoperative and postoperative instructions. A suggested list of pre- and postoperative instructions is found in Appendix B. It is not uncommon for suborbital or facial ecchymosis and/or edema to occur following a lateral sinus elevation procedure, and it is important to advise the patient of the possibility prior to therapy (Figure 6.16).

<table>
<thead>
<tr>
<th>Early Postoperative Complications</th>
<th>Late Postoperative Complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Swelling</td>
<td>Blockage of the ostium</td>
</tr>
<tr>
<td>Bleeding</td>
<td>Chronic sinus infection</td>
</tr>
<tr>
<td>Wound Dehiscence</td>
<td>Graft failure</td>
</tr>
<tr>
<td>Flap Necrosis</td>
<td>Implant failure</td>
</tr>
<tr>
<td>Acute Sinusitis</td>
<td>Osteomyelitis</td>
</tr>
<tr>
<td>Hemo-sinus</td>
<td>Thrombosis of the cavernous sinus</td>
</tr>
<tr>
<td>Hematoma</td>
<td>Orbital cellulitis</td>
</tr>
<tr>
<td>Pain</td>
<td></td>
</tr>
<tr>
<td>Paresthesia</td>
<td></td>
</tr>
</tbody>
</table>

Figure 6.16 A common surgical complication is the formation of hematomas in the face. Note bruising underneath the eye.
# Appendix A

## Medical preoperative conditions

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Examinations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diabetes mellitus</td>
<td>HbA1C, Medical consultation</td>
</tr>
<tr>
<td>Immunodeficiencies</td>
<td>Medical consultation</td>
</tr>
<tr>
<td>History of bisphosphonate use</td>
<td>CTX, Medical consultation</td>
</tr>
<tr>
<td>Joint replacement</td>
<td>Antibiotic premedication</td>
</tr>
<tr>
<td>Cardiac problems</td>
<td>Medical consultation, possible premedication, review AHA 2007 guidelines</td>
</tr>
<tr>
<td>Chronic liver disease</td>
<td>PT INR, medical consultation</td>
</tr>
<tr>
<td>History of radiation therapy to head and neck</td>
<td>Medical consultation</td>
</tr>
<tr>
<td>Recreational drug use</td>
<td>Medical consultation</td>
</tr>
<tr>
<td>Smoking</td>
<td>Medical consultation, arrange smoking cessation</td>
</tr>
</tbody>
</table>

## Preoperative sinus conditions

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Examinations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blockage of osteum</td>
<td>Otolaryngology consultation</td>
</tr>
<tr>
<td>Cysts</td>
<td>Otolaryngology consultation</td>
</tr>
<tr>
<td>Malignant neoplasms</td>
<td>Otolaryngology consultation</td>
</tr>
<tr>
<td>Mucoceles</td>
<td>Otolaryngology consultation, care taken not to block osteum</td>
</tr>
<tr>
<td>Polyps</td>
<td>Otolaryngology consultation, care taken not to block osteum</td>
</tr>
<tr>
<td>Previous sinus surgery</td>
<td>Consultation with treating physician</td>
</tr>
<tr>
<td>Septa</td>
<td>CT scan, clinician be advised because of the possibility of Schneiderian membrane perforation</td>
</tr>
<tr>
<td>Sinusitis</td>
<td>Otolaryngology consultation</td>
</tr>
<tr>
<td>Thickened sinus membrane</td>
<td>Clinician should be aware not to block osteum</td>
</tr>
<tr>
<td>Previous oro-antral fistula</td>
<td>Clinician be advised of possibility of a Schneiderian membrane perforation</td>
</tr>
</tbody>
</table>

## Preoperative dental conditions

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Examinations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulpal pathology</td>
<td>Periapical radiograph, pulp vitality test, endodontic consultation</td>
</tr>
<tr>
<td>Caries</td>
<td>Periapical radiograph, restorative consultation</td>
</tr>
<tr>
<td>Conditions</td>
<td>Examinations</td>
</tr>
<tr>
<td>------------------------------------------------</td>
<td>--------------------------------------------------</td>
</tr>
<tr>
<td>Periodontal disease</td>
<td>Complete mouth periapical radiographs, complete</td>
</tr>
<tr>
<td></td>
<td>mouth periodontal charting, periodontal consultation, total treatment planning</td>
</tr>
<tr>
<td>Aesthetic concerns and/or missing teeth</td>
<td>Prosthodontic consult, total treatment planning</td>
</tr>
<tr>
<td>Malposed teeth</td>
<td>Orthodontic consultation, complete treatment plan</td>
</tr>
<tr>
<td>Limited oral opening</td>
<td>TMD consultation</td>
</tr>
<tr>
<td>Intraoral or extraoral soft or hard tissue lesions</td>
<td>Oral pathologic consultation</td>
</tr>
</tbody>
</table>

**Appendix B**

**Preoperative instructions**
1. Eat well prior to the surgical appointment unless intravenous conscious sedation or general anesthesia is being used, in which case nothing to eat or drink 8 hours prior to the surgical procedure.
2. Do not take aspirin 7 days prior to the surgical procedure.
3. Have a good night’s sleep prior to the surgery.
4. Take Augmentin 875 mg 1 hour prior to the procedure. If allergic to penicillin substitute with 300 mg of clindamycin.
5. Take 600 mg ibuprofen 1 hour prior to the procedure unless allergic or unless you are asthmatic.
6. Arrange for an individual to bring you home following the procedure.
7. Do not plan to return to work following the procedure.

**Postoperative instructions**
1. Physical activity: Rest for the remainder of the day and maintain your head in an elevated position. Avoid physical activity for 2 weeks, including sports activities that raise the heart rate.
2. **DO NOT SMOKE.**
3. Swelling: Apply cold (ice) packs to your face. Maintain them on your face for 20 minutes and then off for 20 minutes frequently during the day until sleep for the first 24 hours. Some facial swelling is expected and there might be some swelling underneath the eye along with some evidence of bruising.
4. Eating: Maintain a soft cool diet the first day and a soft diet the remainder of the week. Avoid chewing on the side of surgery. If both sides were treated, maintain a very soft diet for 2 weeks. Do not use a straw to take liquid as vigorous suctioning can promote bleeding.
5. Sneezing: Avoid heavy lifting and blowing through your nose. Do not stifle sneezes by blocking your nose.
6. Do not drink with a straw or drink carbonated liquids (minimum 3 days).
7. Bleeding: Expect some slight bleeding from the surgical site over the next 12 hours. Some slight bleeding from the nose is also expected during the next 2 days.
8. Medications—take your medications as directed:
   a. Antibiotics: Amoxicillin with clavulanate potassium 875mg BID for 10 days or clindamycin 300mg TID for 10 days.
   b. Anti-inflammatory: Ibuprofen 600mg QID for 3 days then QID PRN comfort.
   c. Pain medication: Acetaminophen 300mg with 30mg of codeine phosphate 1 TAB QID PRN comfort, or hydrocodone 5mg with 500mg of acetaminophen 1 TAB QID PRN comfort.
   d. Chlorhexidine 1.2% oral rinse: Rinse 30cc BID for 10 days.
   e. Steroid therapy: Medrol Dosepak take as directed.
9. Dental home care:
   a. Do not brush or floss the teeth in the surgical area until instructed by the doctor or staff.
   b. Brush, floss, and use other hygiene aids for all other teeth daily or as directed.
10. Follow-up: Plan to see the doctor and his staff for a postoperative appointment in 7–10 days. Sutures will be removed in 2 weeks.

References

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39 Valsalva AM. *De auro humana tractatus* (Bologna: Pisarii C, 1704).


Advanced Techniques of the Lateral Window Technique

Daniel W.K. Kao and Mana K. Nejadi

In this chapter, clinicians can learn the application of piezosurgical technology in the lateral window sinus lift procedures, including step-by-step instructions for using a piezosurgical device.

Background of piezosurgical technology (piezoelectric bone surgery)

The use of piezoelectric techniques for sinus elevation was introduced by Vercellotti in 2001 to avoid complications that have the potential to increase patient morbidity and treatment time and costs, and to achieve more predictable results.\(^1\) A piezosurgery system utilizes ultrasonic microvibrations to cut tissues. It offers more precise cuts, selective cutting action that allows cutting hard tissues while sparing soft tissues and vital structures like nerves and vessels, and enhanced visibility of the surgical field.

The microvibrations of the instrument are caused by the piezoelectric effect. Basically, when an electric current is passed across certain ceramics and crystals, it modifies them and results in oscillation of ultrasonic frequency. The resultant vibrations are amplified and transferred to the instrument tip, which in turn can incise the tissues\(^2\) [Figure 7.1(a)].

The piezosurgery device consists of a power unit that has holders for a handpiece and irrigation fluid that can be normal saline or sterile water, a handpiece with different tip inserts, irrigation fluid, and an adjustable peristaltic pump. The power of instrument cutting, the frequency of vibrations, and the amount of irrigation can be adjusted as needed. In the piezosurgery system, the frequency of 25–29 kHz is used. This frequency, which creates microvibrations ranging from 60 to 210 μm in amplitude and provides the
handpiece with power exceeding 5 W, cuts only mineralized tissue, while soft tissues including neurovascular tissue are cut at frequencies higher than 50 kHz\textsuperscript{2,3} [Figure 7.1(b)]. This pumped fluid that is emitted from the tip of the inserts removes the debris from the site, acts as a coolant, and creates a blood-free surgical field and better visibility due to the cavitation effect.\textsuperscript{2} The high precision of cutting action in this system is achieved though minimal pressure needed while using the instruments to perform osteotomy. This light pressure also prevents creation of excess heat. If too much pressure is applied, the instrument tip will stop moving and a warning tone is heard.\textsuperscript{3}

The applications of piezosurgical technology in lateral window procedures

Elevation of the Schneiderian membrane is achieved through ultrasonic vibrations of specifically designed tips that work on the internal aspect of window walls and the presence of hydropneumatic pressure of the irrigation fluid that is subjected to the cavitation effect.\textsuperscript{1,4}

The incidence of membrane perforation is shown to decrease to 3.6% and 7%\textsuperscript{5,6} when the piezosurgery technique was used to perform lateral window sinus elevation compared to the use of conventional rotary and hand instruments, respectively.

Besides the clinical effectiveness of this technique, histologic and histomorphometric evidence of bone formation and wound healing in animal models
reveals a more favorable tissue response in piezosurgery than conventional surgical techniques such as diamond or carbide rotary instruments (Figure 7.2).

The first company to make the piezosurgery device available to the dental market was Mectron Medical Technology. There are also several other piezo-surgical devices utilizing similar technology that have been developed in the last decade and are commercially available for clinical use (Figure 7.3).

The Mectron piezosurgery device uses the resonance frequency in the range between 24,000 and 29,500 Hz (24–29.5 kHz) coupled with forced oscillation with a frequency ranging between 10 and 60 Hz to provide precise and selective bone cutting, minimal soft tissue damage, and improved healing of the tissue. Mectron has developed the sinus lift kit that is indicated for
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preparation of the bony window separation and elevation of the sinus membrane. The sinus lift kit includes the following inserts: OT1, OT5, EL1, EL2, and EL3 (Figure 7.4).

**Surgical steps**

**Step 1**

Full-thickness flap is raised (Figure 7.5).

**Figure 7.4** Mectron piezosurgery sinus lift inserts. The sinus lift kit includes the following inserts: OT1, OT5, EL1, EL2, and EL3. (a) OT1: For micrometric osteotomy (about 1 mm)—to finalize the osteotomy in close proximity to soft tissue (e.g., sinus membrane, vessel, alveolar nerve). (b) OT5: For micrometric osteotomy or osteoplasty—nontraumatic, to finalize the osteotomy or osteoplasty on thin bone and/or near delicate anatomic structures. (c) EL1: For Schneiderian membrane separation from bony walls—separation of the sinus membrane, 2 mm around the frame of the bony window. (d) EL2: The noncutting elevator of the sinus membrane—separation of the sinus membrane in internal zones. (e) ET3: The noncutting elevator of the sinus membrane—separation of the sinus membrane in internal zones.

**Figure 7.5** (a) and (b) Surgical Step 1: Elevated full-thickness flap.
Step 2: bony window osteotomy
Reduction of the thickness of the lateral sinus wall until the dark shadow indicating the sinus cavity is seen. This objective can be achieved by using osteoplasty insert (OP5 or OT5) from Mectron system.

**Tip:** For thick bone, a conventional high-speed round bur can be used in the initial preparation to reduce the working time.

Once the thickness of the wall is reduced to 1mm or less, the window is outlined by either sinus bony window osteotomy insert (OT1: diamond scalpel insert) or by OT5 (round diamond insert). The ideal shape of the window is oval and the length of the window depends on the number and location of implants.

The window preparation can be completed by either OT1 or OT5 inserts. These instruments allow for removal of the bone without perforating the membrane if they come in contact with it (Figure 7.6).

Step 3: sinus membrane separation
Sinus membrane separator (EL1) insert (compressor) is inserted into the frame of the window and is used to separate the Schneiderian membrane. With the help of cavitation, this insert can start elevating the membrane internally (for up to 2mm around the margins of the window). Separation reduces membrane tension and results in membrane mobility, and at this point the membrane can be manually lifted (Figure 7.7).

Step 4: sinus membrane elevation by noncutting elevator
EL1, EL2, and EL3
Sinus membrane elevators (EL2 and EL3 are both noncutting elevators) help further separation in internal zones of the window (Figure 7.8).
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Step 5: sinus membrane elevation by hand instruments
Gently detach the membrane at the apical aspect of the sinus cavity and then the mesial and distal aspects. After initially releasing the lower border, mesial, distal aspect, and upper border of the sinus membrane about 3–5 mm, go farther from the lower aspect of the sinus cavity to separate all the way to the medial wall (Figure 7.9).

Step 6: bone graft and barrier membrane placed
Once the sinus membrane is lifted, bone graft materials can be placed and packed into the sinus cavity and a barrier membrane can also be used to cover the window on the lateral wall (Figure 7.10).

Step 7: suture and postop instruction

Tip: The irrigation tube needs to be flushed with sterile water for 2–3 minutes if the normal saline solution is used.
Advanced Techniques of the Lateral Window Technique

References


Figure 7.9 (a) and (b) Surgical Step 5: Elevation of membrane by hand instrument.

Figure 7.10 (a) and (b) Surgical Step 6: Bone graft and barrier membrane placed.

CHAPTER 8

Basic Instruments and Materials of the Transalveolar Approach: Osteotome Technique

Daniel W.K. Kao and Elana E. Walker

In this chapter, clinicians will review the background and instrument preparation of the transalveolar osteotome approach.

Background

The crestal approach to sinus elevation, the osteotome technique, is a less invasive method of achieving an increase in alveolar bone height in the appropriate situations. The crestal approach allows for vertical bone augmentation and site-specific sinus elevation with minimal surgical trauma. The Summers osteotome technique is to conserve the bone in the site, to selectively displace it upward, and to raise the sinus membrane.\(^1\) Compared to the lateral window technique, there is a reduced bone volume increase that causes only minor changes to the sinus morphology and therefore the function.

The osteotome technique involves the use of a surgical mallet to compact the alveolar bone with an osteotome (Figure 8.1). An increasingly wider series of osteotomes are tapped in an apical direction toward the sinus floor to prepare the osteotomy and infracture the cortical plate.\(^1-4\) Depending upon the density of the bone, the entire site preparation can be completed utilizing osteotomes. A dome-shaped tented space can usually be seen on the radiograph at the osteotome site (Figure 8.2).

Tip: It is recommended that there be 2 mm of graft material around the apex of the implant after osteotome procedures.
Instrument preparation for the transalveolar approach: osteotome technique

See Table 8.1 for a list of instruments of an osteotome kit. The original Summers osteotomes are continuous taper and concave tips. The concave design can collect and hold the bone and also assist in pushing bone graft materials in front of the advancing osteotome. Osteotomes typically have a concave tip that serves to cut and collect bone. This allows for the vertical compression of the bone. It is the apical displacement of the bone that is collected by the osteotome that will cause elevation of the sinus floor and Schneiderian membrane.

A surgical mallet is used to advance the osteotome (see Figure 8.3). The surgeon may identify the cortical floor of the sinus cavity by the change in tactile sensitivity while malleting the osteotome. A different pitch of tapping
Basic Instruments and Materials of the Transalveolar Approach: Osteotome Technique

sound can be a sign that a portion of sinus floor has been fractured upward and inward into the sinus cavity.

Table 8.1 Osteotome instrument kit.

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straight sinus elevation concave osteotome</td>
<td>2.8 mm, 3.5 mm, 4.2 mm</td>
</tr>
<tr>
<td>Angled sinus elevation concave osteotome</td>
<td>2.8 mm, 3.5 mm, 4.2 mm</td>
</tr>
<tr>
<td>Nylon cap mallet</td>
<td></td>
</tr>
<tr>
<td>Bone bowl</td>
<td></td>
</tr>
<tr>
<td>Bone carrier</td>
<td></td>
</tr>
</tbody>
</table>

Figure 8.3 Surgical mallets. (a) Metal mallet. (b) Nylon cap mallet.

Tip: In the author’s experience, a metal mallet tends to increase the patient’s postsurgery discomfort compared to a nylon cap mallet (Figure 8.3).

The osteotomes are available as straight instruments as well as offset to allow access in the more posterior areas or when there is limitation of opening. The magnitude of apical force and tactile sensitivity may be diminished with use of the offset osteotomes (Figure 8.4).

There are also osteotomes with convex tips. The convexity will create horizontal compression. When convex tips are used, they are alternated with concave tips to achieve both vertical and horizontal compression (Figure 8.5).

The choice of suture material is another consideration in the management of the transalveolar approach. Commonly in periodontal procedures utilizing a resorbable suture is the mainstay. However, in complicated procedures such as a ridge augmentation procedure combined with a transalveolar approach, leaving the sutures intact for 3–4 weeks is not uncommon. Utilizing polyflouroethylene (Gore-Tex), a nonresorbable suture, in these procedures allows the wound to heal properly and without separation of the incision line.
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References


Figure 8.4 Straight and offset osteotomes.

Figure 8.5 Concave and convex osteotome. (left) Concave osteotome for sinus floor elevation. (right) Convex osteotome for bone condensation.
Incision design

The flap design of the transalveolar approach is more conservative than the lateral window approach, with flap reflection typically limited to the crestal area. This reduces damage to the vascular supply of the lateral wall of the sinus. The crestal approach involves the use of a surgical mallet to compact the alveolar bone with an osteotome. An increasingly wider series of osteotomes are tapped in an apical direction toward the sinus floor to prepare the osteotomy and infracture the cortical plate. Depending upon the density of the bone, the entire site preparation can be completed utilizing osteotomes. In dense bone, however, a combination of osteotomes and drills is necessary.¹ ²

**Tip:** The osteotome technique can also be performed under flapless design with a punch technique.³

**Step 1**

The crest approach begins with the decision to raise a flap or not. If there is an adequate amount of keratinized gingival at the buccal site and alveolar ridge width without undercuts, a flapless technique can be utilized. A tissue punch the diameter of the planned implant is used to remove the gingiva in the pre-determined implant location. If a flap is going to be raised, only a minimal exposure of bone is necessary. A crestal incision is made with full-thickness...
flap reflection to expose the alveolar crest. If there is tension on the flap, small vertical releasing incisions can be used. The proposed implant site is marked using a round bur in both the flap and flapless approach (Figure 9.1).

**Step 2**
Using a 2 mm cylindrical bur, the implant site is prepared to a depth 1 mm below the sinus floor. This 1 mm distance is a safety zone to prevent the tip of the drill from rupturing the Schneiderian membrane (Figure 9.2).

**Step 3**
A periapical radiograph is taken with the 2 mm guide pin in place. This serves to confirm the integrity of the subsinus cortex and verify both the implant position and the distance from the apex of the osteotomy to the sinus floor (Figure 9.3).
**Tips:** It is recommended to use dental floss or other technique to tie the guide pin and prevent the patient swallowing the instrument accidently [Figure 9.4(a)]. The Rinn system with the parallel technique can be used to determine the distance more accurately. Piezosurgical instruments may be used for minor depth adjustment after the radiograph is reviewed [Figure 9.4(b)].

Figure 9.3 (a) and (b) Step 3: A periapical radiograph is taken with the 2 mm guide pin in place, confirming the integrity of the subsinus cortex and verifying the implant position and the distance from the apex of the osteotomy to the sinus floor.

Figure 9.4 Tips for the osteotome technique. (a) Use dental floss or other technique to tie the guide pin to prevent the patient swallowing the instrument accidently. (b) Use piezosurgical instruments for minor depth adjustment. Note: Images (a) and (b) are for demonstrating these tips and not from the same patient.
Step 4
The osteotomy is enlarged with a 3 mm cylindrical drill to the desired depth, which should remain 1 mm below the sinus floor (Figure 9.5).

Step 5
Before any attempts are made to elevate the sinus floor, graft material is added to the osteotomy. The volume of material should not exceed 2–3 mm in height. The addition of this material makes inadvertent perforation of the sinus membrane less likely (Figure 9.6).

Figure 9.5 Step 4: The osteotomy is enlarged with a 3 mm cylindrical drill.

Figure 9.6 (a) and (b) Step 5: Bone graft material is added to the osteotomy before attempting to elevate the sinus membrane.
Step 6
A 3mm osteotome is inserted into the osteotomy and advanced with light malleting [Figure 9.7(a)].

**Tip:** An assistant can place both hands on the patient’s head to provide support during the malleting [Figure 9.7(b)].

It is difficult to quantify the tapping force because the remaining bone quality and quantity differ between cases. However, if you feel a high degree of resistance or the osteotome does not advance, you may use a small diameter round bur or piezosurgical instruments to delicately pierce a dense spot of apical bone.

**Tips:** Infracturing the cortical bone of the sinus floor may be difficult in some cases due to the bone density and thickness; however, the surgeon can detect the change of tactile sensitivity as the osteotome tip breaks through the cortical floor. A different pitch of tapping sound can also be noticed when the sinus floor has been fractured. The integrity of the sinus membrane can be examined by the Valsalva maneuver or via direct visualization at different time points. In the Valsalva maneuver, the nostrils of the patient are held closed while the patient blows against the resistance. The site is examined for any indication of air leaking through the membrane.

![Figure 9.7](image-url)  
**Figure 9.7** Step 6: Infracturing the sinus floor cortical bone with light malleting. (a) A 3mm osteotome is inserted into the osteotomy and advanced with light malleting. (b) An assistant should support the patient’s head during the malleting.
Step 7
Once the osteotome is advanced to the depth of the sinus floor, infracturing the cortical bone, the remaining bone is pushed apically into the sinus cavity, elevating the sinus membrane. The instrument can then progress about 2 mm deeper than the depth of the infracture at each time. Bone graft material must be added into the osteotomy at each advancement. At no point should the tip of the osteotome penetrate into the sinus or touch the Schneiderian membrane.

**Tip:** A stop may be attached to the osteotome to limit apical advancement and avoid overinsertion and membrane perforation (Figure 9.8).

Step 8
Once the tip of the osteotome has reached the desired height, the osteotomy is widened with a larger diameter osteotome, such as 3.5 mm. The sequence of adding graft material and tapping the osteotome to the predetermined depth continues until the necessary amount of elevation is achieved (Figure 9.9).

**Tip:** The final osteotome diameter should be narrower than the desired implant width, typically 0.5–1.2 mm less. Undersizing the osteotomy will allow osteocompression during implant placement, especially in Type IV bone. For example, the final osteotome for a 4 mm implant would be 3.5 mm, and for a 5 mm implant, a 4.2 mm would be final osteotome.

![Image](image-url) **Figure 9.8** A stop may be attached to the osteotome.
Step 9
The final step of the osteotome procedure is to test the resistance by inserting the final osteotome or guide pin to the desired length.

Step 10
Additional graft material should be added to the osteotomy prior to implant placement. The actual insertion of the implant will displace the material more apical and lateral, stretching the Schneiderian membrane even further. It is recommended that 2–3 mm of bone graft material around the apex of the implant may add the implant primary stability (Figure 9.10).

The osteotome approach can be also combined with extraction. In this premolar case, an appropriate diameter cylinder drill can be used to reach 1 mm prior to the sinus membrane. Follow the previous steps until the desired amount of tented height is achieved. In this particular case, the remaining alveolar bone...
quality and bone graft resistance were appropriate for a simultaneous dental implant approach (Figures 9.11–9.13).

In the delayed approach, the osteotome is placed at the site of the desired future implant placement and a light malleting is begun to intrude the crest.
If the alveolar bone is dense and does not easily move, a trephine bur is then used to cut 1–2mm from the sinus floor. The osteotomy is filled with graft material and the osteotome is used to intrude the material and bone cylinder several millimeters. The latter step is repeated three or more times, until the desired elevation of the sinus floor and membrane is achieved. The flap is then sutured so that primary closure is achieved.

The delayed approach can be combined with maxillary molar extraction as well. In this technique, a trephine bur is used to mobilize a cylinder of the alveolar bone following the extraction of the tooth. This will encompass the septal area. The steps of adding graft material and elevating the segment are followed until the necessary amount of alveolar height is reached. There tends to be difficulty in achieving primary closure when the osteotome sinus elevation is combined with the extraction of a molar, which may impact the amount of alveolar bone that is actually gained.

References

In this chapter, the clinician will review postoperation instructions for the transalveolar osteotome approach, complications management, and some tips to avoid these complications.

Postoperation management of sinus lift surgery is predicated by initiating antibiotic therapy presurgically, commonly utilizing an antibiotic that has a degree of affinity toward bone; for example, amoxicillin 500 mg (one capsule TID × 7 days) or cephalexin 500 mg (one capsule QID × 7 days). These types of antibiotics, being bactericidal in nature, have a higher degree of antibacterial action than those of a bacteriostatic nature, such as clindamycin or tetracycline. Having the patient start the antibiotic at least 1 hour prior to surgery may help minimize postsurgical complications, such as infection and pain.\(^{1,2}\)

It is also wise to consider the use of a presurgical prescription of an anti-inflammatory medication, such as ibuprofen 800 mg tablets (one tablet every 8 hours with food), for minimizing postoperative discomfort and pain. Caution should be taken not to take the medication too close to bedtime because of the possibility of causing gastric distress (e.g., gastric esophageal reflux or gastric bleeding). Taking the anti-inflammatory medication with yogurt may minimize this type of unwarranted side effect. If these types of problems develop, resorting to a central-acting medication (e.g., codeine or hydrocodone) may be necessary. Generally the anti-inflammatory medication needs to be taken for at least 4 days.

Appendix A lists preoperative instructions for the transalveolar osteotome approach. Appendix B lists postoperative instructions.

**Tip:** If the patient stops taking the anti-inflammatory and develops subsequent discomfort, reinitiating the regimen of the anti-inflammatory prescription may be ineffective in reducing the discomfort.
Postoperative instruction

In addition to the utilization of antibiotics and anti-inflammatory medication, ice compresses externally should be used to minimize swelling and discomfort, alternating every 15–20 minutes on and off the site. This should continue for the first 24 hours postsurgically. When sinus augmentation is performed, we suggest that the patient remain at home and relax. He or she may return to work; however, strenuous exercise should be avoided. Swelling is common and the patient should be instructed as indicated regarding the use of ice. Also, a few ice chips may be placed in the surgical area for a few hours to help alleviate any discomfort. If swelling is still evident after the third day, the patient may apply a heat pad or warm compress; also, he or she should be instructed not to sleep on the side of the face where the procedure was performed. In addition, no increase in intraoral pressure should occur. Therefore, the patient should be cautioned against sneezing, coughing, or using a straw for drinking liquids.

It is common to experience bleeding during the first 24 hours following surgery. The patient should be informed to not be concerned if his or her saliva appears slightly red. If bleeding persists, he or she may apply pressure directly to the surgical area with gauze pads or a tea bag for 15–20 minutes.

Patients may experience pain and should take the medication for pain as directed. If ibuprofen is prescribed, this medication should be taken with milk or a light meal to minimize any possible G.I. distress. If a narcotic pain reliever is prescribed, such as codeine, patients should not drive or consume any alcohol. If an antibiotic is prescribed, it must be taken as directed until the medication is finished. If the patient notices a rash, itching, difficulty breathing, or other signs of allergy, he or she should discontinue use and contact the doctor.

The patient should avoid rinsing for the first 3–4 days and just use gravity to allow water to cleanse the mouth, tilting the head side to side and opening the mouth to let the water escape. It is detrimental to have the patient forcibly rinse and cause disturbance to the operated site.

The patient should be instructed to brush, clean, and stimulate all areas as usual, except where the surgical site is. He or she can clean the sutures by swabbing lightly with a cotton swab with chlorhexidine 0.12% twice daily.

The patient should be instructed to drink plenty of liquids every 2 hours for the first day (excluding carbonated or alcoholic drinks). Patients can maintain a normal diet but be careful not to disturb the sutures. Chewing on the opposite from the surgical area will be helpful. A soft diet is recommended. In addition, a liquid supplement, such as Boost, Ensure, or Sego, may be used to ensure adequate nutrition.

Tip: Patient should be cautioned against sneezing, coughing, or using a straw for drinking liquids.
The patient should expect to feel moderately uncomfortable. The discomfort will be minimized if he or she remembers to (1) apply ice as soon as possible, (2) take the medication as directed, and (3) eat an adequate diet. The patient should contact the doctor if there is excessive bleeding, severe pain, or marked swelling.

**Complications in the sinus elevation surgery**

The first consideration in the management of complications is to avoid them. If there is not enough native bone present, as in Figure 10.1, in considering a sinus lift and there are anatomical deficiencies, the surgeon should astutely address and perform the proper technique as well as utilize the proper materials.

The common failures of the transalveolar approach (prior to loading) that were reported stemmed from the patient’s lack of primary stability, membrane perforation, infection, and occlusal trauma due to a parafunctional habit or removable partial denture wearing.

**Inadequate primary stability**

Improper bone height and bone quality are two primary reasons why there could be complications resultant in implant failures. Rosen et al. reported an increase in failure rate of 10–20% when the subantral bone measured 4 mm or less. A minimal bone height can result in the surgeon overpreparing the site and thus leading to trauma and allowing for not attaining primary implant stability.⁴

Gaining primary bone stability could be handled by insertion of a wider diameter implant and utilizing a graft material at the time of insertion. If proper

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**Figure 10.1** Note minimal subantral bone height of 2.0 mm—a lateral window procedure would be indicated rather than an osteotome procedure. Also note the slope of the sinus wall, which could complicate the use of an osteotome.
bone preparation is not considered and primary stability is not achieved, implosion of the implant into the sinus could happen (Figure 10.2). This could result in further pathologic sequela such as the development of an oro-antral fistula and legal complications.

If the implant site is underprepared, the implant inserted could result in pressure, necrosis, delay in the osseointegration of the implant, trauma to the vital bone, and compromise of the ridge width and the development of a mucogingival defect postrestoration. A removable partial denture may have a deleterious effect on the premature loading of the implants placed, thus allowing for the failure of integration.

**Infection**

Infection is also a common complication for the implant surgeon. This could be due to underlying pathology and often could be ruled out by obtaining a preoperative CT scan. Other causes of infection could be contamination of the implant surface prior to insertion, contamination of the graft material during preparation prior to insertion of the implant, or development of an infection following sinus perforation. The complicating factor of the infection could lead to nonintegration of the implant or the development of peri-implantitis.

Management of the infection at the implant site is avoidance first. This could be achieved by practicing strict sterile surgical technique, including preoperative dosing of the patient with a bactericidal drug that has a higher than normal affinity to bone, such as amoxicillin with clavulanic acid, 750 mg BID × 10 days, or cephalixin, 500 mg QID × 10 days. Also, an antihistamine, such as Benadryl 50 mg every 6 hours, or a decongestant, such as Sudafed 25 mg every 6 hours, may be prescribed to allow a patent airway and nasal management for short-term usage (less than 1–2 weeks).

If the infection is persistent, consultation with an otolaryngologist may be warranted, as may consideration of implant removal. Also, minimizing the patient’s bacterial flora with proper periodontal therapy is recommended prior to implant placement, as well a preoperative rinse with chlorhexidine gluconate (0.12%) for 2 minutes, continuing postoperatively.
Sinus membrane perforations
The incidence of a perforation ranges from 4 to 25% in treated osteotome cases. Minimizing the potential of developing of a tear is the most important prerequisite for the surgeon with the development of the technique. Tearing could result due to elevation of the Schneiderian membrane beyond the capacity for the adaptation of the grafting material. To minimize the potential for tearing of the membrane, a slow and not rapid elevation technique needs to be developed. If a >2 mm tear develops, a potential oro-antral fistula could result, diminishing the healing potential for successful osseointegration (see Figures 10.3 and 10.4).

Figure 10.3 A periapical radiograph noting a residual tooth structure #4. This type of situation would allow the immediate extraction with greater than 5.5 mm of osseous height to allow for an osteotome procedure with immediate placement.

Figure 10.4 Note the dome effect of the grafting material to verify the intact membrane following the osteotome lift procedure.
Another problem encountered is the patient experiencing vertigo.\textsuperscript{5,6} The Epley procedure given below should be utilized in the event that the patient experiences such an occurrence.\textsuperscript{7,8}

**Epley maneuver**
1. Sit upright [Figure 10.5(a)].
2. Turn head to the symptomatic side at a 45° angle and lie on the back [Figure 10.5(b)].
3. Remain up to 5 minutes in this position.
4. Turn head 90° to the other side [Figure 10.5(c)].
5. Remain up to 5 minutes in this position.
6. Roll body onto side in the direction you are facing; now you are pointing your head nose down [Figure 10.5(d)].
7. Remain up to 5 minutes in this position.
8. Go back to the sitting position and remain up 5 minutes in this position [Figure 10.5(e)].
The entire procedure should be repeated two more times, for a total of three times.

**Appendix A: preoperative instructions for the transalveolar osteotome approach**

1. Eat well prior to the surgical appointment unless intravenous conscious sedation or general anesthesia is being used, in which case nothing to eat or drink 8 hours prior to the surgical procedure.
2. Get a good night’s sleep prior to the surgery.
3. Take amoxicillin 500 mg 1 hour prior to the procedure. If allergic to penicillin substitute with 300 mg of clindamycin.
4. Take 800 mg ibuprofen 1 hour prior to the procedure unless allergic or unless you are asthmatic.
5. Arrange for an individual to bring you home following the procedure.
6. Do not plan to return to work following the procedure.

**Appendix B: postoperative instructions for the transalveolar osteotome approach**

1. Physical activity: Rest for the remainder of the day and maintain your head in an elevated position. Avoid physical activity for 2 weeks, including sports activities that raise the heart rate.
2. DO NOT SMOKE.
3. Swelling: Apply cold (ice) packs to your face. Maintain them on your face for 20 minutes and then off for 20 minutes frequently during the day until sleep for the first 24 hours. Some facial swelling is expected and there might be some swelling underneath the eye along with some evidence of bruising.
4. Eating: Maintain a soft cool diet the first day and a soft diet the remainder of the week. Avoid chewing on the side of surgery. If both sides were treated, maintain a very soft diet for 2 weeks. Do not use a straw take liquid as vigorous suctioning can promote bleeding.
5. Sneezing: Avoid heavy lifting and blowing through your nose. Do not stifle sneezes by blocking your nose.
6. Do not drink with a straw or drink carbonated liquids (minimum 3 days).
7. Bleeding: Expect some slight bleeding from the surgical site over the next 12 hours. Some slight bleeding from the nose is also expected during the next 2 days.
8. Medications—take your medications as directed:
   a. Antibiotics: Amoxicillin 500 mg (one capsule TID × 7 days) or clindamycin 300 mg TID for 7 days.
   b. Anti-inflammatory: Ibuprofen 800 mg TID for 4 days then TID PRN comfort.
   c. Chlorhexidine 1.2% oral rinse: Rinse 30 cc BID for 10 days.
   d. An antihistamine, such as Benadryl 50 mg every 6 hours or a decongestant, such as Sudafed 25 mg every 6 hours, may be prescribed to allow a patent airway and nasal management for short-term usage (less than 1–2 weeks).

9. Dental home care:
   a. Do not brush or floss the teeth in the surgical area until instructed by the doctor or staff.
   b. Brush, floss, and use other hygiene aids for all other teeth daily or as directed.

10. Follow-up: Plan to see the doctor and his staff for a postoperative appointment in 7–10 days. Sutures will be removed in 2 weeks.

References


The two main surgical approaches for sinus floor elevation are the lateral window approach\(^1\)\(^-\)\(^4\) and the transalveolar approach.\(^5\)\(^-\)\(^8\) Compared to the lateral window approach, the transalveolar approach is more conservative and less invasive. The original concept of the transalveolar technique was to use a set of osteotomes of various diameters to create a “green-stick fracture” by hand tapping force in a vertical direction and to create a “sinus membrane tent.” Bone grafting materials, blood clot, and the dental implant may be inserted into the tented space through the osteotomy opening. However, the most challenging aspect of the transalveolar osteotome approach is the tapping force, which needs to be sufficient enough to infracture the sinus floor cortical bone but restrained enough to prevent the osteotome tip from traumatizing the Schneiderian membrane.\(^9\)\(^,\)\(^10\) Complications may be associated with the tapping force, such as benign paroxysmal positional vertigo (BPPV)\(^11\)\(^-\)\(^15\) and sinus membrane perforation.

The sinus lift balloon was created to reduce the chance of sinus membrane perforation. The Zimmer inflated sinus balloon was designed to lift the Schneiderian membrane gently and uniformly. The balloon instrument can also be used to anticipate the required bone graft material, such as 1 cc of saline, which is used to inflate the balloon, equal to 1 cc of grafting material. On average, with 1 cc of saline the sinus lift balloon may elevate sinus membrane 6 mm.

There are three types of design (see Figure 11.1):
- Angled design can be used in the lateral window/Caldwell-Luc approach
- Straight design can be used in the crestal/Summers approach

This chapter will review some new, innovative transalveolar sinus elevation techniques, such as the balloon sinus lift technique and the controlled hydrostatic sinus lift procedure.
Clinical procedures

Step 1 (to create access)
The initial osteotomy (a pilot drill of 2 mm in diameter) after a flap or flapless procedure is performed to a depth approaching the floor of the sinus cavity but stopping 1–2 mm short of the floor. A small diameter osteotome can be used to penetrate the sinus floor (Figure 11.2). A guide pin is used to indicate the depth of the osteotomy.

Step 2 (to insert the sinus lift balloon)
It is recommended to inflate and deflate the balloon extraorally several times with normal saline before inserting into the sinus cavity (Figure 11.3). Make sure not to overinsert the metal tube into the sinus cavity, as doing so will increase the chance of a membrane tear.

**Tip:** Do not overinstrumentation.

Step 3 (to detach the sinus membrane)
Once the balloon is inserted into the sinus cavity, the balloon can be pumped with normal saline (Figure 11.3). On average with 1 cc of saline the sinus lift balloon may elevate the sinus membrane 6 mm.

Step 4 (bone grafting material placement)
Bone graft can then be inserted through the osteotomy site. The dome-shaped bone grafting material can be seen via radiograph (Figure 11.4).
Step 5 (dental implant placement)
A dental implant may be placed during the same procedure (Figure 11.4).

Other surgical techniques
Besides balloon sinus lift, other surgical techniques have been proposed to minimize the tapping motion by using hydraulic pressure, the so-called “hydraulic sinus lift” procedure. The unregulated hydraulic pressure is applied into the osteotomy site by means of air/water exhaust spray from a...
high-speed dental handpiece\textsuperscript{16} or an uncontrolled water jet from a plastic syringe,\textsuperscript{17} to detach the Schneiderian membrane from the sinus floor (Figure 11.5). The applied hydraulic pressure is designed to loosen the membrane.

Figure 11.3 (a) and (b) Inflate and deflate the balloon extraorally several times with normal saline before inserting into the sinus cavity. (c) Insert the metal tube into the sinus cavity without touching the sinus membrane. (d) Once the balloon is inserted into the sinus cavity, the balloon can be pumped with normal saline.

Figure 11.4 (a) The dome-shaped bone graft material can be seen in the radiograph to indicate the tented space. (b) A dental implant may be placed during the same procedure if primary stability has been achieved.
However, without controlling the direction and intensity distribution of the hydraulic pressure, sinus membrane perforations may still occur because all the hydraulic pressure is directed against the apex of the “tent” being created. In order to provide suitable equal distribution of hydrostatic pressure, the concept of “controlled hydrostatic sinus elevation” was introduced. Controlled hydrostatic sinus elevation is presented herein as a safer, more controlled “lifting pressure” that simultaneously places equal force per square millimeter of bone-membrane interface. Hydraulic pressure in a closed system places equal pressure on all surfaces within the system, thereby eliminating “point sources” of pressure, and gently elevating the Schneiderian membrane equally at all points of attachment. This controlled hydrostatic sinus lift procedure is accomplished by using a calibrated, hand-controlled pump and pressure sensor meter (Figure 11.6).
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Surgical protocol

Before the surgery, it is necessary to complete a full evaluation of the sinus cavity through radiographs and/or computerized tomography to assess mucosa thickness, bone height and density, sinus septa locations, and the possible presence of pathology.\textsuperscript{20, 21}

Surgical step 1 (to create access)

The initial osteotomy (a pilot drill of 2 mm in diameter) after a flap or flapless procedure is performed to a depth approaching the floor of the sinus cavity but stopping 1–2 mm short of the floor [Figure 11.7(a)]. A diamond piezosurgical drill can also be used to just gently perforate the floor of the sinus bone without harming the Schneiderian membrane [Figure 11.7(b)].\textsuperscript{22} The piezoelectric device is designed to cut or grind bone but not damage adjacent soft tissue.\textsuperscript{23, 24} The integrity of the sinus membrane is then examined by Valsalva maneuver or direct visualization.
Step 2 (initial detachment of the sinus membrane)

The initial detachment of the Schneiderian membrane can be achieved by the following method: after clearing all the air from the tubing, the Luer-Lock cannula with tapered plug-in end (2 mm diameter) is inserted into the osteotomy preparation before touching the sinus floor and pressed snugly using finger pressure (Figure 11.8). The normal isotonic saline fluid is pumped slowly into the closed system, and the gentle pressure will begin to elevate the Schneiderian membrane via the hydrostatic pressure from the hand-actuated pump (Figure 11.9). The pressure sensor meter inserted into the closed system will monitor the pressure and also indicate the force necessary to just detach the Schneiderian membrane without tearing. It is imperative that the bone-to-cannula interface be airtight so that there is no lateral leakage of the normal saline solution.

Step 3

Once the desired initial elevation is obtained, a second examination of the integrity of the sinus membrane is done. After the initial lift is complete, the surgeon switches to a 3 mm implant drill through the previous osteotomy site. Then, the previous controlled hydrostatic sinus lift procedure is repeated using an appropriately matched larger-sized cannula and tools. The sinus membrane is now lifted to the desired extent, followed by placement of bone grafting materials through the enlarged osteotomy.
Step 4
Bone graft may proceed through the enlarged osteotomy site (Figure 11.10).

Step 5
A dental implant may or may not be placed into the osteotomy site depending on the probability of achieving adequate primary stability (Figure 11.11).

Clinical case
A 65-year-old man presented to the office for dental implant placement at the upper right first molar (#3) area [Figure 11.12(a)]. The patient had controlled hypertension and no history of sinus disease. The tooth was extracted due to unrestorable caries 4 months earlier. The radiographic analysis and CT scan
Advanced Techniques of the Transalveolar Approach

were performed to evaluate the mucosa thickness, pathology, bone height, bone thickness, and major blood vessels. They revealed an alveolar bone remaining height of 6.5 mm [Figure 11.12(b)]. Nothing remarkable was noted in the maxillary sinus. Local anesthetic was administered (2% lidocaine with 1:100,000 epinephrine x 2 carpules) at #3 buccal and palatal site. The surgical site was prepared by elevating a full-thickness flap after a midline incision along the alveolar ridge. These flaps are reflected only far enough to gain access to the central ridge area for adequate instrumentation. The flapless approach may also be used.

The controlled hydrostatic sinus elevation technique was then applied. The initial 2 mm drill was inserted stopping at 1–2 mm before reaching the sinus floor (Figure 11.13). The surgical guide pin was used as a radiographic reference. The piezosurgical machine was used to gently penetrate the sinus floor without tearing the sinus membrane. The integrity of the sinus membrane was examined by Valsalva maneuver and direct visualization. The Luer-Lock cannula with tapered plug-in end was inserted into the osteotomy site until it was firmly seated and sealed. The hydrostatic pressure meter with pump was then connected to the cannula with flexible tube (Figure 11.14).
Normal saline was then slowly pumped into the sinus cavity under controlled hydrostatic pressure to initially detach the sinus membrane. Once the sinus membrane was initially elevated by hydrostatic pressure, the pressure sensor detected a slight decrease in pressure. The hand-actuated pump then gradually increased the hydrostatic pressure until the pressure sensor once again revealed another pressure drop as the membrane was slowly and safely elevated. This sequence was repeated several times until the desired amount of sinus membrane elevation was achieved.

It is important to note that the initial hydrostatic pressure needed to detach the sinus membrane may vary due to the thickness of the mucosa, the anatomic configuration of the sinus cavity, or simply individual variation.
After the initial lift was complete, the previous osteotomy site was then enlarged with a 3 mm twist drill and the controlled hydrostatic sinus elevation procedure was repeated using a matching size insert tube (Figure 11.15).

Once the desired elevation was obtained (usually more than 10 mm), the pressure was then released and the normal saline was removed with the tube. A second Valsalva maneuver or direct visualization test of membrane integrity was done. Allograft bone material was then carefully packed into the ostetomy site under the elevated sinus membrane. Next, a 4.5 mm x 11 mm implant with healing abutment (Ankylos Dentsply Friadent, Mannheim, Germany) was then placed in #3 osteotomy site [Figure 11.16(a)] with primary stability. Flaps were closed by 4–0 sutures. A periapical radiograph was taken after the implant placement [Figure 11.16(b)].

The patient was given the following prescriptions: antibiotics (amoxicillin 500 mg Q6H for 7 days), a nonsteroidal anti-inflammatory (ibuprofen 400 mg Q4–6H as needed), and chlorhexidine mouth rinse. Minimal postoperative pain and swelling were reported. Sutures were removed 10 days after surgery. No sinus complications or other postoperative sequelae were reported or observed.

![Figure 11.15](image1.png) Controlled hydrostatic sinus elevation procedure was repeated using a matching size insert cannula. (a) 2 mm cannula. (b) 3 mm cannula.

![Figure 11.16](image2.png) (a) A 4.5 mm x 11 mm implant with healing abutment (Ankylos Densply Friadent, Mannheim Germany) was placed. (b) Radiographic image of implant placement. (c) Fixed crown restoration with 4 months loading (restored by Dr. T.S. Zhuo, prosthodontist).
After 3 months of healing, the implant was determined to be osseointegrated and was subsequently restored with a fixed provisional crown [Figure 11.16(c)].

Several innovative techniques have been proposed for sinus elevation procedures; however, future clinical trials are needed to evaluate the effectiveness of these techniques.

References


CHAPTER 12

Decision Tree for Maxillary Sinus Elevation Options

David Minjoon Kim and Daniel Kuan-te Ho

In rendering dental implant therapy to patients with atrophic posterior maxilla, clinicians are often required to perform maxillary sinus floor elevation due to inadequate alveolar ridge height as a result of sinus pneumatization and ridge atrophy following tooth extraction. Maxillary sinus floor elevation technique was initially introduced by Boyne and was later modified by many clinicians who presented various techniques in elevating the Schneiderian membrane and placing bone grafts in the sinus cavities.

There are mainly two techniques used by clinicians to perform sinus floor elevation: the lateral window technique and the transalveolar crestal technique. In the lateral window technique, access to the maxillary sinus cavity is obtained by removing cortical bone on the lateral surface of the sinus. Specifically, a full-thickness flap is raised to expose the bony wall of the lateral aspect of the sinus. A window is then made through this bony wall by removing osseous structure with diamond burs or piezosurgical tips (Figure 12.1). The underlying Schneiderian membrane is then carefully reflected with sinus membrane elevators until the medial bony wall of the maxillary sinus can be sounded. Bone grafts are then placed inside this space directly above the sinus floor and below the membrane. A resorbable collagen membrane is usually placed over the bone grafts at the sinus window and the flap is sutured together with primary closure. Figure 12.2 shows a “wall-off technique” where a modified trephine bur is used to create a window on the lateral wall. This modified trephine
Clinical Maxillary Sinus Elevation Surgery

bur is inserted through the lateral wall with caution until the shadow of the Schneiderian membrane can be seen. Afterward, this bony island is then gently detached completely from the surrounding wall with sinus membrane elevators.

In the transalveolar crestal approach, access to the maxillary sinus cavity is gained through the alveolar crest. The transalveolar crestal approach was first introduced by Tatum\(^2\) and later modified by Summers, who described the

![Figure 12.1 Lateral window maxillary sinus bone augmentation. (a) Different types of piezosurgical tips useful for removing osseous structure lateral to maxillary sinus and elevating Schneiderian membrane. (b) A piezo bur was used to create a window by removing bony wall lateral to the sinus. (c) Schneiderian membrane has been partially elevated. (d) Preoperative CT scan shows signs of sinus pneumatization and residual bone height (height of bone apical to sinus floor) of 1–3 mm, making it necessary to perform a separate lateral window sinus elevation based on the decision tree presented in Figure 12.5. (e) Six-month postoperative CT scan shows evidence of augmented bone in the sinus with 12–13 mm of vertical bone height gained.](image)
Figure 12.2 Wall-off lateral window sinus bone augmentation technique. (a) Preoperative panoramic radiograph shows approximately 5 mm of residual bone height (height of bone apical to sinus floor) at sites #2 and #3. The clinician has decided to place 10 mm long implants and thus will perform a lateral window sinus elevation based on the decision tree in Figure 12.5. (b) This schematic shows the modified trephine-like drill (DASK Drill #6, Dentium) designed to detach bony island from the lateral wall of sinus in this wall-off technique. (c) The same drill is used to prepare a bony window on the lateral wall. (d) Sinus membrane has been elevated. (e) Two 10 mm long implants are placed simultaneously with lateral window sinus bone augmentation, and the bony island has been repositioned back to the window to contain the bone grafts in the sinus. (f) Nine-month postoperative panoramic radiograph showing evidence of bony augmentation in the sinus with completed implant restoration.

well-known “osteotome technique.” In osteotome sinus floor elevation, the implant osteotomy site is first created just short of the floor of the maxillary sinus. A small amount of bone graft is then placed in the osteotomy site, along with the insertion of the osteotome with the desired diameter. By gently
tapping the osteotome with the mallet, the sinus floor is fractured. Subsequently, by placing additional bone grafts and tapping the osteotome, the Schneiderian membrane will be elevated and the space below the membrane will be filled with bone grafting materials. Figures 12.3 and 12.4 demonstrate two examples of transalveolar crestal maxillary sinus elevation technique: the osteotome technique and the “thin-out” technique.

In selecting the treatment approach—lateral window or transalveolar crestal technique—to perform maxillary sinus floor elevation, the clinician needs to consider the following factors. First, one needs to determine the amount of residual bone height (RBH) that is available for the implant(s) to be placed with primary stability. RBH is defined as the height of bone immediately below the sinus cavity. It is commonly accepted that a residual bone height of less than 4 mm warrants a lateral window sinus elevation approach without simultaneous implant placement, as the primary stability of the implant at the time of placement may be jeopardized. Second, the length of the implant planned also influences the treatment approach. A disadvantage of the transalveolar crestal technique is its limitations in elevating the Schneiderian membrane.

![Figure 12.3](image_url)

**Figure 12.3** Osteotome transalveolar crestal sinus bone augmentation technique. (a) Preoperative radiograph shows residual bone height (height of bone apical to sinus floor) of about 8 mm at site #13. The clinician has determined to place a 12 mm long implant and thus decided to place the implant while performing a transalveolar crestal sinus bone graft. (b) An osteotome was used to place bone grafts into the sinus while lifting the Schneiderian membrane. (c) Five-month postoperative radiograph demonstrates evidence of bone augmentation apical to implant #13. (d) Implant #13 has been restored.
Often, it is difficult to elevate the membrane more than 4–5 mm apically. As such, the length of the planned implant(s) and the residual bone height together will determine how much elevation of the membrane is needed, thereby dictating whether a lateral window or a transalveolar crestal approach would be chosen.

In both the lateral window and transalveolar crestal approaches, simultaneous implant placement together with sinus bone grafting is sometimes possible when implant primary stability can be achieved. Depending on the amount of RBH present and the length of the dental implant to be placed, clinicians will determine whether or not the implant(s) can be placed at the same time with the sinus floor elevation procedure. The following flow charts
Figure 12.5 Decision tree for performing lateral versus transalveolar crestal sinus bone augmentation when sufficient alveolar buccal-palatal width is present. RBH, residual bone height (height of bone apical to sinus floor); m, months; IMP, implant; TAC, transalveolar crestal.
(Figures 12.5 and 12.6) show the decision tree in choosing the technique for maxillary sinus floor elevation and simultaneous implant placement [modified from Fugazzotto (2003)\textsuperscript{5} and Chiapasco et al. (2008)\textsuperscript{6}].

<table>
<thead>
<tr>
<th>Insufficient buccal-palatal alveolar ridge width</th>
<th>RBH $&lt; 5$ mm</th>
<th>Ridge width inadequate to obtain implant primary stability</th>
<th>Lateral window approach</th>
<th>Horizontal ridge augmentation</th>
<th>Implant placement</th>
<th>6–8 months</th>
<th>Restoration</th>
</tr>
</thead>
<tbody>
<tr>
<td>RBH $\geq 5$ mm</td>
<td>Ridge width adequate to obtain implant primary stability</td>
<td>Lateral window approach</td>
<td>Horizontal ridge augmentation</td>
<td>Implant placement</td>
<td>6–8 months</td>
<td>Restoration</td>
<td></td>
</tr>
</tbody>
</table>

Figure 12.6 Decision tree for performing sinus bone augmentation when insufficient alveolar buccal-palatal width is present. RBH, residual bone height (height of bone apical to sinus floor).

Tip: Studies have shown that the transalveolar approach in comparison to the lateral window approach is less invasive and of shorter surgical duration. However, the lateral window approach may be more appropriate in more advanced situations, such as severe resorption and multiple implant placement, instead of using individual transalveolar site preparation.

There are several systematic reviews examining the survival of implants placed in maxillary sinuses augmented either with the lateral window or the transalveolar crestal approach. In the lateral window approach, most reviews reported implant survival rates after 3 years of loading ranging from 91.8\% to 98.3\% when rough surface implants are used with membrane coverage over the lateral windows.\textsuperscript{7,8} Generally, placement of a resorbable membrane over the lateral window results in higher implant survival rate than those without membrane placement.\textsuperscript{7,8} Implant survival rates are similar for all types of particulate bone grafting materials either used alone or in combination, and these particulates include autografts, allografts, xenografts, and other bone substitutes.\textsuperscript{7,8} In the transalveolar...
approach, the estimated implant survival rate after 3 years of function was reported to range from 92.8% to 96.0%.\textsuperscript{9,10} In either approach, the survival rates of the implants are comparable to those implants inserted in nonaugmented sites.

\textbf{Tip:} The osteotome technique with simultaneous implant placement becomes less predictable when the RBH is less than 5mm.

\textbf{References}

CHAPTER 13

Choices of Bone Graft Materials

David Minjoon Kim and Daniel Kuan-te Ho

Bone grafting materials overview

Over the past decades, clinicians have used a variety of bone grafting materials in performing sinus floor elevation. These materials include autografts, allografts, xenografts, and alloplasts. Autogenous bone grafts are grafts transferred from a donor site to the recipient site in the same individual. The main advantage of the autogenous bone graft is its osteogenic potential, defined as the “formation of new bone by viable cells such as osteoblasts derived from grafting material itself.”¹ In a sinus floor elevation procedure, autogenous grafts can be utilized in block form or particulate form. However, autogenous block grafts have fallen out of favor to autogenous particulate mainly due to the difficulty in stabilizing the blocks in the sinus (for lateral window sinus bone grafting) and the lower survival rate associated with implants placed in block grafted sinus sites.² One major disadvantage of autogenous grafts in general is the involvement of a second surgical site(s) where the bone grafts are harvested.

Allogenic bone grafts, also known as allografts, are grafts harvested from another individual of the same species. Allografts used in dentistry are of cadaveric origin and are frequently used as bone grafting materials in sinus floor elevation. Examples of allografts include freeze-dried bone allografts (FDBAs) and demineralized freeze-dried bone allografts (DFDBAs). Most of the allografts are osteoconductive, as they provide scaffolds that allow clots to stabilize, promote revascularization, and facilitate host cells to repopulate, ultimately leading to new bone formation.¹ In addition to its osteoconductivity, DFDBA specifically has been reported to be also osteoinductive because it
contains a molecule called bone morphogenetic protein (BMP) that induces neighboring host cells to become osteoblasts. The particle size of DFDBA appears to have an influence on its osteoinductivity. A study in Rhesus monkeys suggests that the particle size optimal for the osteoinductive potential of DFDBA ranges from 100 to 300 microns, and that a larger particle size (1000–2000 microns) is less effective in inducing bone formation. In contrast, particulates smaller than 100 microns may elicit greater macrophage response and are resorbed rapidly without concurrent bone formation.

Xenogenic bone grafts, known also as xenografts, are grafts taken from another species such as bovines or equines. Like allografts, xenografts are also osteoconductive. Examples of xenografts include Bio-Oss, Endobon, and Equimatrix. Xenografts are again very often used for sinus floor elevation procedures. One major advantage of using xenografts in sinus bone grafting is its radiopacity, which allows the clinician to visualize on radiographs the amount of bone that has been placed in the sinus cavity or around the implants during or immediately after the procedure. Histological analyses have shown that resorption of this anorganic bovine bone matrix is very slow and can be present after many years. Hence, from a space maintenance standpoint, these xenografts can be advantageous.

According to the 1996 World Workshop in Periodontics, alloplastic materials are bone substitutes made synthetically or derived from coral or algae hydroxyapatite. Alloplasts include coralline calcium carbonate from natural coral, bioceramic alloplasts with a certain proportion of calcium and phosphate (e.g., β-tricalcium phosphate), bioactive glass, and many others. In addition, many of these alloplastic bone substitutes can be made from a combination of different alloplast materials. For example, Bone Ceramic and Osteon are made of hydroxyapatite (HA) and β-tricalcium phosphate (β-TCP) in different proportions. Similar to xenografts, some of the alloplasts are also very radiopaque and exhibit a slow resorption rate.

It is not uncommon that many clinicians use a combination of various bone grafting materials for sinus floor elevation. For example, by combining the allografts and xenografts, clinicians are able to reap the benefit of allografts’ faster resorption rate with concurrent new bone formation while taking the advantage of xenografts’ radiopacity. In addition, by mixing autografts with other nonautogenous grafts, one will retain the osteogenic potential available from autogenous grafts. Most systematic reviews reported a similar survival rate of implants placed in autogenous particulated bone, allografts, xenografts, bone substitutes, or a combination of any of the above. Also, it appears that the size of the particulates used for sinus floor elevation has minimal impact on the success of the sinus bone grafting.

**Tissue engineering materials**

With advances in dental materials and the emerging field of tissue engineering, clinicians now have more than just the bone grafting materials to choose from when performing sinus floor elevation. BMPs, first identified
by Urist in the 1960s, are a family of proteins critical in inducing bone formation. In canine models, BMP-2 has been demonstrated to promote de novo bone formation and to increase bone formation in various bony defects. The safety of recombinant human BMP-2 (rhBMP-2) use in humans has been established. A study by Boyne and colleagues has shown evidence of de novo bone growth by rhBMP-2 in maxillary sinus floor augmentation. According to a randomized parallel evaluation of sinus floor elevation done in humans using rhBMP-2 or autogenous grafts, the group with rhBMP-2 exhibited significantly denser bone than the group receiving autogenous grafts. Figure 13.1 demonstrates a lateral window sinus floor elevation procedure in which rhBMP-2 was used and implants were simultaneously placed.

Recombinant human platelet-derived growth factor-BB (rhPDGF-BB) is another growth factor widely used in dentistry. PDGF is a strong chemotactic and mitogenic factor for cells from alveolar bone and periodontal ligament. PDGF is also an important player in promoting angiogenesis, which is crucial in wound healing after sinus bone grafting surgery. A recent study by Nevins and colleagues has shown with human histology that when rhPDGF-BB was added to anorganic bovine grafts,
there was a rapid resorption of these xenografts which usually resorb slowly (Figure 13.2). In summary, the use of biologics such as BMP-2 or PDGF may allow for improved quality of bone regenerated in maxillary sinus in preparation for implant placement.

The survival rates of implants placed in all types of particulate bony matrix materials, either used alone or in combination with other matrix materials, are very similar. As mentioned earlier in this chapter, the addition of biologics such as PDGF or BMP-2 to these matrix materials may improve the quality of the newly formed bone. Therefore, when choosing between different types of bone grafting materials for sinus floor elevation, in general clinicians should take the following into consideration:

1. Incorporate xenografts or alloplasts if one desires to “visualize” the amount of bone placed in the sinus during or right after the sinus bone graft;
2. Utilize allografts if one desires to have a faster resorption rate of the matrix materials;
3. Use xenografts or alloplasts if space maintenance
Figure 13.2  Human histology of anorganic bovine bone mineral (ABBM) combined with rhPDGF-BB in maxillary bone augmentation. [Courtesy of Dr. Myron Nevins; Nevins et al. (2009)].
(a) Micro-CT scan of the core biopsy taken at the time of implant placement 6 months after sinus bone augmentation showing mostly bone (red) with minimal amount of ABBM particles left (white). (b) A core biopsy taken 6 months after sinus bone augmentation revealing a considerable amount of bone formation at augmented site with few ABBM particles remaining. (c) At higher magnification, evidence of active osteoid formation, woven bone, and lamellar bone is present.
of the matrix materials in the sinus is desired; and (4) possibly combine matrix materials with biologics if one desires to enhance the quality of the bone formed in a shorter time period. Figure 13.3 shows the clinical images of different types of bone grafting materials that can be used either alone or in combination to perform sinus floor elevation. Figure 13.4 outlines the materials available for sinus floor elevation, including autografts, allografts, xenografts, alloplasts, and biological growth factors.

**Tip:** A recent study has shown that the combination of rhBMP-2/ACS and Bio-Oss produces significantly less new bone formation than Bio-Oss alone. These results indicate that the clinician should consider the use of these materials in a singular manner in order to optimize bone regeneration in the maxillary sinus.23
References

18 Triplett RG, Nevins M, Marx RE, Spagnoli DB, Oates TW, Moy PK, Boyne PJ. Pivotal, randomized, parallel evaluation of recombinant human bone morphogenetic protein-2/ absorbable collagen sponge and autogenous bone graft for maxillary sinus floor augmenta-


CHAPTER 14

14

Review of Dental Implant Success and Survival Rates

Wai S. Cheung

This chapter will review the implant survival and success rate of the most commonly used sinus lift techniques and grafting materials.

- Dental implant success and survival rates of the lateral approach
- Dental implant success and survival rates of the transalveolar approach
- Factors that could affect the success and survival rates
  - Implant design/length
  - Residual bone height/quality
  - Medical/dental conditions
  - Selection of grafting materials

The ultimate goal of the lateral window and the transalveolar approaches is the elevation of the Schneiderian membrane from the underlying sinus wall, creating room for the insertion of either bone grafts or the implant(s) or both. Implant(s) can be placed either together with the procedure (simultaneous placement) or during a second appointment after a period of healing (delayed placement). While the advantage of the simultaneous placement technique is obviously the reduced treatment period, numbers of surgeries, and the potential accompanying morbidity, whether it is appropriate in a certain clinical situation largely depends on the amount of the residual bone.

It has been advised that simultaneous placement is indicated when the height of the residual ridge beneath the sinus floor is at least 5 mm; when it is 4 mm or less, the delayed placement technique should be applied (Table 14.1).1–3

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On the other hand, the disadvantages of delayed placement technique are a longer treatment period and the need for additional surgical procedures. In this chapter, we will examine the success and the survival rates of both techniques as well as the factors affecting them.

Table 14.1 Criteria for selecting between the delayed placement and the simultaneous placement techniques.

<table>
<thead>
<tr>
<th>Residual alveolar ridge ≤ 4 mm</th>
<th>Residual alveolar ridge ≥ 5 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delayed placement</td>
<td>Simultaneous placement</td>
</tr>
</tbody>
</table>

Table 14.2 Definition and criteria for implant survival.

<table>
<thead>
<tr>
<th>Definition/Criteria</th>
<th>Proposed by</th>
</tr>
</thead>
<tbody>
<tr>
<td>Survival</td>
<td>The implant(s) remaining in situ</td>
</tr>
<tr>
<td></td>
<td>Absence of implant mobility</td>
</tr>
<tr>
<td></td>
<td>Absence of pain</td>
</tr>
<tr>
<td></td>
<td>Absence of peri-implant radiolucency</td>
</tr>
<tr>
<td></td>
<td>Absence of paresthesia, anesthesia, or dysesthesia</td>
</tr>
<tr>
<td>Short-term</td>
<td>Within 1 year after loading</td>
</tr>
<tr>
<td>Long-term</td>
<td>Longer than a year after loading</td>
</tr>
<tr>
<td></td>
<td>Radiographic marginal bone loss less than 1.5 mm after the first year and less than 2.5 mm after 5 years</td>
</tr>
<tr>
<td></td>
<td>Absence of progressive marginal bone loss of &gt; 5 mm</td>
</tr>
</tbody>
</table>

On the other hand, the disadvantages of delayed placement technique are a longer treatment period and the need for additional surgical procedures. In this chapter, we will examine the success and the survival rates of both techniques as well as the factors affecting them.

Tip: When the height of the residual ridge beneath the sinus floor is 4 mm or less, the delayed placement technique should be applied.

Success and survival criteria

Over the years, the survival of an implant has been loosely defined as the implant remaining in situ during the entire follow-up period. Recently, the definition was interpreted explicitly by a couple of research teams (Table 14.2). The follow-up period of the short-term survival is often within a year after loading of the implant, whereas an observation period longer than that is usually referred to as long-term survival.

The criteria for success of an implant is more strict and harder (Table 14.3). In addition, it usually involves a longer follow-up period and patient opinion.

Success and survival rates

Success and survival rates of the lateral approach

In general, when a lateral window approach with simultaneous placement is considered, the short-term survival rates range from 77% to 99.3%, long-term survival rates range from 72.2% to 98.4%, with the cumulative survival rates
61.2% to 97.9% (Table 14.4). In other situations, the delayed placement of implants is chosen after the healing of the sinus grafts is complete. Short-term and long-term survival rates average 90% (ranges between 82.4% and 96%) and 94.9% (ranges between 77.2% and 100%), with the success rate of 88.4% (Table 14.5).

Studies that employed and compared both techniques (the simultaneous and the delayed placement) generated satisfactory survival rates in general with a few exceptions (Table 14.6). The mean long-term survival rates are 90.44% ranging from 56% to 100% for the delayed placement group, and 93.26% ranging from 69.9% to 100% for the immediate placement group. The differences in the time of the entire treatment course vary from 3 to 6 months.

Review studies did not find significant differences between the two techniques. Pjetursson and colleagues compared the two techniques—simultaneous and delayed placement of the implant(s) via the lateral window approach—in a systematic review.4 Forty-eight studies with a mean follow-up time of at

Table 14.3 Criteria for implant success.

<table>
<thead>
<tr>
<th>Criteria for Implant Success</th>
<th>Proposed by</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absence of implant mobility</td>
<td>30–34</td>
</tr>
<tr>
<td>No evidence of continuous peri-implant radiolucency</td>
<td>30–34</td>
</tr>
<tr>
<td>Absence of persistent pain and infection</td>
<td>30–34</td>
</tr>
<tr>
<td>Absence of persistent neuropathies, parathesias, and violation of vital structures</td>
<td>31,32</td>
</tr>
<tr>
<td>Negligible progressive bone loss (less than 0.2 mm annually) after physiologic remodeling during the first year of function</td>
<td>31,32</td>
</tr>
<tr>
<td>Radiographic marginal bone loss less than 1 mm during the first year of loading and no more than 0.2 mm resorption per year</td>
<td>30</td>
</tr>
<tr>
<td>Patient/dentist satisfaction with the implant supported restoration</td>
<td>31,32</td>
</tr>
</tbody>
</table>

Table 14.4 Ranges of survival and cumulative survival rates (%) for the simultaneous placement technique via the lateral window approach.

<table>
<thead>
<tr>
<th></th>
<th>Short-Term Survival (%)</th>
<th>Long-Term Survival (%)</th>
<th>CSR (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simultaneous placement w/lateral window</td>
<td>77–99.3</td>
<td>72.2–98.4</td>
<td>61.2–97.9</td>
</tr>
</tbody>
</table>

Table 14.5 Ranges of survival and success rates (%) for the delayed placement technique via the lateral window approach.

<table>
<thead>
<tr>
<th></th>
<th>Short-Term Survival (%)</th>
<th>Long-Term Survival (%)</th>
<th>Success (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delayed placement w/lateral window</td>
<td>82.4–96</td>
<td>77.2–100</td>
<td>74.7–96.5</td>
</tr>
</tbody>
</table>
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least 1 year after functional loading were included. It was concluded that the implants inserted with the simultaneous technique had a slightly higher annual failure rate (4.07%) than implants inserted with the delayed technique with an annual failure rate of 3.19%, translating into a 3-year survival of 88.5% and 90.9%, respectively. The difference did not reach statistical significance ($p = 0.461$).

**Tip:** Success and survival rates of the transalveolar approach—implants inserted with the simultaneous technique had a slightly higher annual failure rate; however, review studies did not find significant differences between the two techniques.

### Success and survival rates of the transalveolar approach

When applying simultaneous placement via the transalveolar approach, the short-term and long-term survival rates range between 91.8% and 100% as well as 91.4% and 98%, respectively, with an average success rate of 92.4% (72–99.99%) (Table 14.7). The advantages of the technique are that it is less invasive and it allows condensing of the bone. This feature is especially attractive in the posterior maxilla dominated by Type III–IV bone.

One common feature is quickly noticed as we look at the studies: those with lower success rates and/or higher failure rates had either used nothing in the sinus, autogenous coagulum from drilling, or collagen sponge.$^5$–$^9$ Three studies reported on the success rates, averaged 83.8% (72–90.8%); two survival rates, 72% and 91%. Other studies used varies grafting materials such as xenografts, allografts, autogenous bone graft, and, more recently, biomaterials in the form of platelet-rich fibrin (PRF). The average survival rate is 96.98% (94.8–98%) and the success rate is 96.68% (93.5–99.9%).

**Tip:** There are better clinical outcomes when bone graft(s) is applied in the transalveolar approach.

The increases in the height of the residual alveolar crest from the transalveolar approach with simultaneous placement of implants range between 1.2 mm and 7.27 mm (Table 14.7).

<table>
<thead>
<tr>
<th>Long-Term Survival [%; mean (range)]</th>
<th>$\Delta$ Time of Treatment (Months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delayed placement</td>
<td>90.4 (56–100)</td>
</tr>
<tr>
<td>Simultaneous placement</td>
<td>93.3 (69.9–100)</td>
</tr>
</tbody>
</table>

Note: $\Delta$ Time of Treatment (Months): differences in months between the courses of the two techniques.

Table 14.6 Mean, ranges of survival rates (%), and the time differences between the simultaneous placement and the delayed placement techniques.
Factors that could affect the success and survival rates

In summary, let us look at some of the factors that could affect the success and survival rates of the dental implants placed in augmented sinuses (Table 14.8). It must be stressed that clinical situations are often much complicated when the factors interact with each other. Empirical experience plays an important role in making clinical judgments.

Membrane coverage over the lateral window

It is recommended that the lateral window be covered by a piece of well-trimmed membrane. Meta-analysis confirmed that when placing a membrane over the lateral window, the annual failure rate was 0.72%, translating into a survival of 97.9% after 3 years; when the membrane was absent, the annual failure rate was 4.04%, translating into a survival of 88.6% after 3 years.10

Implant surfaces

Rough implant surfaces are recommended. It is believed that roughened dental implant surfaces produce higher survival rates in both the lateral window and the transalveolar approaches.2,11 In fact, the authors of the above-mentioned systematic review concluded that when both rough surface

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**Table 14.7** Ranges of survival, success rates (%), and bone gain (mm) for the simultaneous placement technique via the transalveolar approach.

<table>
<thead>
<tr>
<th></th>
<th>Short-Term Survival (%)</th>
<th>Long-Term Survival (%)</th>
<th>Success (%)</th>
<th>Bone Gain (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simultaneous placement</td>
<td>91.8–100</td>
<td>91.4–98</td>
<td>72–99.99</td>
<td>1.2–7.27</td>
</tr>
<tr>
<td>w/transalveolar</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>w/out grafts</td>
<td>91.8–93</td>
<td>72, 91.4</td>
<td>72–90.8</td>
<td>1.2–3.5</td>
</tr>
<tr>
<td>w/grafts</td>
<td>97.8–100</td>
<td>94.8–98</td>
<td>93.5–99.99</td>
<td>3.25–7.27</td>
</tr>
</tbody>
</table>

Note: w/out grafts: studies either used nothing or fast-absorbed grafting materials.

**Table 14.8** Factors that could affect implant success and survival rates.

<table>
<thead>
<tr>
<th>Factors that could affect success and survival rates</th>
<th>Affects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Membrane coverage over the lateral window</td>
<td>Lateral window</td>
</tr>
<tr>
<td>Implant surfaces</td>
<td>All approaches</td>
</tr>
<tr>
<td>Implant length</td>
<td>Immediate placement</td>
</tr>
<tr>
<td>Residual bone height</td>
<td>Immediate placement</td>
</tr>
<tr>
<td>Residual bone quality</td>
<td>Immediate placement</td>
</tr>
<tr>
<td>Uncontrolled occlusion</td>
<td>All approaches</td>
</tr>
<tr>
<td>Oral hygiene</td>
<td>All approaches</td>
</tr>
<tr>
<td>Smoking habit</td>
<td>Inconclusive</td>
</tr>
<tr>
<td>Estrogen replacement</td>
<td>Inconclusive</td>
</tr>
<tr>
<td>Complications</td>
<td>Inconclusive</td>
</tr>
<tr>
<td>Selection of grafting material</td>
<td>All approaches</td>
</tr>
</tbody>
</table>
implants and membrane coverage were utilized, the incidence of implant loss before functional loading was only 0.6% and the annual failure rate was 0.6% as well, translating into a survival of 98.3% after 3 years. On the other hand, we must remember the seemingly weaker resistance to bacterial invasion has been one of the concerns that were raised for rough surface implants. In a Cochran’s systemic review, it was demonstrated that machined surfaces had a 20% reduction in risk of being affected by peri-implantitis over a 3-year period.

**Implant length**
The length of the implant is suggested to be at least 10 mm. It has been advocated that the crown to implant ratio should be equal to or more than 1. Several authors have related unfavorable survival rates to the use of shorter implants. In a previously mentioned study, Tawil and colleagues evaluated the efficacy of membrane coverage in both approaches. A side finding was that the survival rates for 8 mm and 10 mm implants were 0% and 72%, respectively. In a recently published study in which the Summers osteotome technique was used, only 47.6% of the 6 mm implants survived, while the overall survival rate was 97.4%.

**Tip:** The length of the implant is suggested to be at least 10 mm.

**Residual bone height**
Minimal residual bone height has been associated with higher failure rates, lower survival rates, and negatively correlated to intrasinus bone gain for both approaches with simultaneous placement of implants. However, it produced comparable results with adequate heights in delayed placement cases. Therefore, selecting the right technique for the right cases is of utmost important. Simultaneous placement is selected when the primary stability is expected to be achieved; otherwise, delayed placement should be chosen for the ridges with less than 5 mm height.

**Tip:** When the height of the residual ridge beneath the sinus floor is 4 mm or less, the delayed placement technique should be applied.

**Residual bone quality**
Type IV bone has been labeled as a risk factor. However, with advancements in biomaterials and tissue engineering, as well as the experience of the surgeons, the challenge is limited to fewer situations.

**Uncontrolled occlusion: permanent/temporary removable partial denture (RPD), parafunction**
Whether short term or long term, uncontrolled shear force is detrimental for dental implants. Blomqvist found as much as 40.4% of the implants were lost in patients with temporary restorations and overdentures.
et al. found overdentures to be responsible for 26% of the failure. The uncontrolled shear force can be either from poorly fabricated permanent/temporary RPDs, misuse of the RPD, or a parafunctional habit.

Hence, it is recommended to have the patient leave off the removable denture for a period of time till the soft tissue wound is primarily healed. If possible, avoid a temporary RPD. If it is inevitable, then reline the denture with soft lining material and repeat it as often as needed. Occlusal adjustment must be performed thoroughly to eliminate all contacts on lateral excursion and throughout the treatment period. The patient should be instructed on correct use of the denture, and it must be emphasized repeatedly.

Oral hygiene
It has been suggested that poor home care is associated with lower survival rates. Kan and colleagues examined and graded the oral hygiene of 60 patients who returned for recall appointments. The results showed that the survival rates for patients whose oral hygiene grades were good, fair, and poor were 98.6%, 86%, and 40%, respectively. Oral hygiene instruction, including education on the importance of home care, should initiate during phase I therapy. The patient should be put into a maintenance program. Modification and reinforcement should be given periodically and as needed.

Smoking habit
The effect of smoking on implants placed in augmented sinuses seems to be inconclusive. Some researchers found the effect of smoking was either not significant or nonrelevant. Others stated that smokers, especially heavy smokers, may experience negative impact on the survival rate of the implants.

Tip: Heavy smokers may experience negative impact on the survival rate of the implants.

Complications—intraoperative and postoperative
The most common intraoperative complication for both approaches is the perforation of the Schneiderian membrane. The mean prevalence in the lateral approach was 19.5%. With the introduction of the piezoelectric technique to sinus augmentation surgery, it was declared that the membrane perforation rate had been reduced to 7%. For the transalveolar approach, membrane perforation varied between 0% and 21.4%, with a mean of 3.8%. Recently, a study compared the transalveolar approach with the osteotomes and the lateral window approach with the piezoelectric device in 25 patients. No incidence of membrane perforation was found in the piezoelectric group, while there was one perforation (3%) in the osteotome group.

When it comes to whether membrane perforation has any influence, some researchers correlated membrane perforation with implant failure, while others found no correlation.
Smaller perforations (< 5 mm) were usually closed by suturing, using tissue fibrin adhesive, autogenous fibrin and collagen sponges, or by covering them with a resorbable barrier membrane. In cases of larger perforations, larger barrier membranes, demineralized lamellar bone membrane, or suturing was used either alone or in combination with tissue fibrin glue to provide a superior border for the grafting material. Sometimes the surgery has to be aborted to allow a period of healing when the size of the perforation is beyond repair.

The most common postoperative complication is infection. In the lateral approach, the mean incidence was 2.9%, ranging from 0% to 7.4%. In the transalveolar approach, the mean incidence was 0.8%, ranging from 0% to 2.5%. Infection of the grafted sinuses is usually seen 3–7 days postsurgically and has been related to membrane perforation and the loss of bone grafts. It is usually treated by additional antibiotic administration, incision and drainage, mechanical debridement of the implant(s), frequent follow-ups, and an extended healing period. In more severe cases or when the infection is persistent, more aggressive treatment, such as the removal of graft material as well as implant(s) (when placed simultaneously) and ample rinsing, is usually necessary.

Other postoperative complications like excessive bleeding from the subantral artery, or the sinus membrane, hematoma, wound dehiscence, fistula, nasal bleeding, blocked nose, injury of the infraorbital neurovascular bundle, implant migration into the sinus cavity, cover screw loosening resulting in suppuration, embolism in the central artery of the retina resulting in permanent narrowing of the visual field, and sinusitis were also reported occasionally.

Donor site complications including numbness in the chin region, sensory disturbances in the lower incisors, lip strain, pain in the iliac crest and walking difficulties, ramus infection, hematoma, and seroma, as well as transient hypoesthesia, have been described.

Postloading complications includes implant or porcelain fracture, cement washout, and screw loosening.

**Selection of grafting materials**

The selection of the grafting materials is the last, but not the least, to be mentioned—avoid using material with a fast absorbable rate ALONE in the sinus. Speaking long term, many of the materials on the market resorb to some degree over a certain period of time, and the amount of resorption is acceptable and can be predicted. However, the resorption pattern of certain other materials is more unpredictable whether long term or short term, and the amount of resorption is unacceptable.

**Tip:** Avoid using material with a fast absorbable rate ALONE in the sinus.
References


Additional relevant works


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