INTRODUCTION

Definition of Problem

A discussion of augmentation of the posterior maxilla is inadequate in view of therapeutic capabilities. Increasing the vertical dimension of bone alone should no longer be considered a successful treatment outcome. Rather, the clinician must look toward reconstruction of the posterior maxilla in a three-dimensional manner. Such reconstruction must have specific goals, which are attainable and address the multilevel concerns of both the clinician and the patient regarding comfort, function, aesthetics, and long-term predictability.

Sinus augmentation was once considered successful if adequate bone was present posttherapeutically for placement of at least a 10-mm-long implant. No consideration...
was given to the buccopalatal positioning of the implant, nor its diameter. The definitions of success often used after sinus augmentation, and subsequent implant placement and restoration, are flawed at best.

The surgical rehabilitation of the atrophic maxillary has been established as a predictable treatment. Several recent reviews have shown implant survival rates using lateral window and transcrestal techniques for sinus elevation surgery to be more than 95%. Jensen, in a review of 85 studies, reported survival rates for the rough-surfaced implants of 88.6% to 100%. These rates were found to be comparable with nongrafted sites.

The concept of implant success versus implant survival is still debated. Initially, all implants that attained osseointegration and fulfilled the criteria of Albrektsson and colleagues regarding immobility, lack of suppuration, or tissue inflammation, and so forth were considered successful. As has long been evident through a historical analysis of the development of knowledge, concepts once believed revolutionary become foundational building blocks on which to evolve a more nuanced understanding and outlook. Although the Albrektsson criteria were an invaluable starting point, such criteria do not assess the stability of bone on the buccal or palatal/lingual aspects of an implant.

Any discussion of implant success must include an implant assessment, which combines the Albrektsson and colleagues’ criteria with buccal and lingual/palatal bone assessment to ensure peri-implant marginal bone stability. Once these measurements are taken, the clinician can truly claim a successful implant therapeutic outcome. Such considerations are not purely semantic. To appropriately assess therapeutic efficacy in the long-term, criteria must be used that separate true success from mere survival. Unless the clinician is to assume the role of an actuarial, success is the only true goal.

As already mentioned, reconstruction of the posterior maxilla should always be viewed in a three-dimensional manner. Adequate bone must be present after regenerative efforts to place an implant in the ideal, prosthetically driven position. However, such a regenerative outcome is not in itself adequate. Although the concept of prosthetically driven implant placement is popular and well intentioned, it does not take into account the diameter of the tooth being replaced, or the fact that functional and parafunctional forces have their greatest effect on the peri-implant crestal bone. The greater the implant diameter, the greater the potential surface area of the osseointegrative bond at the crest of bone, to help better dissipate these forces. Therefore, buccopalatal/lingual regenerative efforts should be aimed at rebuilding adequate bone for prosthetically driven placement of an implant of the ideal diameter for the tooth being replaced (Fig. 1). Of course, when such placement results in a thin patina of bone on the buccal or palatal/lingual aspect of the implant, treatment should not be deemed successful. The likelihood of this thin patina of bone resorbing under function over time is high. Such resorption results in significant compromise of the osseous support of the implant. Buccopalatal/lingual regeneration should be considered successful if the following criteria are met.

An implant of ideal dimensions for the tooth being replaced may be placed in a prosthetically driven position, and show a minimum of 2 mm of bone buccally and palatally/lingually at the osseous crest. Such a treatment result helps ensure long-term stability of the bony support of the implant under function. Another and most important criterion for success is a maximization of treatment outcomes in conjunction with a minimization of therapeutic insult to the patient. The most conservative treatment approach possible must always be used, assuming that the final treatment
outcome is not compromised. A treatment approach that is easier or faster is of no use if the final treatment outcome is not equal in all respects to the therapeutic result after a more complex approach.

**Treatment Options**

When reconstructing the posterior maxilla, regenerative options include the following:

a. Lateral wall Caldwell-Luc sinus augmentation
b. Lateral wall Caldwell-Luc sinus augmentation in conjunction with buccal or palatal ridge augmentation
c. Trephine and osteotome use in anticipation of implant placement at a second stage
d. Trephine and osteotome use with simultaneous implant placement
e. Trephine and osteotome use followed by a second procedure of trephine and osteotome use, with simultaneous implant placement

Although complications may arise with any of these procedures, it is imperative to understand that an appropriate consideration of complications goes beyond surgical or postsurgical problems. Complications may occur before active therapy, during the surgical procedure, immediately after the surgical procedure, before implant loading, after implant loading, and after months or years of implant loading.

**Pretreatment Evaluation**

Complete medical, dental, social, and habit histories are required. The avoidance of complications must include addressing both absolute and relative contraindications. Absolute contraindications include systemic conditions such as radiation therapy, poorly controlled diabetes, hypertension, immune compromise, neoplasm,
and associated polypharmacies. However, it is valuable to know that well-controlled type 2 diabetics have shown implant survival rates comparable with nondiabetics. Tawil and colleagues\textsuperscript{13} treated 45 well-controlled and fairly well-controlled (hemoglobin A\textsubscript{1c} <7\% vs 7\%–9\%) diabetic patients (143 implants) and 45 nondiabetic controls (142 implants) with classic protocol sinus elevation and bone grafting. Followed for 1 to 12 years the overall implant survival for the diabetic patients was 97.2\% versus 98.8\% for the nondiabetic control group.

Other significant risk factors for complications include active periodontitis, active sinusitis, large cysts, and history of chronic sinus disease.\textsuperscript{14–17} Active periodontics has been shown to reduce the survival rates for dental implants and, prospectively, even if successfully treated, as a risk for peri-implantitis.\textsuperscript{18} Acute or chronic sinusitis must be resolved before sinus elevation. Brook\textsuperscript{19} suggested that 10\% to 13\% of maxillary sinusitis is attributable to odontogenic infection. Conventional dental and medical treatment should be undertaken to eliminate these factors.

Smoking is a relative risk factor and has been linked to reduced implant survival outcomes. In an 8-year follow-up study of 13,147 implants placed in 4316 patients, Busselechner and colleagues,\textsuperscript{20} found a 3-fold failure rate in the smokers compared with nonsmokers. In a recent systematic review, Pjetursson and colleagues\textsuperscript{5} found that there was almost twice the rate of implant failures in smokers compared with nonsmokers.

Assuming a noncontributory medical history, a thorough clinical examination must be carried out to assess both the patient’s regenerative needs and the feasibility of performing the proposed regenerative therapy. An accurate assessment of the condition of the soft tissues, not only of the site to be regenerated but throughout the mouth, must occur. A full occlusal examination must also be carried out.

At the least, digital clinical photographs must be taken, including photographs in various lateral and protrusive positions. A formatted computed tomography (CT) scan is usually necessary in addition to properly angled individual digital radiographs, to assess the presence or absence of various diseases and the morphology of the site to be treated. Face bow mounted models are a key component in facilitating an accurate diagnosis and helping to formulate a comprehensive treatment plan. In addition, face bow mounted models allow for fabrication of regenerative and implant placement stents, to help guide the clinician in assessing regenerative needs, and thus rebuilding the necessary hard and soft tissues.

Failure to perform a thorough examination and accomplish a comprehensive diagnosis often lead to either use of a less than ideal surgical approach, selection of an inappropriate restorative modality, postoperative complications, or implant loss after restoration and varying lengths of time in function. In addition, failure to identify either the etiologic factors, or cofounding factors that must be managed to ensure long-term maximization of treatment outcomes, compromises patient care. For example, an undiagnosed parafunctional habit often leads to loss of bony support around implants under function and a poorer prognosis.

All treatment plans must be grounded in biological principles and therapeutic possibilities. Such treatment plans must strive to attain the most optimal treatment outcomes possible with the available technologies and techniques. To do so, the treating clinician(s) must constantly visualize ideal treatment outcomes and strive to attain them. For example, the determination of whether or not buccal or palatal ridge augmentation therapy is necessary should be based on neither specific clinician’s limitations nor manufacturer’s claims. Rather, an implant of the ideal diameter for the tooth being replaced must be able to be inserted in a restoratively driven position and show 2 mm of bone buccally and palatally, at the alveolar crests.
SINUS ANATOMY

Any discussion of treatment of complications related to sinus elevation procedures must include sinus anatomy. The maxillary sinus is a pyramidal cavity, volume of 12 to 15 mL, contained within the maxillary bone. It is bounded superiorly by the orbital floor, inferiorly by the alveolar process, medially by the lateral nasal wall, and laterally by the zygomatic process and buccal alveolus. The sinus is lined with a thin layer of mucoperiosteum, the Schneiderian membrane, of variable thickness, with an average of approximately 1.0 mm. The sinus drains medially and superiorly into the nasal cavity via the ostium. The maxillary artery and nerve provide blood supply and innervation. The posterior superior branch of the maxillary artery may pass through the area of the posterior lateral window preparation, with average distance from the artery to the alveolar crest 16.9 mm. However, this distance has been found to be as little as 11.25 ± 2.99 mm (standard deviation) mean vertical distance from the lowest point of the bony canal to the alveolar crest.

COMPLICATIONS AFTER VARIOUS TREATMENT APPROACHES

Complications may be divided into intraoperative and postoperative events, and they may be interrelated (Table 1). Moreno Vasquez and colleagues, in a retrospective study, reported on the complication rate of 200 consecutive sinus lift procedures in 127 patients. The complications included Schneiderian membrane perforation, 25.7% (with no postoperative complications), 14.7% had wound infections, abscesses, drainage, dehiscence, maxillary sinusitis, graft exposure; and loss of graft (2 cases). Nolan and colleagues reported on 359 sinus augmentation procedures in 208 patients. The incidence of sinus perforation was 41%. Of the 6.7% of the sinus grafts that failed, 70.8% had perforated sinus membranes. Lee and colleagues reported a complication rate of almost 28% in a retrospective analysis of 97 sinus elevations. Although the sinus lift surgery is a reliable procedure, it is not without risk.

Complications do not automatically imply failure. The most common complications of sinus floor elevation and their effect on the final outcome of therapy have been extensively discussed.

LATERAL WALL CALDWELL-LUC SINUS AUGMENTATION

Conceptual Complication

It is important to adequately visualize the shape of the sinus to be augmented. Failure to do so may result in an attempt to prepare a sinus window in the alveolar ridge.

Treatment

When this problem occurs, the solution is to reassess the area with appropriate imaging and adjust the position of the osteotomy window accordingly.

Technical Complications

The most frequent technical complication is perforation of the sinus membrane. Various investigators reported incidence of sinus membrane perforation during sinus augmentation therapy to range between 19.5% and 41% (Table 2). Numerous factors have been described as risk providers related to membrane perforation, including the presence of septa, the width of the sinus, the angle of the sinus walls, residual height, and membrane thickness. This complication may happen during window preparation, initial reflection, final reflection, or graft placement. The chances of
<table>
<thead>
<tr>
<th>Article</th>
<th>Aim</th>
<th>Materials</th>
<th>Criteria</th>
<th>Results</th>
<th>Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maxillary sinus functions and complications with lateral window and osteotome sinus floor elevation procedures, followed by dental implants placement: a retrospective study in 60 patients&lt;sup&gt;24&lt;/sup&gt;</td>
<td>Evaluate maxillary sinus functions and complications by using lateral window and osteotome sinus floor elevation then implants placement</td>
<td>60 patients sinus floor elevation using lateral window with residual subsinus alveolar bone height (RSABH) of 3 mm and osteotome with RSABH of &gt;4 mm</td>
<td>Dizziness Nausea Sinus membrane perforation</td>
<td>More dizziness and nausea with osteotome than lateral window, which disappeared within 2–4 wk 4 of 79 sinus perforation cases (2 osteotome and 2 lateral window)</td>
<td>No obvious maxillary sinus complications for 24 mo after sinus floor elevation using osteotome and lateral window, followed by implants placement Clinical assessment of individual risk and modifying factors before procedures</td>
</tr>
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Bio-Oss graft was used with lateral window
Implants were placed immediately at time of lateral window, or after 9 mo using surgical guides
Bio-Oss graft was used with lateral window
Retrospectively evaluated clinically and radiographically for 24 mo
| A retrospective study of the effects on sinus complications of exposing dental implants to the maxillary sinus cavity | Investigate whether dental implant exposure to the maxillary sinus cavity increased the risk of maxillary sinus complications | 9 patients 23 implants inserted into the maxillary sinus >4 mm No sinus membrane lift 6–10 mo evaluation using questionnaire and CT Astra implants and 1 Osstem implant used | Nasal congestion Obstruction Pathologic secretion Pain and tenderness in the sinus region No clinical signs of sinusitis CT scans showed postoperative sinus mucus thickening around 14 of the 23 implants | This study showed that implant exposure to the maxillary sinus cavity can cause sinus mucus thickening around the implants Implant exposure to the sinus cavity might contribute to the development of maxillary sinusitis in patients with a predisposition for sinusitis Implant extension into the nasal cavity can give rise to rhinosinusitis (Raghoebbar and colleagues) |

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<table>
<thead>
<tr>
<th>Article</th>
<th>Aim</th>
<th>Materials</th>
<th>Criteria</th>
<th>Results</th>
<th>Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>A case of massive maxillary sinus bleeding after dental implant</td>
<td>A case of maxillary sinus bleeding during dental implant</td>
<td>Maxillary sinus osteoplasty with a vascularized pedicled bone flap through a maxillary sinus approach</td>
<td>General anesthesia</td>
<td>Signs of posterior nasal bleeding and swelling of the gingiva were not controlled</td>
<td>Surgery is needed in cases in which nasal bleeding is not conservatively controlled</td>
</tr>
<tr>
<td></td>
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<td>Hemoglobin level measured 7.1 g/dL</td>
<td>1 d after admission, the bleeding was not controlled</td>
<td>Cauterization of the bleeding site using a nasal endoscope is the most common operative technique</td>
</tr>
<tr>
<td></td>
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<td>1 d after surgery, there were no signs of rebleeding</td>
<td>Vascularized pedicled bone flap allows a shorter length of hospital stay and fewer outpatient clinic visits because it causes minimal swelling of the isthmus and minimal injury to the maxillary mucosa</td>
</tr>
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Fugazzotto et al.
<table>
<thead>
<tr>
<th>Fungal infection as a complication of sinus bone grafting and implants: a case report</th>
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<tr>
<td><strong>Report a case of a middle-aged male patient along with the clinical, radiographic, and histologic findings</strong></td>
</tr>
</tbody>
</table>
| **48-y-old man**  
10 cigarettes/d  
Failed sinus bone grafting (irradiated cancellous bone) and osseointegration of implants (Nobel Biocare), which were placed after 6 mo of sinus graft  
Surgical exposure of the maxillary sinus  
Systemic prophylactic antibiotics used  
Removal of infected bone graft  
Sinus membrane elevation  
Perforation sealed with bioresorbable membrane and fibrin glue (to stabilize the membrane)  
Demineralized bone matrix paste with cancellous bone was grafted into the sinus and covered by Tutoplast pericardium  
Postoperative systemic antibiotics, nonsteroidal antiinflammatory drugs for 10 d and antifungal drug  
Implants placed after 8 mo |
| **Increased radiopacity of the right maxillary sinus**  
Sphere-shaped foreign body mass composed of dark brown and red material curetted from maxillary sinus  
Caused by *Aspergillus* and polypous mucosa  
Newly grafted allograft in the sinus showed no specified inflammation or fungal hyphae |
| **First case report of fungal sinusitis that developed after maxillary sinus bone grafting followed by implant placement**  
Surgical treatment of noninvasive fungal sinusitis produced good results, and no recurrence was observed |

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<thead>
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<th>Article</th>
<th>Aim</th>
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<tr>
<td>Oroantral communication as an osteotome sinus elevation complication&lt;sup&gt;28&lt;/sup&gt;</td>
<td>Case report of an oroantral communication that developed as a complication to a sinus elevation surgery performed with the crestal approach</td>
<td>54-year-old woman with history of sleep apnea and smoking (1 pack/d). Patient has a bridge from 2 to 4 with missing 3. Extraction of tooth 2 and freeze-dried bone allograft socket preservation. After 3 mo, exploratory surgery was performed. Amoxicillin and methylprednisolone for 7 d before surgery. There were no bone fills inside the socket. Freeze-dried bone allograft mixed with platelet-rich plasma to elevate the sinus using osteotome over tooth 3 space. Collagen membrane used. Postoperative instructions and chlorhexidine 0.12% used.</td>
<td>6 d later the patient returned to the clinic and claimed the surgical site had “opened up.” Water coming through her nose while drinking. The sutures were broken and the flaps open.</td>
<td>De-epithelization of buccal and lingual flaps, and rotating buccal flap mesially, to cover the site. Postoperative instructions, and patient instructed to stop using continuous positive airway pressure mask. Patient was followed every 2 wk for 2 mo, and the area appeared to be healed, with complete closure by the end of the first month. After 4 y, patient presented with normal healing, no smoking, and a new lateral window sinus lift was performed to restore 4 successfully.</td>
<td>Use of a positive pressure mask may have complicated a sinus elevation surgery. Other factors that may have contributed to this complication include smoking and delayed healing of the area.</td>
</tr>
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Potential adverse events of endosseous dental implants penetrating the maxillary sinus: long-term clinical evaluation

Evaluate the nature and incidence of long-term maxillary sinus Adverse events related to endosseous implant placement with protrusion into the maxillary sinus

70 patients with 83 implants placed into maxillary sinus (≤3 mm) with membrane perforation
Minimum of 5 y follow-up
Perioperative prophylactic clindamycin
Straumann implants were placed after 1-stage procedure
Postoperative antibiotics for 4 d
Prosthetic rehabilitation after osseointegration from 2–6 mo

Clinical and radiographic assessment
monitoring signs of sinusitis, and by asking the patients about any symptoms, including nasal bleeding, congestion or obstruction, nasal secretion, and pain or tenderness in the infraorbital region

12 patients had >1 implant penetrating the sinus
7 had bilateral perforation
Implants were localized in premolar/molar area
2/83 implants diagnosed with peri-implantitis were treated without recurrence
Radiologic follow-up showed a normal bone healing process in all patients

No sinus complication was observed after implant penetration into the maxillary sinus (≤20 y)
Absence of complications was related to maintenance of successful osseointegration

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<table>
<thead>
<tr>
<th>Article</th>
<th>Aim</th>
<th>Materials</th>
<th>Criteria</th>
<th>Results</th>
<th>Conclusion</th>
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</table>
| The management of complications after displacement of oral implants in the paranasal sinuses: a multicenter clinical report and proposed treatment protocols | Study retrospectively analyzed paranasal sinus complications after displacement of oral implants in the maxillary sinus treated according to clinical situation by functional endoscopic sinus surgery (FESS), an intraoral approach, or a combination of both procedures | 27 patients (13 male; 14 female)  
Age: 27–73 y  
More than 5 y treatment of complications involving the paranasal sinuses after displacement of oral implants in the maxillary sinuses  
Patients were treated with FESS (functional endoscopic sinus surgery), intraoral approach to the sinus, or FESS associated with an intraoral approach | Implant displacement  
Implant displacement with or without reactive sinusitis or with or without associated oroantral communication | 26 patients recovered completely  
1 patient underwent reintervention with FESS and an intraoral approach 2 y after implant removal followed by complete recovery | The results show that a rational choice of surgical protocol for the treatment of complications involving the paranasal sinuses after displacement of implants in the maxillary sinuses may lead to reliable results |
| Effect of Schneiderian membrane perforation on posterior maxillary implant survival | To assess the survival rate of implants placed in the posterior maxilla by intentionally perforating the Schneiderian membrane and protruding the implant up to 3 mm beyond the sinus floor in cases of reduced crestal bone height | 56 patients with 63 implants intentionally penetrated the Schneiderian membrane engaging sinus floor cortical bone (Nobel Biocare)  
Implants were placed using 2-stage technique  
1 y follow-up after implant restoration (12–14 wk)  
Postoperative antibiotics | 1 implant failure  
7 patients experienced mild epistaxis during the immediate postoperative period, with no associated implant loss  
1 patient developed sinusitis secondary to the surgical procedure, which was treated by antibiotic therapy and the patient improved clinically, with no associated implant loss | Intentional perforation of the Schneiderian membrane using a 2-mm twist drill at the time of implant placement and protrusion of the implant up to 3 mm beyond the sinus floor does not alter the stability and outcome of dental implants, 1 y after restoration |
Transcrestal sinus floor elevation with osteotomes: simplified technique and management of various scenarios

Understand the structure of the maxillary sinus region

Describe a simplified transcrestal sinus floor elevation technique

Manage issues and factors that may be encountered when performing a sinus floor elevation

Implant success rate after osteotome sinus lift is 90.9%–92.8%

Septa are present 31.7% at premolar area

Pneumatization of the sinus occurs within 6 mo after tooth extraction

<4 mm of bone subantral then a lateral window is recommended

>5 mm of bone is needed to place an implant with osteotome sinus lift

If only 4 mm of bone is present, then implant needs to be submerged under the gum

>4 mm of subantral bone leads to 96% survival rate compared with only 84.7% when bone is <4 mm

Simplified osteotome technique: used for medium and soft dense bone

Assume there is only 4 mm subantral bone

Complications: most frequently encountered complication is Schneiderian Membrane perforation (38%)

Infection 0.8%

In case of extensive malleting, postoperative headache or benign paroxysmal positional vertigo can occur

Complications When Augmenting Posterior Maxilla

Simplified technique to perform sinus floor elevation in medium dense bone has been presented

Enhances patient comfort and reduces the need to mallet osteotomes

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<table>
<thead>
<tr>
<th>Article</th>
<th>Aim</th>
<th>Materials</th>
<th>Criteria</th>
<th>Results</th>
<th>Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Using Straumann system</td>
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<td>system and the corresponding osteotome</td>
<td></td>
<td>Periapical radiograph is taken, for subantral bone determination</td>
<td>Considering 14% error</td>
</tr>
<tr>
<td>2-mm drill used till</td>
<td></td>
<td></td>
<td>1 mm short of the subantral floor</td>
<td>Guide pin insertion</td>
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<td></td>
<td></td>
<td></td>
<td>Then subsequent drills are used</td>
<td>An osteotome corresponding to the last drill is used to upfracture the</td>
<td>Wide the osteotomy</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>to widen the osteotomy</td>
<td>sinus floor</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>A metal stop is placed on the</td>
<td>A metal stop is placed on the osteotome at 4 mm in this case and the</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>osteotome at 4 mm in this case</td>
<td>tip of osteotome is dipped in saline</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Few gentle malleting taps</td>
<td>Few gentle malleting taps facilitate the infracture</td>
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</table>
Some hemorrhage occurs once penetrating the sinus floor.
Bone graft material could be used before infracture to act as a cushion, although might reduce the tactile perception.
After placing bone grafting material in the osteotomy, using an amalgam carrier, the same osteotome is used to push the bone substitute and elevate the membrane. This provides 2 mm of bone height.
Repeat till desired length is reached.
Bone forms at the sinus floor at a rate of 1 mm.
Slanted sinus floor:
Drill is stopped 1 mm short of the most inferior sinus wall.
Drills are increased in size normally, then, a small osteotome is used angled toward the thicker bone to break the bone.

(continued on next page)
<table>
<thead>
<tr>
<th>Article</th>
<th>Aim</th>
<th>Materials</th>
<th>Criteria</th>
<th>Results</th>
<th>Conclusion</th>
</tr>
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<tbody>
<tr>
<td>Fugazzotto et al</td>
<td>Any sinus perforation should be verified using the Valsalva maneuver</td>
<td>Some clinicians recommend abortion and healing for 4 wk, then, redoing the procedure</td>
<td>Implant platform should be placed supracrestal when there is minimum subantral bone to achieve supracrestal biological width</td>
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</table>
perforation during window preparation are significantly reduced by using a piezo surgical approach, rather than a conventional dental bur. Weitz and colleagues\(^\text{46}\) reported a sinus membrane perforation incidence of 17.5% using a piezo surgical approach. Tactile sense is greatly improved with piezo surgery, as is the accuracy of the osteotomy. Initial membrane elevation runs the risk of a membrane tear occurring as a result of too much pressure being placed in 1 position and direction. To ameliorate this concern, it is recommended that the osteotomy window be wholly detached. A piezo surgical tip is then used, which pushes against the window before touching the membrane, imploding it slightly and creating a small space for insertion of the piezo surgery tip, which then begins membrane reflection. As subsequent curettes are inserted, the curette always applies pressure against the osteotomy window first, further imploding the window and creating space between the outer alveolar bone and the membrane, allowing for passive insertion of the curette. Toscano and colleagues\(^\text{47}\) reported an incidence of sinus membrane perforation involving 3.6% after use of a piezo surgical approach to affect sinus augmentation therapy. Such an approach greatly decreases the chances of membrane perforation.\(^\text{48}\) In contrast, Barone and colleagues\(^\text{40}\) concluded that piezo surgery and conventional instrumentation showed no significant differences in the incidence of sinus membrane perforation.

All membrane reflection must be accomplished in a three-dimensional manner. Reflection should not only be in a medial direction. Medial, mesial, and distal reflections must occur in concert with each other, if perforations are to be avoided in the later stages of membrane reflection. Geminiani and colleagues\(^\text{48}\) compared the incidence of sinus membrane perforations using piezo surgical and conventional handpiece approaches in a total of 130 sinus augmentation procedures (51 rotary instrument and 79 piezo surgery). Incidence of sinus membrane perforation of 27.5% was noted when a rotary instrument approach was used, compared with an incidence of sinus membrane perforation of 12.7% when a piezo surgical approach was used.

**Treatment**

If a membrane perforation occurs, the perforation must be classified and treated accordingly.

Is the presence of a sinus membrane perforation cause to either abort the planned augmentation procedure or modify a planned augmentation with simultaneous

<table>
<thead>
<tr>
<th>Author, Year</th>
<th>Numbers of Sinus Augmentations</th>
<th>Perforations (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Khoury,(^\text{37}) 1999</td>
<td>216</td>
<td>23.5</td>
</tr>
<tr>
<td>Shlomi et al,(^\text{38}) 2004</td>
<td>73</td>
<td>28</td>
</tr>
<tr>
<td>Ardekian et al,(^\text{39}) 2014</td>
<td>110</td>
<td>32</td>
</tr>
<tr>
<td>Barone et al,(^\text{40}) 2008</td>
<td>26</td>
<td>23–30</td>
</tr>
<tr>
<td>Hernandez-Alfaro et al,(^\text{41}) 2008</td>
<td>474</td>
<td>21.9</td>
</tr>
<tr>
<td>Becker et al,(^\text{42}) 2008</td>
<td>201</td>
<td>20.4</td>
</tr>
<tr>
<td>Pjetursson et al,(^\text{5}) 2008</td>
<td>1300</td>
<td>19.5</td>
</tr>
<tr>
<td>Testori et al,(^\text{43}) 2012</td>
<td>144</td>
<td>28</td>
</tr>
<tr>
<td>Nolan et al,(^\text{23}) 2014</td>
<td>359</td>
<td>41</td>
</tr>
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implant procedure so that only the augmentation is performed during the first surgical visit?

These questions are answered, and predictable treatment results obtained, through the use of a framework by which to deal with sinus membrane perforations and effect predictable sinus augmentation, with or without simultaneous implant placement.

Treatment of sinus membrane perforations involves the following steps:

- Classification of the perforation (Fig. 2)
- Management of the perforation
- Possible modification of the timing of implant placement, if used

On discovery of a sinus membrane perforation, the clinician must avoid manipulation of the membrane to ascertain the size of the tear, because such manipulation only worsens the tear. The buccal mucoperiosteal flap may have to be extended through lengthening of the mesial and distal vertical releasing incisions and their horizontal extensions, and further full-thickness flap reflection, to gain greater visualization and access to the prepared sinus window area. After additional mucoperiosteal flap reflection as required, the membrane perforation is evaluated, classified, and treated.49

Membrane perforations are first classified with respect to location. Class I perforations occur at any point along the most apical wall of the prepared sinus window. Class II perforations occur along the lateral or crestal aspects of the prepared sinus window and are further subdivided according to their position relative to the most mesial, distal, or crestal bony walls of the underlying sinus. Class III perforations occur at any location within the body of the prepared sinus window.

**CLASS I SINUS MEMBRANE PERFORATIONS**

The presence of a class I sinus membrane perforation poses no concerns with regard to either sequencing of therapy or the final treatment result, assuming appropriate perforation management. Sinus membrane elevation is easily accomplished. The apical displacement of the sinus membrane after its reflection results in the membrane folding over itself, sealing the class I sinus membrane perforation. A piece of collagen tape may be placed over the area. If simultaneous implant placement had been planned, such implant placement may then be carried out (Fig. 3).

**CLASS II SINUS MEMBRANE PERFORATIONS**

Both the repair of a class II sinus membrane perforation, and the need or lack of need to alter the proposed course of therapy, are dependent on the position of the membrane perforation in relation to the bordering walls of the subantral space to be

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*Fig. 2. Sinus perforation locations.*
augmented. If the initial sinus window was precisely prepared to approximate the bordering sinus cavity walls, repair of a class II sinus membrane perforation is more difficult, and has a greater impact on the course of therapy than if the initial sinus window preparation was undersized and did not approximate the bordering sinus cavity walls.

CLASS IIA SINUS MEMBRANE PERFORATIONS

A class IIA sinus membrane perforation may occur anywhere along the expanse of the lateral or coronal walls of the prepared sinus window, when the sinus cavity to be augmented extends a minimum of 4 to 5 mm beyond the position of the membrane perforation. For example, if the membrane perforation is on the mesial aspect of the sinus window, and the sinus extends at least 4 to 5 mm mesially beyond the prepared sinus window, this perforation is classified as IIA. In such a situation, care is taken after mucoperiosteal flap extension to gently extend the osteotomy further mesially using a piezo surgery tip, thus exposing intact sinus membrane mesial to the perforation. The reflecting instrument is extended over the membrane perforation to the intact sinus membrane area, thus bridging the tear and allowing gentle reflection of the intact sinus membrane and rotation of the membrane and the attached bony window medially and apically. A resorbable membrane is then placed over the area, sealing the membrane. If simultaneous implant therapy had been planned preoperatively, it can be accomplished at this time (Fig. 4).

CLASS IIB SINUS MEMBRANE PERFORATIONS

If the prepared aspect of the sinus window approximates the extension of the sinus cavity in this area, no additional space exists for performance of a further osteotomy

Fig. 3. (A) A class I sinus perforation is noted. (B, C) Preoperative and postoperative panoramic radiographs show successful bone augmentation after repair of the class I sinus membrane perforation.
to expose intact membrane lateral to the perforation. For example, when the mesial wall of the prepared sinus window approximates the mesial extent of the sinus to be augmented, it is impossible to remove additional bone mesial to the prepared sinus window in an effort to uncover intact sinus membrane for use during reflection. Attempts to reflect the remnants of the sinus membrane increase the size of membrane perforation, rendering it unmanageable. It is imperative that a new membrane be recreated, to provide the clinician with a containing element for reception of the planned regenerative materials. Insertion of collagen tape or other pliable, nonsecured materials in an attempt to form a containing element within the augmented sinus is unpredictable. Therefore, a resorbable membrane is shaped and inserted into the sinus window, with its ends extruding out of the window. The extruding aspects of the membrane are secured to the surrounding alveolar bone with 1 or 2 fixation tacks. A curette is used to gently mold the morphology of the membrane within the sinus cavity to be augmented, ensuring the creation of adequate space to receive and contain the augmentation materials. If preoperative planning called for simultaneous implant placement at the time of sinus augmentation, this course of therapy is abandoned. When faced with an extensive membrane perforation requiring the aforementioned reconstructive therapy, only augmentation is carried out during this surgical session. Implant placement occurs at a second visit, after maturation of regenerating hard tissues in the augmented sinus area.

CLASS III SINUS MEMBRANE PERFORATIONS

A class III membrane perforation is treated in an identical manner to that of a class IIIB sinus membrane perforation (Fig. 5).
Postoperative medications after sinus augmentation therapy include augmentin 875 mg twice a day for 10 days (patients allergic to augmentin receive levaquin, 1 a day for 10 days), and etodolac 400 mg, 3 times a day for 5 days, unless medically contraindicated. Patients are instructed not to blow their noses for 14 days postoperatively.

Sinus Augmentation Therapy with Concomitant Bucco or Palatal Ridge Augmentation

Simultaneous sinus and ridge augmentation is a highly predictable procedure. In addition to the concerns addressed earlier, complications may occur with regard to the ridge augmentation procedure.

Diagnostic complications
The most frequent diagnostic complication is an underestimation of the extent of regenerative therapy that must be performed, especially at the alveolar crest.

Technical complications
Inadequate flap design severely limits the clinician’s ability to attain passive primary closure over the regenerative materials that are placed. If passive soft tissue primary closure cannot be attained and maintained, the regenerative results are less than ideal. Therefore, adequate soft tissue management is of paramount importance.

The sine qua non of successful guided bone regeneration therapy is appropriate flap management. Although bone regeneration can be achieved without attaining and maintaining passive soft tissue primary closure over the regenerating site, the extent and morphology of the regenerated hard tissues often fall short of the desired

Fig. 5. (A) A class III sinus membrane perforation is noted. (B) A preoperative radiograph of the maxillary left sinus area, which is to be augmented. (C) After membrane repair, successful sinus augmentation has been carried out. (D) A radiograph taken 11 years after implant restoration shows stable regenerated and crestal peri-implant bone.
ideal treatment outcome. In addition, the resultant soft tissue covering when passive soft tissue primary closure is not maintained is usually thinner than desired and represents a potential aesthetic compromise. Incisions should be made within keratinized tissue to ensure keratinized margins to the mucoperiosteal flaps, both to enhance soft tissue manipulation and to help avoid fraying of the mucoperiosteal flap margins. Incision design is recommended to be as follows.

- A horizontal midcrestal incision within keratinized tissue: this incision is made along the crest of the ridge and carried at least 6 to 8 mm distal to the area to be augmented, to provide appropriate access to the underlying atrophic ridge. The incision is carried to within 1 to 2 mm of the tooth anterior to the edentulous posterior region, but does not reach the adjacent tooth, to preserve a portion of the papilla and thus a soft tissue cover over the supporting bone on the distal aspect of the tooth.

- Releasing incisions: 4 releasing incisions are used. They are placed at the mesio-buccal, distobuccal, mesiopalatal, and distopalatal aspects of the midcrestal horizontal incision, extend beyond the mucogingival junction well into mucosa, and are crucial if appropriate flap reflection and defect visualization are to be achieved. All palatal releasing incisions are placed obliquely. An oblique incision may be placed approximately 30% less deeply into the palatal vault than a straight releasing incision, retaining the same degree of flap reflection and defect visualization.

- Horizontal extensions of the releasing incisions: horizontal releasing incisions are placed at the most apical extents of all buccal vertical releasing incisions in the maxilla. These horizontal releasing incisions may extend up to 10 mm, depending on the need for greater flap mobility. Such horizontal extensions are of no use throughout the palate, because the palatal flap cannot be coronally positioned.

- Full-thickness flap reflection: all flaps are reflected in a full-thickness manner, including the horizontal extensions at the apices of the vertical releasing incisions. No periosteal fenestration is used at any time. Adequate full-thickness flap reflection after appropriate releasing incision design results in greater flap mobility than periosteal fenestration. In addition, postoperative morbidity (ie, swelling) is less when full-thickness reflection is used compared with periosteal fenestration. These flap designs provide adequate flap mobility to attain and maintain passive soft tissue primary closure throughout the course of regeneration. When the previously outlined flap designs are not adequate to attain passive primary closure after placement of regenerative materials in the maxilla, a rotated palatal pedicle is used.

A full-thickness palatal mucoperiosteal flap is reflected. An incision is then made with a 15 blade mesiodistally on the internal aspect of the palatal flap, approximately 3 to 4 mm from the base of the mucoperiosteal flap. Using tissue forceps and a 15 blade, the flap is split internally toward its crestal aspect. The internal aspect of the flap is filleted and rotated crestally to lengthen the palatal flap by approximately 70%. Care is taken neither to perforate the flap at its most crestal aspect nor to render the residual isthmus of tissue so thin as to be in danger of sloughing during healing.

The efficacy of these flap designs in the attainment and maintenance of primary closure of soft tissue throughout the course of regeneration was assessed through the examination of almost 900 consecutive guided bone regeneration cases.53–55

**Postoperative complications**

Loss of soft tissue primary closure results in premature membrane exposure. When this complication occurs, the clinician must carefully assess the situation and
attempt to maintain the area through the use of chlorhexidine gluconate rinses. If the extent of membrane exposure increases, or purulence is noted, the membrane must be removed. If membrane exposure occurs before 8 weeks, the regenerative results are severely compromised at best and often must be classified as a failure. Should such membrane removal occur after 8 weeks, significant bone regeneration is usually achieved.

Treatment
If the ridge augmentation did not result in adequate bone for ideal implant positioning, a new ridge augmentation procedure must be performed before implant placement. If adequate bucco or palatal bone regeneration has occurred to allow ideal implant positioning, the implants are inserted and the area is regrafted with particulate material and a covering membrane at the time of implant insertion, to attain the desired alveolar morphology.

Trephine and Osteotome Use, in Anticipation of Implant Placement

Diagnostic complications
Care must be taken to accurately assess the extent of the alveolar bone that is present crestal to the floor of the sinus and the ability to accomplish the desired extent of augmentation through an osteotome and trephine approach.

Technical complications
Two potential technical complications are encountered.

The first is evidence of the bony core within the trephine on trephine removal from the mouth. In such a situation, the core is gently removed from the trephine, inserted into the osteotomy, and imploded to the desired level.

The second complication is evidence of both the bony core and the corresponding sinus membrane within the trephine on trephine removal. Once again, this complex is gently removed from the trephine, reinserted at the osteotomy, and imploded to the desired level.

Neither complication significantly affects the regenerative outcome, assuming that care is taken when managing the complication.

Use of a Trephine and Osteotome Approach, with Simultaneous Implant Placement

Diagnostic complication
Care must be taken to accurately assess whether or not the implant of the appropriate length can be placed, and the ability to accomplish the desired augmentation through an osteotome and trephine approach. An implant should be placed only at the time a trephine and osteotome sinus augmentation procedure is performed if $2x−2$ is an adequate length for the implant, with $x$ being the preoperative height of the bone crestal to the floor of the sinus (Figs. 6 and 7).56

Technical complications
Three potential technical complications are encountered.

a. The first is evidence of the bony core within the trephine on trephine removal from the mouth. In such a situation, the core is replaced in the osteotomy, and the implant is then inserted as originally planned (Fig. 8).

b. The second complication is evidence of both the bony core and the corresponding sinus membrane within the trephine on trephine removal. In such a situation, the implant is not inserted as originally planned. Rather, the core is replaced in the osteotomy to the desired level, the area is allowed to heal, and the implant is inserted in the second procedure.
Neither of these complications significantly affects the regenerative outcome, assuming care is taken when managing the complication.

c. Overinstrumentation of the osteotomy site before implant placement is a common occurrence, because the bone in the area is both delicate and less than abundant. This complication is managed through a modified technique. A trephine is used with a 2 mm internal diameter and a 2.8 mm external diameter to prepare an osteotomy within 1 mm of the floor of the sinus, at a maximum of 500 RPM. The prepared core of bone is imploded to a depth of 1 mm less than that of the initial trephine osteotomy. Flat-ended osteotomes are used to widen the osteotomy site to 1 bur size less than conventional preparation. For example, if a 4.8-mm-wide body Straumann implant is to be placed, osteotome widening of the site occurs to 3.5 mm. A 4.2-mm-wide bone tap is then used to a depth of 2 threads. A 4.8-mm-wide body Straumann implant is now placed at 30 RPM. The conventional diameter osteotomy attained to the depth of 2 threads of the bone tap allows placement of the implant without any wiggling and undesirable overenlarging of the entry to the osteotomy.

**Trephine and Osteotome Use, Followed by a Second Trephine and Osteotome Procedure, with Simultaneous Implant Placement**

**Diagnostic complications**
Inadequate diagnosis and treatment planning are the most prevalent concern with this double osteotome and trephined approach. Care must be taken to ensure that

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**Fig. 6.** (A) An implant is placed after an osteotome and trephine approach. (B) An 8-year postrestoration radiograph shows stability of both the crestal peri-implant bone and the bone around the implant apex.

**Fig. 7.** (A) The second molar is missing and the first molar presents with an intrafurcal fracture. The tooth is extracted and implants are placed using an osteotome and trephine approach. (B) A radiograph taken 7 years after implant restoration shows stable peri-implant crestal bone.
this is indeed the appropriate treatment modality for the given situation. If $4x-6$ yields an implant of adequate length for the situation in question, with $x$ being the preoperative bone crestal to the floor of the sinus, then the double osteotome and trephine technique is used. A core of bone is imploded to a depth of 1 mm less than the extent of alveolar bone coronal to the sinus floor. Graft material is placed in the osteotomy, and the site is allowed to heal. The area is re-entered approximately 10 weeks postoperatively. At that time, an osteotome and trephine approach is again used, with simultaneous implant placement. The length of the implant does not exceed $2x-2$, where $x$ is the residual alveolar bone crestal to the floor of the sinus, after the healing that has occurred after previous augmentation therapy.

The use of the proposed treatment algorithms for implant placement after, or in conjunction with, trephine and osteotome use, results in placement of shorter implants than is generally suggested. For example, if 5 mm of bone is present crestal to the floor of the sinus, use of the formula $2x-2$ results in placement of an 8-mm-long implant. Is such an implant sufficient to withstand functional forces over time in the maxillary posterior region?

When osseointegrating implants were introduced to the dental community, an assumption was made that longer implants (ie, implants with a greater surface area for potential osseointegration) would prove more advantageous, and present with a superior long-term prognosis when compared with shorter implants, in most if not all clinical situations. Early publications documenting the extensive use of machined screw Branemark implants seemed to bear out this belief. Osseointegrating implants documented in these studies were machined screw, hex headed implants placed in a countersunk manner.

Nevertheless, if success rates are attainable that are comparable with those of their longer counterparts, shorter implant use helps the clinician avoid vital structures, such as the sinus floor and the inferior alveolar canal. The use of shorter implants may also eliminate the need to perform augmentation therapy or simplify augmentation therapy when it is required.

A review of both finite element analysis (FEA) and the clinical literature supported the use of shorter implants in such situations. A total of 315 standard neck Straumann implants were placed in atrophic posterior mandibular areas and followed for up to 84 months in function, with a mean time in function of 36.2 months. Four implants were mobile at uncovery, and 1 implant was lost during the first 12 months of function, yielding a cumulative success rate of 98.4%. The cumulative success rate of the shorter implants in function over the mean time of 36.2 months was 99.7% when the 4
implants mobile at uncovering are excluded, because implants mobile at uncovering cast no reflection up on the ability or inability of shorter implants to withstand functional forces over time. Shorter implants can be routinely used to replace missing maxillary posterior teeth with abutments and single crowns.

A total of 987 implants replaced missing maxillary molars and were restored with solid abutments and unsplinted single crowns. The implants were followed for up to 84 months in function with a mean time in function of 29.3 months, yielding a cumulative success rate in function of 95.1%. Followed to the present day, and including implants placed since publication, a total of 2746 implants have been placed and restored with solid abutments and single crowns in intact arches, in maxillary molar positions, of lengths between 6 and 12 mm. The cumulative success rate of the implants in function is 96.2%.

As discussed earlier, implants of various lengths are often placed in conjunction with trephine and osteotome use to implode a core of the residual bone crestal to the floor of the sinus. Data that examine implants placed in such situations so far show that 306 implants 6, 7, or 8 mm long, placed at the time of trephine and osteotome use and restored with single crowns, were in function for up to 8 years with a mean time in function of 30.9 months and a cumulative success rate of 99.0%. During the same time frame, the cumulative success rates of 10-mm-long and 11-mm-long implants placed at the time of trephine and osteotome use and restored with single crowns was 98.9%. The difference was not statistically significant. Followed to the present day, and including implants placed since publication, a total of 1119 implants have been placed and restored with single crowns, in maxillary molar positions, of lengths between 6 and 8 mm. The cumulative success rate in function is 99.4%.

Technical complications
The technical complications are the same as stated earlier.

a. The first is evidence of the bony core within the trephine on trephine removal from the mouth. In such a situation, the core is replaced in the osteotomy, and the implant is then inserted as originally planned.

b. The second complication is evidence of both the bony core and the corresponding sinus membrane within the trephine on trephine removal. In such a situation, the implant is not inserted as originally planned. Rather, the core is replaced in the osteotomy to the desired level, the area is allowed to heal, and the implant is inserted in the second procedure.

Neither of these complications significantly affects the regenerative outcome, assuming care is taken when managing the complication.

COMPLICATIONS FROM SEPTA
The most effective means by which to manage a septal complication is to avoid it. Certain steps must be taken in the presence of a septa.

Identify the Septum
Appropriate imaging for such septal identification must involve a formatted CT scan, thus allowing appropriate and complete visualization of the septal morphology and position.

Classify the Septum
There is no universally accepted septum classification system. Any such classification system must have direct clinical applications to be of use to the clinician. Such
clinical application must include all innovative techniques for minimizing the impact of the septum on the course of therapy.  

**Class I**  
Class I septa have no impact on the course of treatment because of its position with relation to the planned reconstructive therapy. Augmentation, with or without simultaneous implant placement, is carried out as initially planned.

**Class II**  
Class II septa have minimal impact on the planned course of therapy and do not influence the timing of implant placement. Such septa fall into 1 of 3 categories:

- **Class IIA**: a septum is present in the area of planned reconstructive therapy. However, adequate buccopalatal dimension of the ridge, and adequate bone crestal to the floor of the sinus, are noted both mesial and distal to the septum, in planned positions of implant placements. In such a situation, trephines and osteotomes are used to prepare osteotomies mesial and distal to the septum, as described earlier. If immediate implant placement is planned, it is carried out at this time.

- **Class IIB**: adequate buccopalatal dimension of the alveolar bone is noted, and adequate bone is present crestal to the floor of the sinus mesial or distal of the septum for implant placement, and inadequate bone is present for planned implant placement on the other aspect of the septum (mesial or distal). An osteotome and trephine approach is used, with immediate implant placement as described earlier, in the area of adequate bone crestal to the floor of the sinus for ideal implant positioning. Sinus augmentation therapy is carried out where inadequate bone is present for use of an osteotome and trephine approach. Simultaneous implant placement may occur, depending on the amount of available bone crestal to the floor of the sinus. When performing a lateral wall sinus augmentation approach in the presence of a bony septum, membrane reflection need not extend wholly around the septum in a medial direction. Medial extension of membrane reflection should occur only to the extent needed to affect the desired augmentation therapy. Such an understanding significantly lessens the incidence of membrane perforation during reflection in the presence of a bony septum.

- **Class IIC**: adequate buccopalatal dimension of the alveolar ridge is noted. Inadequate bone is present mesial and distal to the bony septum for the use of an osteotome and trephine approach, with or without simultaneous implant placement. In such a situation, a lateral window ostetotomy is carried out. This ostetotomy often results in 2 distinct windows, on the mesial and distal aspects of the septum, respectively. Sinus membrane reflection is effected to the extent necessary for the desired augmentation therapy. If no membrane, or a class I or class IIA perforation is noted, the perforation is managed as described earlier, and simultaneous implant placement is carried out if indicated. However, should a class IIB or class III perforation be encountered, the course of therapy must be altered. The membrane is reflected as best as possible, and the septum is removed using a piezo surgical approach. The membrane is repaired as described earlier, the septum is lacerated and mixed with the augmentation material, and augmentation is carried out. No immediate implant placement occurs in such a scenario.

The presence of a bony septum is not a contraindication to reconstruction of the posterior maxilla. Such a septum should be viewed as a further challenge, which must be assessed, classified, and managed in a logical manner.
POSTOPERATIVE INFECTION

The most common postoperative complication after sinus lift procedure is postoperative sinusitis.16,59,60 Because maxillary sinus neighbors several vital structures, such a complication may lead to more serious complications, such as cavernous sinus thrombosis. It seems that patients with a history of sinusitis are more prone to postoperative infection of the sinus. Testori and colleagues61 reported that failure in the diagnosis of established chronic sinusitis before the sinus augmentation surgery may lead to acute graft material infection. Emphasis should be made on accurate preoperative diagnosis to rule out any apical pathology of teeth and preexisting sinusitis. Extraction of hopeless teeth and establishment of periodontal health are required before the execution of lateral window procedure. Measures to reduce the incidence of sinus infection should be strictly followed. Poor aseptic technique is the major cause for acute sinusitis after sinus augmentation procedure. Caution during sinus membrane elevation to minimize the chance of perforation, avoidance of the placement of implant into sinus, and aseptic surgical field should be strictly followed. Preformation of the Schneiderian membrane and contamination with saliva creates an ideal atmosphere for bacterial and sinus infection. If postoperative infection of the sinus is noticed, it should be aggressively treated. In case of localized swelling, an incision and drainage should be performed and wide-spectrum antibiotic should be used.

Failure to achieve primary closure after lateral window procedure facilitates the entrance of oral and environmental bacteria to the newly elevated sinus, especially when teeth that communicate with the sinus are extracted at the time of sinus lift.61 Barone and colleagues40,62 reported that the lateral ridge augmentation at the time of lateral window could increase infection incidence significantly compared with lateral window with no lateral augmentation. These investigators also attributed the infection to the absence of primary closure and subsequent graft and sinus infection.

Ostium blockage may occur after the migration of the graft particulates into the maxillary sinus through a Schneiderian perforation, overfilling the maxillary sinus in the apical direction, or postoperative infection or inflammation. Ostium blockage has a negative impact on the healing process, allowing more pathogenic bacteria to grow within the grafted sinus.61 The development of a postoperative sinusitis can be a significant concern. Steps must be taken to assess the extent of the sinusitis, prescribe stronger antibiotics if necessary, and seek a consultation with an ear, nose, and throat (ENT) specialist if the antibiotics are not effective.

Bleeding

Excessive intraoperative bleeding is occasionally encountered during the lateral window procedure.21,50 The main source of bleeding during the osseous lateral window preparation is the trauma to small blood vessels of intraosseous branches of the posterior superior alveolar artery (PSAA), which run in the lateral aspect of the maxilla. Severing the extraosseous branches of the PSAA and branches of the intraorbital artery may cause excessive bleeding during the flap elevation or releasing incisions. The incidence of excessive intraoperative bleeding is low and is reported to be 2%.51 Application of pressure, use of bone wax, or cauterization of the vessels is the first choice of the management of excessive bleeding from these vessels. Crushing of vessels should be the last choice, because it may further fracture the thin wall of the lateral maxilla.
**Implant Exposure to the Maxillary Sinus Cavity**

Implant exposure or displacement into the maxillary sinus can cause sinus mucus thickening around the implant and can give rise to rhinosinusitis. Untreated sinus infection could lead to chronic sinusitis, which might be resistant to antibiotic therapy. The chronic sinusitis could get worse if the implant was improperly pushed into the sinus cavity.

**Loss of Graft Containment into the Sinus**

It is possible for the bone graft particulates to be forced into the sinus cavity. The graft material should be filled and packed sequentially against the anterior wall, the posterior wall, and medial wall of the lateral window, without forcing the graft material into the sinus. In case of small Schneiderian membrane perforation, a collagen membrane can be laid on the perforation to ensure containment of the graft particulates. It is also recommended, in case of membrane perforation, mixing the graft particulates with calcium sulfate, which acts as a particle holder when it sets, and therefore, it prevents the graft material from displacement into the sinus.

**Overfill**

Overfill of the elevated sinus with graft material could cause the perforation of the Schneiderian membrane and loss of the graft material into the sinus cavity and could cause sinus infection. In such a case, the patient usually reports feeling particles in the throat for a few days. Overfilling the sinus with bone graft apically may cause the physical obstruction of the ostium and subsequent sinus infection, congestion, or increase in the pressure within the sinus. An uncommon indication of sinus infection or

![Fig. 9. Inadequate sinus elevation (arrow) caused by incorrect filling and packing of the bone grafting material into the medial and alveolar walls.](image)
congestion is the leak of the graft material through the window, which is caused by increased pressure within the sinus cavity. Postoperative bleeding may also cause increase pressure in the sinus, pushing the graft material out of the lateral window. Blowing the nose and sneezing have a similar effect on the stability of graft material.61

**Hematoma**

Some uncontrolled intraoperative or postoperative bleeding may cause vestibular and facial hematoma and loss of the graft materials. PSAA and its anastomosis injury is usually the main reason for bleeding.50 Amoxicillin (750 mg) with clavulanic acid (125 mg) for 10 days can be administered to the patient to prevent infection of the hematoma site.

**Wound Dehiscence**

Poor flap design and suturing technique and flap closure with no releasing incision may lead to wound dehiscence and subsequent infection. If this infection spreads out, a fistula development and oroantral communication occur. In this case, the graft material should be partially or completely removed, and a pedicle or gingival graft can be used to achieve primary closure.37,52

**Oroantral Communication**

If sinus infection is developed after the lateral window procedure and the ostium is blocked, an oroantral communication may occur. The patient usually complains of water coming through the nose while drinking. Referral to an ENT physician is warranted if infection is not controlled and oroantral communication is not closed (Fig. 10).

**Pain**

Tenderness in the sinus region and tenderness in the infraorbital region are common after the lateral window procedure and may last for 2 to 3 weeks. Adequate narcotic in combination with nonnarcotic analgesic can be administered.

**Vertigo**

Postoperative headache, dizziness, nausea, or benign paroxysmal positional vertigo has been reported in rare cases after the use of extensive malleting during the vertical approach of sinus augmentation. It is recommended to perform such procedures under conscious sedation and to use a gentle intermittent malleting technique.32

![Fig. 10. An oroantral communication (arrow) that occurred soon after a sinus augmentation procedure. The patient had sinus infection with complete obstruction of the ostium.](image-url)
SUMMARY

Sinus augmentation with or without simultaneous ridge augmentation therapy is a highly predictable treatment modality. However, its success depends on exquisite diagnosis, appropriate treatment planning, and impeccable technical execution.

REFERENCES


