Site Development in the Posterior Maxilla Using Osteocompression and Apical Alveolar Displacement

Abstract: Implant placement in the posterior maxilla is often compromised by reduced bone quality and limited bone height beneath the sinus floor. Techniques have been developed using osteotomes to improve localized bone density through osteocompression and provide for additional implant length through apical alveolar displacement. The clinical indications and proposed limitations for these procedures are presented along with the biologic rationale based on relevant literature. The author cites his personal experience with osteotome procedures and presents procedural modifications to aid in simplifying staged sinus elevation. Localized internal sinus elevation may represent a more conservative approach to treat the deficient posterior maxilla, but at present the histologic and clinical comparisons to the traditional lateral sinus elevation are lacking.

Longitudinal human descriptive studies indicate that clinical success rates of implant placement vary according to anatomic location with the long-term success rates of endosseous implants placed in the maxillary posterior region inferior to that in other areas. The lower survival rates for implants placed in the posterior maxilla have been attributed to:
1. The presence of poor bone quality and highly trabecular type 4 bone.
2. Higher occlusal loads produced by the posterior dentition.
3. Compromised bone dimensions resulting from the proximity of the maxillary sinus, which often requires the placement of shorter length implants.
4. The frequency of the occlusal table being wider than the implant diameter, resulting in off-axis forces.

The lack of cortical bone and the low density of cancellous bone correlate significantly with reduced primary implant stability. Dense trabecular bone provides better intimacy of initial fit and implant-bone contact area creating better initial stability. Implant success as well as primary stability is greatly affected by localized bone density with implants placed in areas of poorer bone quality (eg, the posterior maxilla) historically associated with higher rates of implant failure. Clinical strategies to increase success rates in areas of reduced bone quality include the use of longer or wider diameter implants, the use of additional implants, the use of implants with a roughened surface, undrilling the osteotomy followed by placement of a self-tapping implant that is 1 mm to 2 mm wider than the initial preparation, and the use of osteocompressive techniques. These strategies are intended to provide for more bone-to-implant contact supporting the restoration, thus increasing the implant's tolerance to occlusal forces.

Summers has written a series of four articles on the application of osteotomes in implant site preparation. The osteotomes represent an alternative to rotary instrumentation in sites with softer bone, which are generally diagnosed radiographically or clinically by resistance during osteotomy preparation. These articles describe the use of the tapered concave-tipped Summers osteotomes to increase maxillary alveolar width and improve local bone density in combination with posterior maxillary osteocompression.

Learning Objectives:
After reading this article, the reader should be able to:
• discuss the complicating factors for implant placement in the posterior maxilla.
• explain the rationale for the use of osteocompression and apical alveolar displacement in simultaneous and staged implant placement in the posterior maxilla.
• identify the various osteotome techniques and their indications.
• describe the clinical modifications to staged sinus augmentation using an internal crestal approach.
with implant placement, as well as internally elevate the sinus for delayed and simultaneous implant placement. Saadoun and LeGal1 used cylindrical, tapered-tipped Steri-Oss® osteotomes for similar applications. The tapered tip of this type of osteotome may condense bone more efficiently laterally, but increased pressure at the tip may increase the incidence of sinus membrane perforation. When used to prepare the osteotomy in the maxilla, osteotomes compact and elevate existing bone apically and condense and expand it laterally. Lateral compression results in more compact bone around the osteotomy and a denser bone interface. Based on the improvement in localized bone density, osteotomes should improve primary implant stability and success rates in areas of reduced bone quality such as the posterior maxilla.

Implant placement in the posterior maxilla may also be complicated by an inadequate posterior alveolus and increased pneumatization of the maxillary sinus, creating a close approximation of the sinus to the crestal bone. After an extraction, the ridge height decreases dramatically as a result of the absence of osseous stimulation, which leads to crestal atrophy. Periodontal disease frequently causes the loss of maxillary molars with significant resorption of alveolar bone and, in patients with a large maxillary sinus, the resulting bone dimensions are often inadequate for the placement of properly proportioned implants. Subsequent insertion of a removable prosthesis will exert nonphysiologic pressure on the ridge, contributing to additional bone resorption. Because of these anatomical limitations, sinus floor elevation has become a common surgical procedure producing reliable long-term results in oral implant treatment. Various techniques to augment the sinus have been reported using different graft materials in a delayed or simultaneous approach with implant placement. In 1997, Smiler reported on lateral window entry procedures and their indications. The most common variations on the popular trap door technique include the antrostomy and osteotome techniques. An antrostomy involves the removal of the entire lateral trapdoor while maintaining membrane integrity, thus creating a large membranous window in the lateral sinus wall. An antrostomy on the lateral wall may be performed instead of a door preparation sacrificing the bone support and bone inductive element provided by the lateral wall. The antrostomy technique may be chosen in cases of high sinus septa, narrow sinuses, or partially edentulous lateral maxilla (gaps), where the preparation of a door is not possible. In instances where the sinus is narrow, elevation and retention of the lateral wall may not be possible or the prepared lateral window may also be converted into a hatch mobilized on all four sides.
and carefully lifted upward to a higher position in the sinus where the lateral dimensions are larger. In the presence of a narrow sinus, a crestal approach with the use of osteotomes should be considered to easily navigate the narrowed areas and predictably elevate the sinus membrane, retaining antral walls and their bone inductive properties.

Apical Alveolar Displacement With Osteotomes

A less invasive approach for sinus floor elevation with concurrent grafting and implant placement was introduced by Summers in 1994. The bone-added sinus floor elevation technique (BAOSFE) uses osteotomes and graft materials to reposition the preexisting bone beneath the sinus, elevating the sinus floor and increasing bone support for the implant. The procedure was recommended for patients who had at least 5 mm to 6 mm of bone between the ridge crest and sinus floor. The use of drills is minimized with this technique except in initial preparation or expanding the osteotomy in existing cortical bone. Denser trabecular bone may require the combined use of drills and osteotomes to minimize patient trauma from malleting. Several sets of cylindrical and tapered osteotomes with a variety of tips are usually required to ideally prepare the implant osteotomy (Figure 1). A combination of graft materials and autogenous bone particles, from the same surgical segment if possible, is added to the osteotomy. The author uses as much autogenous graft material harvested from the surgical site as possible, and infrequently needs to use the symphysis or ramus. Particulate bone may be gathered from the tuberosity via rongeurs or during any drilling procedures with a specially designed suction device. Natural bone mineral of bovine origin (Bio-Oss®) is then combined with autogenous bone in a 1:1 ratio. Bio-Oss® has recently demonstrated success as a sole graft material in sinus elevation, has shown good osteoconductive properties, and is easily visualized on immediate postoperative radiographs (Figures 2A and 2B). Added graft material (autogenous bone and Bio-Oss®)

Figure 3A—Preoperative radiograph at site No. 3 reveals 4 mm of bone beneath the sinus.

Figure 3B—Postoperative radiograph after placing a 5- X 11-mm fixture in combination with 7 mm of localized sinus elevation. The graft mix consisted of Bio-Oss® and autogenous bone.

Figure 4A—Preoperative radiograph before extraction of teeth Nos. 2 and 4. Note sinus septa which would require dual windows with a lateral approach.

Figure 4B—Immediate postoperative radiograph of implant placement 8 weeks after extractions. The BAOSFE procedure was used with autogenous bone from the tuberosity to simplify placement in the presence of sinus septa.

Figure 6—Preparation after mechanical and th immec memb which mix ar difficult.

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and the bone that has been apically condensed immediately below the sinus floor elevates the membrane. The pressure from the osteotome, which occludes the osteotomy, causes the graft mix and trapped fluids to exert pressure in all directions (Pascal's Law).43

The grafted mass acts much like a hydraulic plug to push up the sinus boundary.17 The pressure elevates the floor of the sinus over a wider area than the diameter of the osteotomy. The addition of a bone graft provides greater and more controlled localized elevation.18 For every 3-mm to 5-mm plug of bone mix, the clinician should anticipate 1 mm of sinus elevation. There should be no direct contact between the osteotomes and the mucosal lining of the sinus. The osteotomes are never inserted past the original sinus boundary because this will increase the likelihood of membrane perforation. After the localized internal sinus elevation is completed, the implants are placed with their apical end in the tented space with initial fixation provided by the preexisting bone. This internal crestal approach requires less combined graft volume, less flap reflection and trauma, and has resulted in less postoperative swelling and discomfort than experienced with the lateral approach.

Osteocompression in combination with internal sinus elevation is designed to improve localized bone density and allow for the placement of longer implants, thereby improving success rates in the posterior maxilla. A recent multicenter study using the BAOSFE procedure demonstrated a 95.4% survival rate for 174 implants with an average loading time of 20.2 months using a variety of implant types and grafting materials.17 The BAOSFE procedure consistently produces 3 mm to 5 mm of sinus elevation and with more experience up to 7 mm to 8 mm of elevation is possible (Figures 3A and 3B). Bruschi and colleagues44 used localized management of the sinus floor (LMSF) with simultaneous implant placement to achieve a success rate of 97.5% placing 499 implants over a 7-year observation period. In a single surgery, this procedure combines elevation of the maxillary sinus floor, buccal expansion of the residual alveolar bone, and implant placement without bone grafting or membrane-
guided healing. Radiographic analysis of the successful implants showed that an increase of 3 mm to 7 mm of available bone is possible with LMSF. Using the BAOSFE procedure, the author has experienced a 95.7% survival rate on 202 implants with an average loading time of 18 months. A variety of implant surfaces and geometric designs have been used with autogenous bone alone or in combination with Bio-Oss®. The author presently prefers using threaded implants with an etched or blasted surface. The procedure has consistently produced a localized sinus elevation of 2 mm to 7 mm with minimal complications and a detectable membrane perforation rate of 3%.

Single tooth implant-supported restorations are an acceptable treatment option capable of withstanding the vertical and lateral occlusal forces generated in the posterior maxilla. The BAOSFE procedure is ideally suited for single tooth implants in the posterior maxilla where there is limited subsinus native bone. Mazor and colleagues published a 3-year retrospective study of 10 consecutive implant-supported, single tooth restorations after sinus augmentation. Because of the limited surgical access, membrane tearing was observed in 4 of the 10 patients. The tears were repaired with resorbable membranes with no effect on healing or bone support after 3 years of loading.

They stated that tearing of the sinus membrane may occur because of the irregular nature of the overlying bone located between the root apices and the small dimension of the access cavity. Repair of the torn membrane was complicated because of minimum access and restricted working space. Based on these reported difficulties and the documented high success rate of the BAOSFE technique, an internal osteotomy approach would simplify implant placement at the single tooth site with limited bone height beneath the sinus.

Luxating the Schneiderian membrane from septa can be difficult, but even more difficult at sinus floor convolutions and root tip expressions, even when the teeth have been extracted many months before. The incidence of antral septa varies between 16% and 58% according to the literature. These septa act as a masticatory force carrying struts during the dentate phase of life and seem to disappear slowly when teeth have been lost. Ostotome sinus floor elevation could be considered in the presence of septa to reduce the risk of membrane perforation (Figures 4A and 4B).

Immediate and delayed fixation of various implant designs have been investigated using the sinus lift procedure, with success seen with both options. The quantity of preexisting bone required for successful simultaneous placement has not been determined, but adequate bone should be available to provide primary implant stability. A lateral approach osteotomy without simultaneous implant placement has been advised when < 5 mm of residual alveolar bone is present between the inferior border of the sinus and the crest of the alveolar ridge. The Sinus Consensus Conference reported smoking as a negative factor and found implant failure rates relatively high in cases with presurgical bone height of < 5 mm. This would seem to indicate a lesser
bone quality of the graft than native bone. The minimum residual alveolar bone height treated with the highly predictable LMSF was 5 mm to 7 mm. Using the BAOSFE technique, < 4 mm of preexisting bone height and smoking have been shown to reduce the likelihood of implant survival. The survival rate was 96% or higher when the pretreatment bone height was ≥ 5 mm and dropped to 85.7% when the pretreatment bone height was ≤ 4 mm. This stresses the importance of the quality and quantity of the remaining native bone in simultaneous placement using internal sinus elevation or the lateral window technique.

Future Site Development

The future site development (FSD) technique is an alternative approach when inadequate crestal bone is present. In this procedure, trephined cores of crestal bone are implored with osteotomes to raise the sinus floor before graft augmentation (Figures 5A and 5B). The cores and added graft material are used to elevate the sinus floor and no direct contact with the membrane is made. The repositioned bone plug has good osteogenic potential as a continuing source of live cells to speed the conversion of the graft into vital bone. The side walls of the osteotomy created during core preparation can also contribute to more rapid graft maturation. The FSD procedure offers the potential benefit of a shorter healing time and elimination of a distant donor site.

One of the difficulties experienced with the FSD technique has been the limited access and visualization for repair of membrane perforations (Figure 6). If an adjacent site has been prepared without a perforation, it may allow for additional membrane reflection to access the tear. A lateral window preparation may be required to better visualize the tear and simplify the repair. If the membrane cannot be repaired, the procedure should be abandoned because of an inability to contain the graft material.

An unpleasant aspect of the FSD technique is the repeated malleting sometimes necessary to implode the trephine sub sinus native bone. Unless the core has been prepared to within 1 mm to 2 mm of the sinus floor (Figure 7), elevation may be very difficult with forceful malleting required to “free” the core. It is difficult to uniformly prepare the core close enough to the sinus floor to ease core elevation. The sinus floor may not be flat at the location of the core, which can lead to underpreparation at points along the core’s perimeter (Figure 8). Conversely, small points are easily overprepared resulting in immediate tearing by the trephine’s teeth (Figure 6). The author has significantly reduced the incidence of membrane tears with the FSD technique by using the personally designed Toffler core osteotome to aid in freeing the boundaries of the core and simplifying its elevation. The osteotome’s 0.5-mm-thick curved tip (Figure 9A) is designed to fit within the borders of the core preparation created with a 5.25-mm or 6-mm trephine. There are 2-mm markings to gauge the depth of penetration avoiding insertion of the instrument into the sinus (Figure 9B). While gently malleting the instrument, the surgeon retains the tactile sensation lost while using a trephine to complete the most delicate aspect of the FSD procedure. The core is prepared to within 1.5 mm to 2 mm of the sinus floor in the area of the most limited bone height. The core osteotome is then gently malleted around the core boundary an additional 1 mm to 1.5 mm. Surgical elevators or chisels may also be used to free the core, but the ability to measure the depth of penetration and modified tip are quite helpful in avoiding membrane contact and potential tearing. A 5-mm to 6-mm-wide diameter osteotome is then gently malleted to evaluate apical core movement. The author prefers to prepare the additional 1.5 mm to 2 mm using the Toffler core osteotome because it is less likely to perforate the membrane than the trephine and reduces the force of malleting often necessary to implode the core (Figures 10A and 10B).

Another difficulty may arise during initial preparation of the core resulting from trephine instability. The trephine may skip before getting a “bite” in the crestal cortical bone. This problem may be avoided by beginning the core.
preparation in reverse at 1,500 rpm under copious irrigation. This will predictably initiate the first 0.5 mm to 1 mm of the preparation. Core preparation to the desired depth may now be completed in the forward position at 1,500 rpm also with copious irrigation. The trephine diameter selected will be based on the thickness of the residual alveolar ridge.

The author has experienced more favorable results using a nonresorbable expanded polytetrafluoroethylene (e-PTFE) membrane stabilized by titanium tacks over the crestal preparation. The bone quality as determined during osteotomy preparation has consistently been better when a nonresorbable membrane has remained submerged during the initial healing period. Similar findings have been reported with the use of a nonresorbable membrane over the lateral window.\textsuperscript{34,51,52} The placement of a nonresorbable e-PTFE membrane over the lateral window has been shown to enhance vital bone formation regardless of the graft material used.\textsuperscript{51,52} Tarnow and colleagues\textsuperscript{52} published a report on 12 bilateral sinus elevations that demonstrated a significant difference in vital bone production when a membrane was used as compared to the contralateral side without a membrane (25% and 11.9%, respectively). They reported a 7.4% greater survival rate for implants placed in membrane-covered sinuses. Froum and coworkers\textsuperscript{51} reported that in cores obtained when a membrane was in place, the graft material appeared to be contiguous and corticalized. When a membrane was not used over the lateral window it was not uncommon to observe loose particles of the graft, sometimes with soft tissue invagination. This encleftation or soft tissue ingrowth may adversely affect the degree of vital bone formation within the graft.\textsuperscript{51} Jensen and Greer\textsuperscript{14} grafted sinuses with mineralized cancellous allografts reporting a more favorable healing response and prevention of soft tissue encleftation when an e-PTFE membrane was placed over the lateral window. The use of a barrier membrane over the lateral window may be considered to do the following:

1. Exclude nonosteogenic flap connective tissue cells from the wound healing.
2. Contain particulate graft material.
3. Prevent soft tissue enclavation.
4. Increase vital bone formation to increase the implant survival rate.\(^{52}\)

The membrane may also cause entrapment of osteoinductive cells and components in the membrane-covered area.\(^{53}\) Membrane coverage of the crestal core preparations should provide the same benefits and may explain the author’s improved results (Figures 11A through 11F). Primary closure may be more difficult to maintain with the crestal core preparation because the membrane is under the sutured crestal incision as opposed to over the lateral window. Every effort should be made to achieve a relaxed closure with a combination of horizontal mattress and interrupted sutures using either an e-PTFE or VICRYL\(^{6}\) suture material. These sutures are allowed to remain in place for 10 to 14 days and will elicit a minimal inflammatory response.

A criticism of the BAOSFE and FSD procedures has been the lack of membrane reflection and reduced volume of generated bone. Is the extensive flap and membrane reflection and the large volume of grafted bone used in the lateral approach truly necessary to produce enough vital supporting bone? Peleg and colleagues\(^{44}\) reported on radiological findings of 57 implants placed in 24 augmented sinuses and showed 28 to have bone fully covering the implant on all sides, that did not extend beyond the apical portion; 20 had bone fully covering the implant that did extend above the apex; and 9 exhibited incomplete bone coverage. All implants supported a fixed ceramometal prosthesis, and no implant failures were recorded after 3 years of follow-up. This would seem to indicate that even when bone coverage is incomplete, the implant can still be successful. Peleg and coworkers\(^{45}\) explained the lack of implant coverage that resulted from their early inexperince with the sinus elevation procedure. Based on early reported success of the BAOSFE procedure\(^{17}\) as well as the author’s personal experience, the reduced generated bone volume would appear adequate and would very well sustain long-term implant function in areas where 3 mm to 7 mm of sinus elevation may be required. Horowitz\(^{22}\) published a short-term report on 34 implants using a modified BAOSFE technique. He found that the 97% success rate was not deleteriously affected by radiographic voids in the graft material or possible tears in the sinus membrane.
The vascular supply and source for cellular activity for wound healing in the sinus comes from the surrounding bony walls. Because it is narrow and close to multiple bony walls, the area adjacent to the crestal bone would be expected to provide the most favorable environment for bone formation. Elevation of the Schneiderian membrane may be required to recruit bone forming cells to aid in maturation of a larger grafted area. The same degree of elevation would not be required for the maturation of grafts of smaller volume placed with osteotomy techniques. The amount of autogenous bone used in the graft mixture can increase the rapidity and amount of new bone formation. A smaller graft volume would allow for an increased proportion of autogenous bone in the mixture, expediting the healing process. This may be an advantage in more conservative sinus elevation (eg, BAOSFE, FSD) with more rapid graft maturation and earlier implant stabilization. However, with no direct comparison between FSD and the lateral window approach or published reports on the long-term survival of implants placed in sites developed using FSD, this procedure must be considered experimental. Success in case reports or personal communications cannot justify its use as an equally successful treatment alternative to the standard lateral approach used in staged sinus elevation. Histologic studies of sinus grafts in a staged or simultaneous osteotomy technique are necessary to determine the area of vital bone as well as the degree of osseointegration; this additional information on the healing patterns in the grafted sinus may allow further refinement of sinus elevation surgery to achieve maximum long-term implant success through the most expeditious and conservative means possible.

Acknowledgments
The author would like to express his gratitude to surgical assistants Grisel Crespo and Opal Lumsden for their help in refining and striving to improve the reported surgical techniques. Additionally, the author would also like to thank Vince Holden of the H & H Company for his assistance in the development of the Toffler core osteotome.

References


