Chapter 20
Complications with transcrestal sinus floor elevation: etiology, prevention, and treatment

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Incidence

The combination of postextraction ridge resorption [1] and pneumatization of the maxillary sinus [2, 3] often limits the bone available for implant placement in the posterior maxilla. Fortunately, the lateral and transcrestal approaches to sinus floor elevation (SFE) and augmentation can reproduce adequate subantral bone volumes for implant-supported rehabilitation in this region. The lateral window osteotomy (LWO) is the most frequently invoked method, providing ready access to the sinus, significant elevation of the floor, and creation of sufficient bone volume to provide long-term support for implants in the posterior maxilla [4–11]. However, this technique can be quite aggressive and often patients would prefer an option that stresses a less invasive (LI) approach.

The LI transcrestal approach for SFE was first suggested by Tatum [12] and later developed as an osteotome technique by Summers [13, 14]. Summers’ bone-added osteotome sinus floor elevation (BAOSFE) procedure uses tapered concave-tipped osteotomes to reposi-tion existing crestal bone under the sinus along with graft materials, elevating the sinus floor and increasing osseous support for the simultaneously placed implant [14] (Figs. 20.1 and 20.2). BAOSFE was recommended for patients with at least 5.0–6.0 mm of residual subantral bone height (RSBH). A number of case series reports [15–21] attest to the success of this procedure, furthering its popularity amongst clinicians.

It was originally suggested that grafting material be used in combination with osteotome-mediated sinus floor elevation (OMSFE) to facilitate the postulated

Fig. 20.1 Implant placement site no. 3 using bone-added osteotome sinus floor elevation (BAOSFE) procedure to elevate sinus membrane 3–6 mm.

Fig. 20.2 Four months later, at stage 2 surgery, apical sinus bone gain beyond the implant apex has been achieved.
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He et al. [29] demonstrated that the subantral space created by elevation of the Schneiderian membrane alone and supported by the implant fills with a stable clot that will mature to form new bone. In fact, studies comparing transcrestal osteotome-mediated sinus lift surgery with or without the use of particulate bone grafting materials [31–34], as well as systematic reviews [35, 36], have reported no significant differences in terms of implant survival and success rates. Also, OMSFE using autologous platelet concentrates without any bone substitutes has been described in literature [37–41]. Platelet derivatives such as platelet-rich fibrin (PRF) [37, 38], plasma-rich growth factors (PRGF) [39, 40], and concentrated growth factors (CGF) [41] have been purported to allow a better control of forces during SFE, protecting the membrane, reducing the incidence of complications, and accelerating healing (Figs. 20.5–20.9).

Like any other procedure, BAOSFE has undergone some evolution with innovative modifications in an effort to achieve greater simplicity and higher success rates with reduced complications. The earliest modifications were designed to expedite the procedure, minimize percussive or malleting force, and simplify sinus floor infracture [19, 20, 42]. These updated versions differ from Summers’ classic procedure with respect to osteotomy hydraulic elevation of the membrane and create more bone volume to aid in supporting the implant. However, there is no conclusive data in the literature reporting on the possible advantage and maturation of a bone graft at the apical portion of the implant [22, 23]. In 2006, Nedir et al. [24] initiated a pilot study that demonstrated a success rate of better than 90% achieved with OMSFE using no graft material at sites where the preoperative bone height averaged approximately 5.5 mm (range 6–9 mm). This study has since been updated [25] and confirmed by others who have modified the internal sinus lift technique, performing the elevation without concurrent use of a bone replacement graft [26–29]. Watzek and Haas [30] proposed that even without the addition of the graft material, some de novo bone formation could still occur at the implant apices, likely arising simply from the perturbation of the periosteal layer of the Schneiderian membrane (Figs. 20.3 and 20.4).

Fig. 20.3 Osteotome-mediated sinus floor elevation (OMSFE) using no particulate graft material at site no. 14.

Fig. 20.4 Four months later the sinus floor has been apically displaced to the implant apex.

Fig. 20.5 Panoramic view of site no. 14 where 4–6 mm of subantral bone is present.
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The difficulty in ascertaining the incidence of complications associated with any procedure or technique from controlled clinical trials or even case reports is inherent publishing bias (positive results are published more frequently than negative results). Determining the incidence of complications, one must first look at implant failures with OMSFE. Table 20.1 summarizes the various systematic reviews performed with OMSFE. What becomes quite apparent is the heterogeneity of the inclusion criteria of the reviews regarding evaluation period, complications reported (i.e., perforation, benign paroxysmal positional vertigo, nasal bleeding), and time frame. Thus, it is difficult to summarize the overall conclusions when comparing the systematic reviews, which suggests that one really needs to more closely evaluate

preparation and membrane access [43–48], how the sinus membrane is lifted [49–56], and on the type of graft used; the current tendency being not to use a graft or solely a biologic [25, 38, 57, 58]. These techniques have all demonstrated high rates of success, but they are still subject to complications similar to those reported with original BAOSFE procedure [14].

Fig. 20.6 After direct infracture of the sinus floor, platelet-rich fibrin (PRF) is placed into the osteotomy.

Fig. 20.7 PRF has been apically displaced to the working depth (5–6 mm).

Fig. 20.8 Immediate postoperative radiograph with 10-mm-long implant at site no. 14.

Fig. 20.9 Periapical radiograph 3 years after loading clearly demonstrates relocation of the sinus floor to implant apex.

The difficulty in ascertaining the incidence of complications associated with any procedure or technique
Table 20.1 Systematic reviews on transcrestal sinus floor elevation: implant survival and complications

<table>
<thead>
<tr>
<th>Systematic review</th>
<th>No. studies, timeline</th>
<th>No. implants</th>
<th>Graft material</th>
<th>Time</th>
<th>BPPV</th>
<th>Survival</th>
<th>Perforation</th>
<th>Infection</th>
<th>Nasal bleeding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Călin et al., 2014 [36]</td>
<td>25</td>
<td>1985–2011</td>
<td>3092 W (AB, DBBM, TCP, BG &amp; Col) or w/o</td>
<td>≥1 year</td>
<td>2.17% (but report states 9/749 patients, which is 1.2%)</td>
<td>96.15%</td>
<td>6.28%</td>
<td>1.5%</td>
<td>2.97%</td>
</tr>
<tr>
<td>Tan et al., 2008 [59]</td>
<td>19</td>
<td>1965–2007</td>
<td>4388 W (Col, DBBM, AB, BG, FDBA, TCP) or w/o</td>
<td>3.1 years</td>
<td>92.8%</td>
<td>3.8%</td>
<td>0.8%</td>
<td>1.5%</td>
<td>2.8%</td>
</tr>
<tr>
<td>Emmerich et al., 2005 [60]</td>
<td>8</td>
<td>1999–2010</td>
<td>1139 W (Col, AB, FDBA, DBBM) and w/o</td>
<td>≥6 months</td>
<td>96%</td>
<td>2.2%</td>
<td>0.6%</td>
<td>1.5%</td>
<td>3.1%</td>
</tr>
<tr>
<td>Romero-Millán et al., 2012 [61]</td>
<td>14</td>
<td>1999–2010</td>
<td>1870 W (DBBM, AB, FDBA, PRP) and w/o</td>
<td>≥1 year</td>
<td>93.5–100%</td>
<td>2.2–21.4%</td>
<td></td>
<td></td>
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<tr>
<td>Viña-Alumnia et al., 2012 [62]</td>
<td>20</td>
<td>1998–2008</td>
<td>2006 W (AB, DBBM, PRF, Col/PB) or w/o</td>
<td>6–144 months</td>
<td>90.5–100%</td>
<td>66/2006</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Del Fabbro et al., 2012 [35]</td>
<td>19</td>
<td>2003–2008</td>
<td>3131 W (DBBM, AB, FDBA, MgHA, PB, PRF or w/o</td>
<td>≥6 months</td>
<td>95.81%</td>
<td>4.2%</td>
<td>1.9%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Antonaya-Mira et al., 2012</td>
<td>11</td>
<td>2003–2008</td>
<td>2063 W (DBBM, AB, TCP, FDBA, Col) and w/o</td>
<td>1.25%</td>
<td>95.5%</td>
<td>6.5%</td>
<td></td>
<td></td>
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</table>

W, With; w/o, without; AB, autogenous bone; DBBM, deproteinized bovine bone mineral; TCP, tri-calcium phosphate; BG, bioactive glass; Col, collagen; FDBA, freeze-dried bone allograft; PRF, platelet-rich plasma; PRF, platelet-rich fibrin; Col/PB, collagen gel with porcine bone; MgHA, magnesium-enriched hydroxyapatite.

In the individual studies themselves. In 2008, Tan et al. [59] published a systematic review based on 19 included studies reporting on 4388 implants after a mean follow-up time of 3.1 years. The annual failure rate was 2.48%, translating into a 3-year implant survival of 92.8%. This was much more extensive than the analysis published in 2005 by Emmerich et al. [60] which included eight articles reporting on 1139 implants with a minimum of six months of loading. The percentage of implants lost were 1.8%, 2.5%, 4.3%, and 9.1% after 6, 12, 24, and 36 months, respectively.

Most recent reviews evaluate implant survival in studies using OMSFE with or without grafting. Romero-Millán et al. [61] found survival rates of 93.5–100% in 14 studies from 1999 to 2010 with a minimum of 1-year follow-up. A survival rate of 90.5–100% for 2006 implants with 6–144 months of loading was reported by Viña-Almunia et al. in 2012 [62]. Del Fabbro et al. [35] looked at 19 studies, 1822 patients and 3131 implants, finding a mean weighted cumulative implant survival at 1, 2, 3, and 5 years of 98.12%, 97.40%, 96.75%, and 95.81%, respectively.

Most recently, Călin et al. [36] systematically reviewed 25 studies comprising 3092 implants with an overall survival rate of 96.15%. In their review, the clear majority of the reported failures (~64.5%) occurred prior to loading, which is certainly consistent with previous reports.

Early implant failure is most likely attributed to poor bone quality, impaired healing, or lack of primary stability [63]. Călin et al. [36] also selected eight studies for meta-analysis, demonstrating a significant difference in the success/failure rates of implants placed with OMSFE when the RSBH is <4 mm. The most frequently reported intraoperative complication was perforation of the sinus membrane, which was reported in 15 of the studies reviewed. The detected perforation rate (DPR) varied between 0% and 26%, with a mean of 6.28% (n = 124) related to 747 sites. Nosebleed was the most common postoperative complication; 15 articles reported on nasal bleeding in 30 of 976 patients (2.97%). The incidence of postoperative paroxysmal vertigo extracted from six of the studies in 748 patients was 2.17% (n = 9). Postoperative infection was the least frequent complication, occurring in 9 of 1150 patients (1.50%) [36].

Etiology

Infection

First on the list of etiologies for possible complications is infection. Factors related to site infection include, but may not be limited to, poor oral hygiene, contamination of the implant surface at the time of placement, graft...
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Contamination, underlying sinus disease, or a membrane perforation. Preoperative sinus disease has been positively correlated with the development of acute postoperative sinusitis after maxillary sinus grafting [64–66]. If it is not possible to eradicate the sinus disease prior to proceeding, the procedure must be modified to reduce the risk of infection (Figs. 20.10–20.12). In addition to altered anatomy (Fig. 20.13), postoperative swelling [67], formation of a hematoma, or seroma can fill up the maxillary sinus, leading to reduction of the ostiomeatal unit’s patency. This can play a critical role in the development of sinusitis [65, 67, 68]. An acute postoperative maxillary sinusitis may jeopardize the survival of the implant(s) and graft [68] (Fig. 20.14).

**Fig. 20.10** Patient’s right sinus is completely occluded and the patient’s ENT physician has advised that no implant should enter the sinus. Simulated placement of 8-mm-long implant at no. 3 and 11-mm-long implant at no. 4 just shy of the sinus floor.

**Fig. 20.11** Cross-section site no. 3 shows opacified sinus and planned placement of a 6 x 8 mm implant with no sinus intrusion.

**Fig. 20.12** Immediate postoperative radiograph confirms ideal preplanned placement avoiding sinus elevation.

**Fig. 20.13** Coronal view shows healthy lifted left sinus. Right sinus with elevated fluid level or membrane thickening that could possibly contribute to postoperative complications as well as blockage of the ostium.

**Fig. 20.14** Acute postoperative maxillary sinusitis at a BAOSFE site where the membrane was perforated 10 days earlier. Implant was removed one week later.
Inadequate primary stability related to pretreatment subantral bone height

Primary implant stability is critical for successful osseointegration and this can be related to the implant’s surface geometry, the surgical technique employed, and local bone quantity and quality [69–71]. A low initial stability decreases the implant’s resistance to micromotion during healing and thus carries an increased risk of osseointegration failure [72]. The subantral bone height prior to placement with OMSFE appears to impact stability and implant success [17, 19, 20, 26, 73, 74]. Rosen et al. [17] and Toffler [20] provided case series data that demonstrated an almost 10–20% increase in failures when subantral bone measurement was 4 mm or less at the time of implant placement (Figs. 20.15–20.17).

Inadequate primary stability related to bone quality

In the atrophic posterior maxilla, primary stability is more difficult to achieve because of the limited cortical bone, and in most instances bone is more highly medullated (i.e., type IV quality) [75]. As initial mechanical retention of the implant or primary stability is more difficult to achieve in low-quality bone [76], modifications to the conventional regular surgical protocol for implant placement, such as undersized drilling [77, 78], the use of tapered implants [79], and bone condensation with osteotomes [13, 80, 81], have been advocated. There is a belief that nonablative implant bed preparation by means of osteotomes condenses bone, relocating it both laterally and apically, thereby enhancing local bone density, bone–implant contact (BIC), and consequently primary implant stability [71, 82–84]. Several studies using radiographic densitometry have found significant increases in trabecular thickness, reduction of its separation, as well as histomorphometric increases in BIC following bone condensation [85, 86].

Inadequate primary stability related to site preparation

In areas of minimal RSBH any inadvertent surgical trauma or widening of the osteotomy will have a much greater effect than when the implants are placed in a greater volume of bone [87]. Overpreparation is a concern using a BAOFE technique, as grafting material is repetitively introduced into the sinus cavity by osteotomes, possibly increasing the diameter of the osteotomy and thereby reducing primary stability [31]. Osteotomes with a 30-degree offset should be considered for preparing...
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first and second molar sites to maintain ideal axial inclination while avoiding overexpansion of the osteotomy (Fig. 20.18).

Underpreparation can also be of concern. If the site were to be underprepared, particularly in those cases where there might be denser bone, irreversible damage might occur from excess compressive force, leading to necrosis or bone fracture rather than the establishment of vital bone. The question of how much compression and underpreparation is advantageous and are there any biological limits to which trabecular bone can be compressed has yet to be clearly defined. Tabassum et al. suggested in their animal study that underpreparing the final diameter of the osteotomy to greater than 15% of the implant’s diameter demonstrated no improvement upon percentage of BIC in early healing [88].

Inadequate primary stability related to premature loading of the implant

Several studies have postulated that the wearing of a removable partial denture may have caused premature loading of implants placed via OMSFE, leading to their failure to integrate [19, 89]. The option of avoiding the use of a removable partial denture, if practical, would be ideal; however this is not always possible. Thus, the clinician has to make sure that when a patient is wearing a removable prosthesis, there will be no transmucosal forces placed on the implant(s), especially when the prosthesis is in use.

Implant displacement

The timing of this occurrence may vary from an intraoperative event [90, 91] (Figs. 20.19 and 20.20), to several days after implant placement [92], to abutment connection surgery [93], or even as late as several years after function [94] (Fig. 20.21). Inadequate primary stability is often the cause of early migration [91, 95]. Delayed migration of an implant into the sinus is less well understood. Some of the mechanisms proposed for this include changes in sinus and nasal pressure, incorrect distribution of occlusal forces, or peri-implantitis [96, 97]. The exact cause is not always clear; however, three essential conditions must be present for this complication to occur: a lack of osseointegration, membrane perforation, and intrusive forces on the implant toward sinus [98].
Sinus membrane perforations related to overzealous tapping, anatomy, or overzealous elevation

Membrane perforation has indeed been identified as the most frequent complication encountered with OMSFE (Fig. 20.22). Systematic reviews by Tan et al. [59], Del Fabbro et al. [35], and Călin et al. [36] have reported mean DPRs of 3.8–6.28%. The problem with all internal sinus lift elevation methods is the difficulty of controlling the lifted volume and reliably confirming membrane integrity throughout the elevation process. Perforation may occur at all phases of the procedure, including osteotomy preparation, sinus floor infracture, apical advancement of the graft, and implant placement. Tears may be detected via direct visualization, blunt probing, or by using a Valsalva maneuver or nose-blow test. In reality, it is not possible to accurately diagnose microscopic tears due to limited visualization [99]. Also, the reliability of the Valsalva maneuver in detecting a perforation has been seriously questioned [21, 73]. This certainly suggests that the incidence of transcrestal perforations has been historically underestimated.

Perforation can only be accurately assessed during all phases of the procedure through intraoperative endoscopy [73, 100] and the data on endoscopic procedures demonstrates perforation rates of no less than 13% [73, 101–103], suggesting that the majority of transcrestal perforations go undetected. Moreover, the majority of perforations may actually occur at the time of implant placement, where detection is impossible without an endoscope [103] (Fig. 20.23). Early postoperative indications of a tear can include epistaxis, exfoliation of graft particles out of the nose, and the development of sinusitis. Another method of detecting tears if a graft material is being used is to expose a periapical radiograph during the procedure after a small amount of bone has been placed and see if the bone is contained around the apex of the osteotomy. Membrane lacerations during OMSFE can be attributed to the presence of a thin sinus membrane, sinus septae, overly aggressive use of osteotomes, drills, or trephines (Fig. 20.24), or hastily adding large increments of graft materials with sharp edges and bone chips [21, 104]. The risk of perforation may also be increased (25–26.6%) if extraction is performed at the same time as OMSFE [105] or crestal core elevation (CCE) [81, 104, 106, 107].
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Reiser and his colleagues [22] identified sinus anatomy as a possible etiology to tears. These authors looked at the membrane response to BAOSFE in human cadavers. Of the 25 sites that were implanted, 6 demonstrated perforations, a rate of 24%. Of these 6, 4 of the perforations were associated with proximity of the osteotomy to antral septae (Fig. 20.25) or the collateral wall of the nose. This same principle applies to an elevated risk for transcrestal perforation at sites with an oblique sinus floor (Fig. 20.26). There may also be a significant correlation between membrane thickness and perforation rate. Wen et al. [108] reported that the perforation rate was higher when membrane thickness was ≥3.0 mm or ≤0.5 mm. The risk for perforation was lowest when the thickness was 1.5–2.0 mm. It has been reported that smaller lacerations (≤2 mm) during OMSFE (Fig. 20.27) are likely to be clinically inconsequential in the short- and long-term postoperative periods [73, 101, 102, 109]. The authors’ experience can confirm these reports, but only in patients with no preoperative sinus pathosis or history of sinus disease.

The clinician is constantly challenged in determining what is a reasonable elevation of the membrane since a wide variability has been reported. The maximum
Another concern with sinus membrane tear is the potential progression to an oral–antral communication (OAC) [113] (Fig. 20.30). This occurrence would be more likely should the patient have underlying sinus disease, which would diminish the possibility for membrane healing and closure of the overlying soft tissues [114].
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Osteotome malleting leading to benign paroxysmal positional vertigo or poor patient experience

Benign paroxysmal positional vertigo (BPPV) has been reported following the use of osteotomes for internal SFE [115–119] and for alveolar expansion [120–123]. Symptoms of BPPV include dizziness or vertigo, imbalance, lightheadedness, and nausea. These symptoms are initiated when carrying out certain lateralization and extension head movements toward the affected side [124, 125]. BPPV is not progressive, will occur suddenly and unpredictably, and can be temporarily incapacitating. Di Girolomo et al. [116] postulated that osteotomes and a surgical mallet generate percussive forces capable of detaching heavy inorganic particles (otoliths) from the otocochlear layer of the utricular macula. These calcium carbonate crystals, while floating in the inner ear fluid, could strike against sensitive nerve endings within the balance apparatus at the end of each semi-circular canal, creating position- or motion-induced vertigo. The patient’s head position, hyperextended and tilted opposite to the side from where the operator is working, favors the entry of these free-floating particles into the posterior semi-circular canal of the implanted side [118].

BPPV commonly resolves within a month without treatment [117] although as previously stated, the symptoms involved are very unpleasant. The incidence of iatrogenic BPPV following closed internal sinus elevation with osteotomes has been reported at anywhere between 1.25% and 3.06% [58, 116, 118, 123]. Poor patient experience related to the malleting involved with osteotomes is the most common single complaint following OMSFE. Diserens and colleagues [126] compared the responses of 35 patients who had undergone sinus elevation with the Summers’ BAOSFE technique [14] to those of a group of patients who received implants in the same location during the same period using standard implant placement. A visual analogue score was used to help gauge patient responses. The groups did not differ in their perception of pain; however, the osteotome group judged the procedure more negatively. The biggest concern centered around the tapping, during which some patients expressed that they had experienced strong sensations and discomfort. However, pain itself was not the primary complaint.

Prevention

The best way to manage complications is to avoid them rather than treat them. The cost in time, effort, and aggravation to fix the problem(s) that have occurred can be prohibitive. This section on prevention is divided along the topics of the etiology section: infection, primary stability, premature loading, overpreparation of the site, membrane tears, and BPPV/poor patient experience. Please bear in mind that it is impossible to solely provide an evidence-based approach to complication avoidance. The subjects of prevention and management of complications are very dynamic and will continue to evolve as more information comes to light. The information that follows is based upon the authors’ experience, a review of the literature, and conversations with other clinicians. Over time, the hints that have been offered may change as new information becomes available and as newer techniques are studied and adopted.

Infection

When performing OMSFE, strong consideration should be given to minimizing the bacterial burden at the time of the surgery. If there is any active endodontic infection, periodontal or sinus disease, particularly in the area of the procedure, these should be addressed prior to proceeding. Sinus health must be established in the patient with a history of chronic sinus disease or relevant symptoms prior to performing a transcrestal SFE or LWO (Figs. 20.31 and 20.32) because postsurgical complications or compromised results tend to be associated with pre-existing sinus disease or a documented susceptibility to sinus disease [65, 66]. Cone beam computed tomography (CBCT) evaluation prior to sinus augmentation could be utilized to determine the status of the Schneiderian membrane (thickness, morphology). Shanbhag et al. [127] found that membrane thickening >5.0 mm, especially of a polypoid type, is associated with an increased risk for ostium obstruction. Carmeli and colleagues [128] reported that the risk for sinus
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Primary stability

Good primary stability for the implant is essential to success when elevating the sinus floor with osteotomes. An undersized drilling technique should be considered to enhance BIC in this primarily trabecular bone [76–78, 129, 130]. The authors have traditionally under-prepared the diameter of the osteotomy by 0.5–1.0 mm (~15%) based on the thickness of the remaining cortical bone, localized bone density as well as the RSBH as determined intraoperatively or with preoperative CBCT analysis. Consideration might also be given to selecting a tapered implant design versus one that is parallel in macro-geometry, since the taper of the implant will give some added stability from the wedging that occurs during implant placement [70, 131]. A rough-surfaced implant is imperative since it will aid in gaining more optimal primary stability as well [79].

Earlier studies on OMSFE have emphasized the need for measuring at least 5 mm of RSBH at the site prior to surgery, reporting a 5–20% reduction in the success rate when falling short of this requirement [14, 17, 19, 20]. It is also important to note that more recent studies on OMSFE [28, 32, 132, 133] and alternative transcrestal techniques [41, 49, 55, 134, 135] have demonstrated higher success rates at sites with an RSBH of <5 mm, quite possibly due to enhanced implant surfaces and design and innovations in site preparation and membrane elevation. However, a systematic review by Del Fabbro et al. in 2012 [35] suggested that transalveolar sinus augmentation with simultaneous implant placement could be a viable treatment option even in cases with minimal residual bone height, although the prognosis is still more favorable when the residual ridge is at least 5 mm high. If the RSBH is less than 5 mm, as an alternative, one can consider a staged transcrestal approach using a CCE procedure [81, 107, 136] or the modified trephine osteotome technique (MTOT) [137]. Simultaneous placement may also be possible accessing the sinus via an LWO. Soften bone quality also remains a concern in the resorbed posterior maxilla [72, 138]. In situations where softer bone quality is encountered, bone condensation with osteotomes might be considered versus drilling of the site with the hope that compression of the bed will lead to denser bone and greater primary implant stability [71, 84, 139]. An alternative to this might be to underprepare the site with the drill and use a substantially larger

Fig. 20.32 Six months after functional endoscopic sinus surgery (Erich Voigt MD, New York, NY) and removal of tooth no. 5, patient is now ready for sinus elevation.

Fig. 20.33 CBCT cross-section reveals >10 mm of membrane thickening significantly increasing risk of a blocked ostiomeatal complex.
diameter (≈15%) implant to facilitate better primary stability [77, 78, 130].

The malleting process may also diminish primary implant stability [140], particularly in denser bone [141]. Due to the imprecise nature/vibration that occurs with osteotome-mediated site preparation, it is more likely that overwidening of the osteotomy site may occur. Donati et al. [142] evaluated immediately loaded implants placed with the osteotome technique, conventional site preparation, and implants placed with a conventional site preparation and a submerged healing. They reported that immediately loaded implants placed with the osteotome technique had higher failure rates compared to those placed with a conventional drill preparation (5.5% versus 2%). Again, it might be better to underprepare the site by one osteotome size, complete the sinus grafting/elevation, then expand the coronal 2–4 mm of the osteotomy with a pilot drill so that the diameter of this part of the osteotomy is 0.3–0.5 mm less than the implant diameter. This will prevent wobble during placement which will compromise the implant’s primary stability. An alternative method to avoid overwidening of the site is to use the drill unit as much as possible as there is higher precision for site preparation with its use. Apical penetration while sequentially drilling is easily and safely controlled by using systems with precise fitting depth stops. Because most patients, especially the elderly, find repeated malleting disconcerting, the combination of drills in the expansion of the osteotomy and using an osteotome to directly infracture the thin remaining sinus floor has proven to be the most expeditious and “patient-friendly” approach to OMSFE and simultaneous implant placement [104].

Premature loading

If a patient will be wearing an interim removable appliance, it is imperative that no forces are transmitted to the healing implant. This can be avoided by either submerging the implant beneath the tissue as a two-staged procedure and/or by checking for any pressure transmitted to the site from the prosthesis and removing any contact that it may have with the implant. Rest seats can be placed into the adjacent teeth and occlusal stops could be included in the design of any transitional removable appliance that will be worn. If multiple implants are to be placed with OMSFE, then transitional implants could be considered to support a fixed interim prosthesis. One might also consider a submerged or protected healing protocol if the RSBH is 5 mm or less (Fig. 20.34) or the implant stability quotient (ISQ) is <65, to prevent any inadvertent premature loading on implants placed with lower primary stability, reducing the possibility for increased risk of failure [104].

Membrane tear/perforation

Membrane tear is best avoided by limiting drill and osteotome penetration to the sinus boundary; therefore, presurgical measurements of the RSBH, most accurately attained via CBCT, are essential to the success and safety of the technique. However, when using osteotomes to directly infracture the sinus floor with no interposed graft material, it is necessary for the osteotome to extend 1–2 mm beyond the sinus boundary to breach the sinus floor and initiate membrane elevation. This insertion depth is usually safe and does not exceed the elastic limits of the membrane, rarely resulting in a perforation. The use of adjustable stop devices will dictate the working length of an osteotome (Figs. 20.35 and 20.36), limiting apical penetration, thus minimizing the risk for membrane perforation. Novel atraumatic drills, reamers, and crestal bone planing burrs (Figs. 20.37 and 20.38) are now available that can safely rotate in close proximity to the sinus membrane, leaving a very thin floor which is easily infractured with an osteotome.

As an alternative to osteotome-mediated infracture, these “membrane-safe” drills may be inserted in 1 mm depth increments, performing a controlled erosion of the sinus floor, safely exposing the membrane (Fig. 20.39) [47, 134]. A bone plug can be created in advance of drill penetration, preventing direct contact with the membrane and further improving procedural safety (Fig. 20.40). This approach then limits osteotome usage to apical displacement of grafted materials to facilitate membrane elevation. Osteotomy techniques using a piezoelectric device have also been developed to avoid perforating the membrane with drills and to eliminate percussive forces [45, 143] (Figs. 20.41–20.47).
Fig. 20.35 Direct infracture of sinus floor with osteotome.

Fig. 20.36 Adjustable stop limits osteotome penetration to 1 mm beyond the sinus floor, eliminating risk of membrane perforation.

Fig. 20.37 Bone planning bur (dentium.com) with stop can be used to erode sinus floor and expose the sinus membrane.

Fig. 20.38 Crestal approach sinus (CAS) drill (hiossen.com) with stop safely deepens and widens osteotomy in close proximity to sinus.
Complications with transcrestal sinus floor elevation

The authors’ current technique for OMSFE uses a membrane-safe drill system with stops to prepare an osteotomy 1 mm shy of the sinus floor with an undersized diameter of ~15%. An osteotome slightly smaller in diameter with stop set at 1 mm more than the RSBH is utilized to directly infracture the sinus floor. Collagen or PRF is then added as the sole graft material or in advance of a particulate graft to perform the initial sinus elevation prior to insertion. This technique has effectively reduced the incidence of membrane perforation.

Transcrestal SFE using an osteotome-mediated or balloon-assisted approach may generate a tearing force...
Dental implant complications

Dental implant complications would be under an equal amount of the hydrostatic force, reducing the tension usually generated at the delicate margins where the membrane is still attached to the sinus floor. The Schneiderian membrane is not smoothly lifted if the injected fluids run off or out of the crestal osteotomy since enough pressure is not provided in the closed area to initiate membrane elevation. Unregulated water pressure applied into an osteotomy site by means of air/water exhaust spray from a high-speed dental handpiece [44] or an uncontrolled water jet from a plastic syringe does not permit equal distribution of hydraulic pressure as all the forces are directed against the apex of the “tented” membrane [53]. Manual and screw-retained hydrants have been developed which are inserted through the alveolar ridge to the maxillary sinus to seal the osteotomy and allow for concurrent fluid passage directly to the Schneiderian membrane (Figs. 20.48 and 20.49) [145]. In the authors’ experience these screw elevators or hydrants have not demonstrated a reduced membrane perforation rate nor have they greatly simplified transcrestal SFE when compared with an osteotome-mediated approach. It is also important to note that the initial hydrostatic pressure needed to detach the sinus membrane may vary due to its thickness, the anatomical configuration of the sinus cavity, or simply individual variability [53].

Fig. 20.45 The implant is placed into the osteotomy and allowed to heal transgingivally.

Fig. 20.47 Clinical view of the final cement-retained crown (prosthetics performed by Dawn Rickert DMD, New Hope, Pennsylvania).

Fig. 20.46 Radiograph 1-year post-loading. Apical graft appears well contained, suggesting intact membrane at placement.

Fig. 20.48 Hydraulic lifter (hiossen.com) must be manually retained with firm pressure in the prepared osteotomy then saline injected to elevate the sinus membrane with hydraulic pressure.

Fig. 20.49 Radiograph 3 weeks post-loading. Membrane attachment appears intact, indicating healed bone composition.
Complications with transcrestal sinus floor elevation

In an attempt to further improve membrane safety, ultrasonic piezoelectric vibration and hydraulic pressure have been combined to create a hydrodynamic sinus elevation [45, 46, 55, 146, 147] (Figs. 20.50 and 20.51). To reiterate, when balloon-assisted or osteotome-mediated elevation is used, the membrane undergoes tensile forces, whereas with a hydrodynamic elevation there is no traction as microcavitation gently detaches the membrane in all directions, not just at a single pressure point [46, 55].

Membrane tear may also occur if excessive force is applied when malleting to infracture the sinus floor or apically displace the grafted materials. Cavicchia et al. [19] advocated the placement of a collagen membrane into the osteotomy site to help cushion the graft being tapped into the space created beneath the sinus membrane. Autologous platelet concentrates may also be used for this same purpose, providing added healing benefits as well [37–39]. This approach would further obviate the concern of graft particle sharpness causing a membrane tear. In Summers’ original BAOSFE procedure [14], the osteotomy was partially filled with graft to provide additional cushioning during infracture and subsequent membrane elevation. The primary clinical concern with using a bone-cushioned sinus floor infracture is that when forcing these potentially sharp-edge graft materials or bone chips in an apical direction, a perforation may occur. If so, there is the serious clinical concern of graft displacement into the sinus cavity and the subsequent potential for adverse ramifications. In addition, a higher perforation rate has been reported when OMSFE is performed with a graft (7.87%) than without grafting (2.62%) [133].

Three-dimensional imaging might be utilized prior to the procedure to elucidate anatomical considerations that might increase tear likelihood using a transcrestal approach (i.e., septae or an oblique sinus floor). Measuring the sinus width at the proposed implant apex may also be of value [148] as the detachment force of the membrane is related to the circumference of the elevated area [110]. In cases of a wide internal sinus anatomy, a greater degree of force may be required to elevate the antral membrane, possibly increasing the risk of a perforation. Furthermore, the anatomy of the sinus floor may also play a role, as one whose floor anatomy is concave may react differently than one that is convex [149].
The use of an endoscopic approach to sinus elevation may be one additional method to avoid tearing of the sinus membrane or at least evaluate if this has occurred [73]. Direct intraoperative endoscopic visualization of sinus membrane integrity allows the clinician to adapt the progressive addition of the bone graft mass to the deformation capacity of the membrane, thus optimizing the increase in bone height and the length of implants to be used [101]. Endoscopic investigations have demonstrated the maximum elastic limit of the Schneiderian membrane to be 3–5 mm and to avoid perforations, it is suggested that this limit not be exceeded during internal SFE procedures [73, 102, 103].

Benign paroxysmal positional vertigo and headache

The sequelae of headache and BPPV with osteotome use can be quite debilitating, especially if they interfere with a patient’s lifestyle or work schedule. Invoking newer techniques incorporating atraumatic drills with stops and piezolectric devices can minimize or eliminate the percussive forces generated by osteotome malleting and will go a long way toward reducing the incidence of BPPV and improving the patient experience. When using OMSFE, a working depth 0.5–1 mm from the sinus floor should be confirmed radiographically (Fig. 20.52). Then the osteotomy can be widened using newer membrane-safe drills or traditional drills with stops. The final diameter of the osteotomy is 0.5–1.0 mm smaller than the implant diameter to maximize primary stability. When the implant osteotomy is prepared in such a manner, it should require minimal percussive force to advance the osteotome and atraumatically upfracture the thin remaining sinus floor. Although the osteotome technique for preparation of the osteotomy can yield higher primary or initial stability than conventional drilling, it has been demonstrated that it was not superior to the conventional drilling protocol after three months [139].

When malleting osteotomes to directly infracture the sinus floor or displace grafted materials, the patient’s head should be stabilized by placing firm pressure on the forehead. It is also recommended to avoid hyperextension of the neck when performing the procedure.

Poor patient experience

The greatest complaint expressed by patients who undergo osteotome SFE is related to the intraoperative malleting. Diserens and colleagues [126] interviewed patients about their experience and suggested that patients who are to undergo the osteotome procedure should be informed in detail about what might be encountered. It is always easier to manage patient expectation than surprises. As previously mentioned, techniques that obviate or minimize the use of the malleting may be tolerated better by patients.

The future

The internal sinus lift technique has evolved over time and will continue to do so. Clinicians need to evaluate what aspects of care should be retained and which modifications and/or new technologies should be embraced. New devices and the techniques associated with them have been introduced, all with the claim of reducing complications, improving on osteotomy site preparation, easing the infracture of the inferior sinus wall, safely increasing the degree of membrane elevation, and reducing postoperative morbidity. Clinicians should consider using innovative drill designs with modified cutting edges and adjustable stops as they will safely and atraumatically expedite osteotomy preparation in closer proximity to the sinus floor. Endoscopically controlled sinus lift [73] can provide direct intraoperative visualization of sinus membrane integrity. Unfortunately, the technical training and costs associated with such an approach may make it impractical for the vast majority of clinicians.

Alternative means of membrane elevation using hydraulic pressure [53, 54, 135], balloon-assisted [49, 150, 151], piezolectric/hydrodynamic [41, 55, 152] and gel pressure [56] have been reported. All these approaches show promise and are receiving increasing attention from more widespread use and publication. The authors’ clinical experiences with the above techniques to simplify membrane elevation have been primarily positive. However, the clinically proven osteotome-mediated approach

Fig. 20.52 Ideal working depth 0.5–1.0 mm from sinus floor confirmed prior to finalizing diameter of the osteotomy.
remains the primary means of transcrestal elevation. These alternate approaches may be considered for those sites with 3–4 mm RSBH where OMSFE has proven to be less predictable.

Management

The management of complications is best done by preventing them. Once complications have occurred it is not always easy to fix them. That being said, the following is a list of management tips.

When infection occurs at the site of an implant, the first line of treatment would be to place the patient on a bactericidal antibiotic such as amoxicillin/clavulanic acid 875 mg/125 mg oral twice daily for 7 days. If the patient fails to respond to antibiotic therapy it may be that the graft or sinus is infected. As graft removal is not possible without lateral access, implant removal may be necessary. Perforation, whether detected or not, may increase the risk for early sinus infection or implant failure [111, 153].

If rotational instability is present on placement one could consider submerging the implant and allowing additional healing time or removing the implant and replacing it with a slightly wider one. As a general rule, the authors opt for prolonged (4–5 months) submerged healing if the implant stability quotient (ISQ) is <65 or insertion torque is <25 N cm. If primary stability is not achieved, then one may consider trying to stabilize the implant with a bone replacement graft. A graft that is demineralized versus one that is mineralized may be the material of choice in this situation. The clinician would back-out the loose implant, place some demineralized allograft particles into the osteotomy and attempt to retread the implant into the site. A mineralized graft may interfere with smooth insertion of the implant, causing wobble and possible suboptimal implant placement. Again, a wider implant may be considered as long as the added site preparation leaves adequate buccal–palatal bone dimension (≥1.0 mm) to maintain crestal bone height and implant stability.

If none of these options have worked, the implant should probably be removed and additional graft should be placed into the osteotomy with a bioabsorbable collagen membrane to cover it and the tissues primarily closed. The clinician should allow 4–6 months for healing of the area before placing another implant. One must also be aware of the risk of possible implant migration into the sinus if there is poor stability at the time of placement determined by measurements of insertion torque (<15 N cm) or resonance frequency analysis (ISQ <60) [69–72]. If this does occur, then removal of the implant will be necessary to avoid further adverse consequences for the patient such as sinus infection or oral–antral communication.

Premature loading of the implant is more difficult to treat other than to further relieve the cause of the loading or to instruct the patient to stop wearing the interim prosthesis.

When a perforation of the Schneiderian membrane is detected, four treatment options are available: (i) localized repair and implant insertion; (ii) using shorter-than-planned implants (4–8 mm) to avoid intrusion of the implant into the sinus; (iii) abort and repeat procedure after at least three months; or (iv) revert to an LWO to repair the perforation, graft the sinus, and possibly place an implant.

As previously stated, microlacerations (≤2 mm) during OMSFE are likely to be clinically inconsequential in the short- and long-term postoperative periods [20, 22, 26, 73, 101, 102]. Reiser et al. [22] speculated that it is possible for minor perforations to be obturated in vivo, as a result of combined bone graft and blood clot stabilization, although the possibility of graft migration still remains a concern. Using endoscopic evaluation, both Nkenke et al. [73] and Berengo et al. [102] reported that if the tear is very small, the procedure can be continued and the grafting material packed into the site will be kept in place by the remaining intact membrane. However, this requires some prior elevation of the membrane and further elevation is no longer possible [154]. Once a perforation has occurred, the addition of graft material will perpetuate a vertical pattern of augmentation at the implant apices and not allow a lateral distension circumferentially to the implant apices, as membrane damage will hinder the sealing of the submembranous space and reduce the pressure applied to the sinus membrane [102] (Fig. 20.53).

If there is concern that a microtorn or tear may have occurred, localized repair can be attempted with the placement of a collagen membrane or a plug made from a biologic agent such as PRF [37, 38] which gets inserted into the osteotomy. Unfortunately, the clinician still cannot be assured the perforation has been sealed, so there remains the concern that subsequent placement of a particulate graft may enlarge the perforation and encourage graft migration. Jank et al. [155] in an animal cadaver study, demonstrated that an initial 1.2 mm membrane rupture increased in size in 85% of the cases when Summers’ BAOSFE procedure was used. In their study, further membrane elevation using a combination of hydraulic pressure and ultrasonic cavitation yielded the lowest risk of an enlarged rupture due to minimization of tensile forces on the membrane. In a cadaver study using endoscopic assessment of transcrestal SFE,
Garbacea et al. [103] reported that as the implant reached its final position, the graft was displaced in an apical or lateral direction, creating perforations or enlargement of previously detected membrane tears. Pjetursson et al. [31] found the Valsalva test for perforation detection to be positive in 11% of their OMSFE cases. In such situations, it was recommended that implant insertion be aborted, or the implant placed without grafting material.

When membrane laceration is confirmed, one should consider avoiding the use of a particulate graft, using only collagen or autologous platelet concentrate (APC) to eliminate the risk of graft migration as the clinician cannot be assured the perforation has been sealed without direct or endoscopic visualization. After a perforation and attempted repair, one must decide whether implant placement is appropriate and just how far it can safely extend beyond the original sinus floor boundary.

In a monkey study, Boyne [156] presented spontaneous bone formation extending around the implants with rounded apices when they penetrated only 2–3 mm into the created space below the membrane. When the same implants penetrated 5 mm or more into this same area of the maxillary sinus, only a partial (50%) growth of new bone was seen toward the apex of the implant.

Jung et al. [157] confirmed Boyne’s findings in a dog model. They reported on the risk of maxillary sinus complications in implants which penetrated the bone and Schneiderian membrane of the sinus floor at 2, 4, and 8 mm extensions. When implants penetrated the membrane less than 2 mm, spontaneous covering of the implants with the sinus mucosa occurred. On the other hand, when implants penetrated the membrane by more than 4 mm, the apical parts of the implants extending...
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into the sinus cavity were not covered with the growing antral membrane.

The long-term consequences of exposure of implants ≥4.0 mm into the sinus cavity are unknown (Figs. 20.54 and 20.55). Nooh [158] intentionally perforated the Schneiderian membrane using a 2 mm twist drill at the time of implant placement and all 63 implants protruded up to 3 mm beyond the sinus floor. Seven of 56 patients experienced epistaxis and one developed sinusitis but there was a 98.4% success (1 failure) rate at 1-year post restoration.

Based on the available literature and clinical experience, the authors have developed a transcrestal perforation protocol [104]. If a perforation is detected through direct vision (Fig. 20.56), Valsalva maneuver, or blunt probing, no particulate graft material is added, only a PRF plug attained from the patient’s centrifuged whole blood introduced into the osteotomy and gently advanced apically to the original sinus floor (Fig. 20.57). Alternatively, a collagen sponge saturated with a recombinant platelet-derived growth factor (Gem 21S; Osteohealth, Shiley, NY, USA) could be inserted as it is not easily displaced and may act as a barrier between the sinus and the implant site [19, 20].

At the perforated site, implant length should be only 2–3 mm longer than the original RSBH (Figs. 20.58–20.60). If this does not allow for the placement of an implant at least 8–9 mm in length, ≥4 mm in diameter, with an ISQ of ≥65, the site is abandoned, and implant placement is delayed for three months. This perforation protocol has been developed as the literature supports that in the majority of cases small rifts of the Schneiderian membrane will not disturb the healing process [20, 22, 26, 73, 101, 102, 154]; the possible protrusion of an implant 2–3 mm into the sinus does not adversely affect sinus physiology or postoperative outcome [24, 31, 156, 159]; platelet concentrates (e.g., PRF) can seal and aid in repair of the damaged membrane [160–162]; and transcrestal SFE without particulate grafting material has demonstrated excellent success rates [25, 27, 34, 35, 37, 38, 159, 163].

Another consideration might be to perform an LWO for membrane repair and elevation along with delayed or simultaneous implant placement (Figs. 20.61 and 20.62). The LWO still remains an invaluable technique not only for severely atrophic ridges but also for visualization
and repair of membrane perforations, which may be as prevalent with the transcrestal approach as they are with an LWO [28].

If the procedure is abandoned at the perforated site, retreatment is delayed for 3–6 months to allow for both membrane and osseous repair of the osteotomy. If bone does not fill the osteotomy on reentry, the soft tissue core has to be removed to near the level of the sinus membrane and what remains of it then has to be elevated with the newly formed membrane (Figs. 20.63–20.65). If upon reentry a crestal sinus communication is still present, then consider a repair with APC and delay implant placement for an additional 3–4 months (Figs. 20.66–20.70) or use a lateral approach to repair and consider placing an implant simultaneously if possible.

If the clinician believes that a microtear/tear has occurred, consideration should be given to placing the patient on a systemic antibiotic (amoxicillin/clavulanic...
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Fig. 20.64 Soft tissue filling osteotomy has been apically displaced using a 2.5-mm-diameter osteotome and platelet-rich fibrin.

Fig. 20.65 Lateral window osteotomy provides access to complete membrane elevation and grafting for delayed implant placement.

Fig. 20.66 CBCT cross-sections of site no. 3, 6 weeks after failed implant was removed due to postoperative infection.

Fig. 20.67 Debridement of soft tissues reveals small sinus communication.

Fig. 20.68 Residual crestal defect is filled with platelet-rich fibrin only to assist in membrane and ridge repair.

acid 875 mg/125 mg oral twice daily for 7 days) with bactericidal properties along with a decongestant. The patient should be instructed to refrain as far as possible from blowing his or her nose. Should repairing the tear be unsuccessful with implant loss and a subsequent patient OAC, it may be necessary to attempt to revise this area. If sinus health is maintained a small (<3.0 mm) OAC will close on its own whereas those larger than this size require surgical revision [164, 165]. The most common cause of failure to close the OAC is insufficient control of maxillary sinusitis. For this reason, foreign bodies, infected and degenerated polypoid mucosa and infected bone should be removed immediately [166, 167]. If an OAC is present, the patient should be instructed to rinse...
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with a 50:50 diluted hydrogen peroxide–water solution, gently lavaging the osteotomy in the interim along with the use of systemic antibiotics such as amoxicillin–clavulanic acid or levofoxacin.

The repair may involve the use of a collagen membrane over the window opening, along with advancing a buccal flap [168], palatal rotating flap [165], or a pediculated buccal fat pad [169, 170] to gain primary closure. Consideration must be given to referring the patient to someone with experience in this area of care or to an otolaryngologist, especially if the clinician is not experienced with these advanced procedures.

If BPPV has occurred, it commonly resolves itself within a month without treatment [117]. However, the canalith repositioning procedure, known as the “Epley maneuver,” has been reported to be very effective in treating BPPV, particularly if the particles are located in the posterior semi-circular canal [171–173]. Clinicians may consider pharmacological management to either reduce the spinning sensation of vertigo and/or to reduce the accompanying motion sickness symptoms. The most commonly used medications are benzodiazepines and antihistamines [119]. As the symptoms may be very incapacitating, immediate referral to an otolaryngologist is strongly recommended. Early diagnosis of BPPV and immediate application of the Epley maneuver may help reduce the patient’s discomfort.

Finally, poor patient experience is best managed by considering the use of techniques that minimize the hammering process in infracturing the sinus floor, along with giving the patient a realistic expectation of what may be encountered in the procedure. This can only be accomplished by spending the time to fully inform the patient of the procedure and potential adverse consequences, along with documenting the patient’s understanding of this through filing appropriate consent forms.

Take-home hints

● Adequate sinus screening (history and CBCT) and establishment of preoperative sinus health may reduce postsurgical complications and compromised results.

● The presence of sinus septae, an oblique sinus floor, or a widened sinus are anatomical concerns that increase the risk for membrane perforation. A high level of experience may be needed to successfully manage patients who present with these.

● In the posterior maxilla where there is often poorer bone quality and reduced subantral bone, an
undersized drilling technique (5–15%) should be considered to improve primary stability.

● Initial preparation of the osteotomy can be performed rapidly and safely with sequential membrane-safe drills fitted with stops designed to penetrate 1 mm shy of the sinus floor.

● When tapping osteotomes, the patient’s head should be stabilized by using firm pressure on the forehead. Also prop the patient’s head up to avoid hyperextension of the neck.

● Consider the use of adjustable stops on osteotomes when directly infracturing the sinus floor to limit apical penetration. The stop should be set at 1 mm greater than the measured and confirmed subnasal bone height.

● If placing particulate graft material into the osteotomy, consider first inserting a protective/cushioning agent such as a collagen membrane/plug or formed membrane/plug from autologous platelet concentrate. These may also help with sealing undetected perforations that have occurred.

● If a perforation is detected, one may wish to consider avoiding the placement of a particulate graft, using only platelet concentrate or collagen to elevate the membrane and act as a barrier between the implant and sinus cavity. However, if using a particulate graft consider hydrating the graft with a small quantity of 0.5% metronidazole solution to reduce the risk of infection [174].

References


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