

MAXILLARY SINUS ELEVATION BY LATERAL WINDOW APPROACH: EVOLUTION OF TECHNOLOGY AND TECHNIQUE

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ABSTRACT

Context: The maxillary sinus elevation procedure has become an important pre-prosthetic surgical procedure for the creation of bone volume in the edentulous posterior maxilla for the placement of dental implants. Research and clinical experience over the past 30 years has increased the predictability of this procedure as well as reduced patient morbidity.

Evidence Acquisition: Data on grafting materials and implant survival rates comes from 10 published evidence-based reviews that include all relevant published data from 1980 to 2012. Supporting clinical material comes from the experience of the authors.

Evidence synthesis: The evidence-based reviews report and compare the implant survival rates utilizing various grafting materials, implant surfaces, and the use or non-use of barrier membranes over the lateral window. Clinical studies report on complication rates utilizing piezoelectric surgery and compare them to complication rates with rotary instrumentation.

Conclusions: The conclusions of all the evidence-based reviews indicate that the utilization of bone replacement grafts, rough-surfaced implants, and barrier membranes result in the most positive outcomes when considering implant survival. Further, the utilization of piezoelectric surgery, rather than rotary diamond burs, for lateral window preparation and membrane separation leads to a dramatic reduction in the occurrence of the intraoperative complications of bleeding and membrane perforation.

INTRODUCTION

Maxillary sinus elevation became part of our pre-prosthetic surgical armamentarium after being first presented by Tatum¹ in 1977 and first published by Boyne and James² in 1980. We presently have 32 years of clinical research and surgical experience with many innovations in techniques and technology and, yet, there is still no consensus with regard to grafting materials or as to which surgical technique leads to the best clinical outcome.

One must bear in mind that consensus is not an easy task in either case, owing to the unparalleled introduction of new grafting materials and biomimetic enhancement factors, as well as the continuous reinvention of the surgical technique.

This article follows the evolution of the 2 most important trends in lateral window sinus augmentation surgery: the transition from autogenous bone to bone

Keywords: Maxillary sinus augmentation, maxillary sinus elevation, sinus augmentation technique, sinus bone grafts, xenografts, piezosurgery, DASK

TABLE 1. Implant survival with minimum loading time of 1 year⁶

implant survival with different sinus grafting materials	
• alloplasts	81.0%
• iliac crest	88.0%
• composite grafts	92.0%
• allograft	93.3%
• 100% xenograft	95.6%

Aghaloo TL, Moy PK Int J Oral maxillofac Implants 2007;22:49-70

TABLE 2. Implant survival with minimum loading time of 3 years¹³

• ridge height ≥5 mm vs <5mm	94.5%, 92.7%
• simultaneous vs delayed	96.0%, 93.3%
• rough vs machined	96.6%, 81.0%
• 100% BRG vs 100% autogenous	96.3%, 85.3%
• prospective vs retrospective	96.4%, 89.4%
• graft material / implant surface confounding variables	

Del Fabbro M, Wallace S, Testori T Int J Periodontic Rest Dent (accepted 2011)

TABLE 3. Implant survival of all implants compared with rough-surfaced implants only: 1-year minimum loading time⁷

1 year implant survival excluding machine-surfaced implants		
	all	rough only
100% autogenous particulate	94.3%	98.7%
100% autogenous block	92.6%	99.9%
composite	98.5%	98.9%
100% bone replacement graft	97.4%	98.9%

Pjetursson BE, Lang N, et al J Clin Periodontol 2008;35(suppl 8):216-240

replacement grafts as a donor material and the desire to develop a surgical technique that is simpler to perform and has the least chance for complications.

It must be realized that this review is performed with the understanding of the following limitations:

1. It is not possible, or necessary, to discuss every bone replacement graft available to reach a consensus on trends.
2. We must accept the fact that success is usually measured by the secondary outcome measures of percentage of vital bone formed (histologic) or by implant survival rates (clinical) rather than by the success of the actual surgical procedure.
3. We do not know what percentage of vital bone must be formed to result in implant survival.
4. Our data is in many instances subject to the effects of confounding variables (more than 1 variable may be responsible for the observed outcome).

EVOLUTION OF GRAFTING MATERIALS

Autogenous bone has always been considered the “gold standard” of grafting materials. The rationale is that with an autogenous graft, bone formation can occur through the multiple pathways of osteoinduction, osteoconduction, and osteogenesis. It is therefore reasonable that autogenous bone was the early standard for maxillary sinus augmentation. Because of the relatively large volume of grafting material required, early donor sites were extraoral, coming from the hip, tibia, and cranium. In fact, as late of 1996, the majority opinion of the Academy of Osseointegration Consensus Conference³ was that autogenous bone was appropriate for sinus grafting and that allografts, alloplasts, and xenografts may be effective in selected clinical situations.

From 2003 until the present there have been 10 evidence-based reviews reporting on the efficacy of all forms of graft materials.⁴⁻¹³ The reviews are in agreement that more favorable results have been achieved with bone replacement grafts than with autogenous bone. “Success” in these reviews is reported as the secondary outcome measure of implant survival. All the listed reviews report implant survival rates

Figure 1. Histology 6-months post sinus grafting with 100% xenograft (BioOss) demonstrating “bone bridging” between residual xenograft particles (yellow) and newly formed vital bone (red) (Stevenel’s blue, van Geisson’s picric fuchsin stains, original magnification ×100).



with a minimum loading time of 1 year, with the exception of the review by Del Fabbro et al,¹³ which reports on a minimum of 3 years loading with similar results (Tables 1 and 2).

It is important to realize that evidence-based reviews use data from multiple and often diverse studies. For that reason, it is difficult, if not impossible, to establish a large database without it being subject to what are described as confounding variables. When evaluating the efficacy of graft materials, it is impossible to ignore the variable effect of implant surface texture. The review by Pjetursson et al⁷ specifically addresses this issue. When machine-surfaced implants are removed from the database, the results with each of the graft materials appear to be equal (Table 3).

The information from all reviews does, however, substantiate the finding that implant survival with bone replacement grafts, specifically the most rigorously evaluated group (xenografts), are equal to or better than that achieved with autogenous bone. These data, coupled with the reduction in patient morbidity realized by eliminating the need for a secondary surgical (donor) site, appears to position bone replacement grafts as the graft material of choice today.

The success of xenografts may be attributed to 3 factors:

1. They are osteoconductive with approximately 25% vital bone formation by volume at 6-8 months
2. They are not resorbed, adding approximately 25% to the mineral content of the future implant receptor sites (25% new vital bone + 25% residual nonvital graft material)
3. The residual graft material is never seen in direct contact with the implant surface, and therefore does not interfere with osseointegration.

The histologic results with xenografts present a pattern that has been called “bone bridging.” Residual particles of

xenograft are surrounded in part by new vital bone, and through that mechanism they are joined to approximating particles (Fig. 1).

Long-term maintenance of the early histologic results obtained with xenogeneic bone has been shown at 9 years by Traini et al¹⁴ and at 11 years by Mordenfeld et al.¹⁵

One question that has long been unanswered is the relationship of xenograft particle size to vital bone formation. A study by Chackartchi et al¹⁶ reported a nonsignificant difference between small and large particle grafts; however, a recent study by Testori et al¹⁷ has shown a statistically significant difference with vital bone formation of 26.8% versus 18.8% at 6 months for large and small particle size respectively.

There are both histologic^{18,19} and clinical studies demonstrating that graft maturation times can be reduced when using autogenous bone or composite grafts with autogenous bone as a component. Although the use of autogenous bone may have this advantage, it also has the disadvantage of increased morbidity and significant graft resorption, resulting in partial re-pneumatization of the sinus with concomitant loss of graft height.

It should be noted that successful outcomes have also been reported with other bone replacement grafts, such as allografts²⁰ and alloplasts²¹; however, the studies are fewer in number.

The past decade has seen the introduction of biomimetic and stem cell technologies in clinical practice. These technologies are presented as a means to achieve more favorable outcomes, or as a way to achieve comparable outcomes to that of autogenous bone grafts without the use of graft materials.

Bone morphogenetic proteins (BMPs) were evaluated for many years before becoming available in the dental marketplace. BMP-2 had been used in spinal fusion surgery for many years with purportedly successful outcomes. The Infuse Bone Graft (Medtronic), an autogenous bone replacement graft, was introduced to the market following safety and efficacy studies by Boyne et al.²² Very rigid randomized, controlled clinical trials were conducted by Boyne et al²³ and Triplett et al,²⁴ showing implant survival rates similar to that of autogenous bone. Drawbacks with this procedure were high cost, immature bone quality at early time intervals, and the propensity of the grafts to shrink. Attempts to resolve issues with graft shrinkage and poor density by incorporating mineralized bone replacement grafts with the collagen sponge have not been entirely successful, as studies have shown a BMP-2-mediated accelerated resorption of the added allograft material.²⁵ A recent bilateral sinus study by Kao et al²⁶ has shown a less favorable histologic result when rhBMP-2/ACS was added to the xenograft than that achieved with xenografts alone.

Although no adverse events are yet to be reported in the sinus grafting literature, concerns about the voracity of the initial spine studies has recently come to light. Reports by Carragee et al^{27,28} claim that reported results of the 13 initial studies on spinal fusion may have been presented in an overly positive fashion and that they also failed to reveal adverse events that have subsequently come to light in later studies.

Platelet-rich plasma, produced by the centrifugation of freshly drawn venous blood from the patient, has been proposed as an autologous source of multiple growth factors. Available centrifuge systems are able to increase the concentration of blood-borne growth factors by 3 to 5 times. The major growth factor is PDGF- $\beta\beta$. There are some published reports that claim improvements in soft tissue healing and increased vital bone formation. Three evidence-based reviews have not supported claims for enhanced outcomes in maxillary sinus elevation.²⁹⁻³¹

Recombinant human platelet-derived growth factor $\beta\beta$ (rh-PDGF $_{\beta\beta}$) has a long history of development before its introduction to the dental market as GEM-21S (Osteohealth; Shirley, NY). The effect of this growth factor on wound healing, including its effect on type I collagen synthesis, has been well documented in the periodontal literature and this product has been approved for use in periodontal regeneration.^{32,33} The concentration of growth factor in the recombinant product can be 3000 times that of whole blood. At present, utilization in maxillary sinus elevation is off-label. There are, however, sinus studies that show both above-average vital bone formation³⁴ and earlier bone formation,³⁵ the latter study reporting 21.1% versus 11.8% at 4 to 5 months for BioOss + rh-PDGF $_{\beta\beta}$ and BioOss (Geistlich Pharma AG, Wolhusen, Switzerland) alone respectively.

Osteocel, (Nuvasive, San Diego, CA) a fresh frozen allograft (multipotential cellular bone matrix) with enhanced stem cell content, has also been used in sinus augmentation. A study by Gonshor et al³⁶ has shown vital bone formation at 3 to 4 months to be 32.5% versus 18.3% when comparing Osteocel to a traditional allograft control.

The 2 outcome measures that could be influenced by these new technologies are implant survival and/or graft maturation time. As implant survival rates of more than 98% can be achieved by using rough-surfaced implants, xenogeneic bone, and the placement of a membrane over the window,⁴⁻¹³ it is unlikely that this survival rate can be improved with biomimetic technologies. There are, however, bilateral clinical studies that show more rapid (earlier) bone formation when using either rh-PDGF $_{\beta\beta}$ or OsteoCel. There are no published studies as yet on implant survival with these technologies.

There also has been an alternative development of lateral window techniques that do not use a bone graft but rely on a blood clot or a centrifuged autogenous blood product as the sole grafting material. Initial studies by Lundgren et al³⁷ showed

that the sinus membrane could be elevated with simultaneous implant placement, using the implant to support the membrane. The study showed new bone formation in the area filled by the blood clot. A recent study by Cricchio et al³⁸ reported a 5.3-mm average bone gain with a 98.7% implant survival rate. Studies by Lin et al³⁹ and Borges et al⁴⁰ showed similar results. Mazor et al⁴¹ has likewise shown favorable radiographic and histologic results with Choukron's platelet-rich fibrin. In all these studies, bone height gain was to the level of, or just short of the implant apices, depending on the size of the clot formation and the ability of the implant(s) to "tent" the membrane.

Digesting all the information available in the literature is a formidable task. The authors have taken the tack of relying on the results of the multiple evidence-based reviews in forming their daily treatment protocol. What we can derive from these reviews is, in part, the following:

1. Rough-surfaced implants are more favorable than machined implants.
2. Bone replacement grafts can be substituted for autogenous bone with similar or more favorable results.
3. Placing a membrane over the window results in an increased implant survival rate.
4. Simultaneous and delayed implant placements have similar survival rates assuming primary stability is achieved at placement and maintained through the early graft maturation period.

Modifications to the above protocol can be made, using the results of studies with overall smaller databases, to reduce graft maturation times. The authors take advantage of such materials as rh-PDGF $_{\beta\beta}$, which may upregulate bone formation, giving us the advantage of autogenous bone without the need for, or the morbidity of, a bone harvest. This is not to say that other options do not result in successful outcomes. It may be said, however, that they have smaller evidence bases at the present time.

EVOLUTION OF SURGICAL TECHNIQUE

The sinus augmentation procedure first entered our surgical armamentarium with presentations and publications by Tatum¹ and Boyne and James.² Entry into the sinus was made either through the crest or the lateral wall. The lateral wall technique of Boyne and James² used a large round carbide bur to obliterate the wall to make a window access for the placement of an autogenous bone graft. Multiple modifications to this technique have been published over the years. The original rotary techniques with either surgical hand pieces or high-speed hand pieces were modified by Wood and Moore,⁴² who first published the hinge osteotomy technique in 1988, and by Smiler,⁴³ who reviewed multiple technique variations in 1996. In 2001, Vercellotti⁴⁴ introduced the

Piezoelectric technique in the United States (introduced earlier in Europe) and in 2011 the Dentium Advanced Sinus Kit (DASK) technique was first published by Lozada et al.⁴⁵ Multiple publications have demonstrated transcresal approaches to the sinus using osteotomes, special safe-cutting drills and diamonds, hydraulic pressure, piezoelectric surgery, and balloon elevation techniques.

The ultimate goal of the sinus augmentation technique is to increase the available height for implant placement. This is accomplished by the sequential steps of flap entry, window access to the sinus cavity, elevation of the Schneiderian membrane to create a confined space for the placement of graft material, graft material placement, barrier membrane placement, and flap closure.

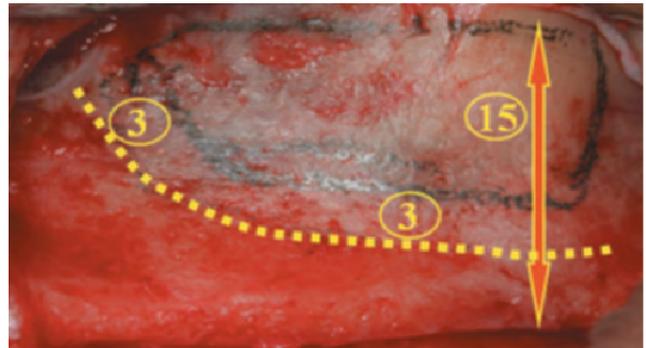
The continuous introduction of new techniques for lateral window entry are, in reality, surgical modifications designed to increase the predictability of the procedure while reducing the occurrence of the 2 main intraoperative complications: profuse bleeding and sinus membrane perforation. These complications can affect the procedural outcome by resulting in the abandonment of the procedure.⁴⁶ They can also affect procedural success by creating postoperative complications and, ultimately, they can affect implant survival by resulting in a deficient quantity and/or poor quality of bone.⁴⁷

PRESURGICAL ASSESSMENT

Although not the subject of this review, it is incumbent on the clinician to obtain sufficient diagnostic information before proceeding with this surgical technique. This information should include material relevant to both the surgical procedure and to the proposed prosthetic treatment plan, realizing that maxillary sinus elevation, after all, is a pre-prosthetic surgical procedure. In a survey paper of New York State ear, nose, and throat (ENT) specialists by Cote et al,⁴⁸ only 58.7% of this specialist group agreed that a computed tomography (CT) scan was a necessary part of presurgical diagnostic procedures. This viewpoint may result from an extension of the ENT's general protocol of not performing a surgical procedure on an asymptomatic patient, as well as the general trend toward reducing radiation exposure to patients. One could and should question this rationale for a number of reasons:

1. Knowledge of the health status of the sinus can prevent major postoperative complications.
2. Knowledge of the sinus anatomy can prevent many intraoperative complications.
3. Knowledge of 3-dimensional sinus anatomy can determine the validity of the proposed prosthetic plan.
4. Knowledge of preexisting sinus health and anatomy can prevent medico-legal complications.

Figure 2. Window location 3 mm from sinus floor, 3 mm from anterior wall.



For these reasons, the authors feel that a presurgical CT scan or cone-beam scan is strongly suggested before maxillary sinus elevation surgery.

FLAP ENTRY

Visualization of and access to the lateral sinus wall are accomplished via a full-thickness mucoperiosteal flap originating from the midcrestal area or slightly to the palate if the sinus floor is close to the crest or there is a minimal zone of keratinized tissue. Anterior and posterior releasing incisions are made of sufficient length, and in a slightly flaring direction, to provide both sufficient access and a flap with a good basal blood supply. A preoperative CT scan and clinical evaluation should make the location of the proposed antrostomy evident so that the releasing incisions are made distant to the proposed window site and the position of the overlapping barrier membrane. This will generally eliminate the potential for flap dehiscence.

ANTROSTOMY TECHNIQUES

An antrostomy is made in the lateral sinus wall to gain access to the Schneiderian membrane for the purpose of elevating this membrane, thereby creating a space for the placement of the bone graft material. The size of the window is generally a trade-off between preserving the lateral wall as a source of blood supply to the graft and achieving sufficient access and vision to perform the membrane elevation and graft placement without complications. It is the author's opinion (SSW) that larger windows should be made when the surgeon expects the elevation procedure to be difficult. This would include sinuses with septa, suspected membrane adhesions, narrow lateral to medial anatomy, "v-shaped" medial walls, and preexisting lateral wall defects from extractions or prior failed sinus augmentation procedures. The author (SSW) further likes to position the window approximately 3 mm from the sinus floor and 3 mm from the anterior wall, as this position greatly facilitates membrane elevation. The superior osteotomy is made at 15 mm from the crest to

Figure 3. Postoperative CT cross sectional views of a properly (A) and improperly (B) grafted sinus.

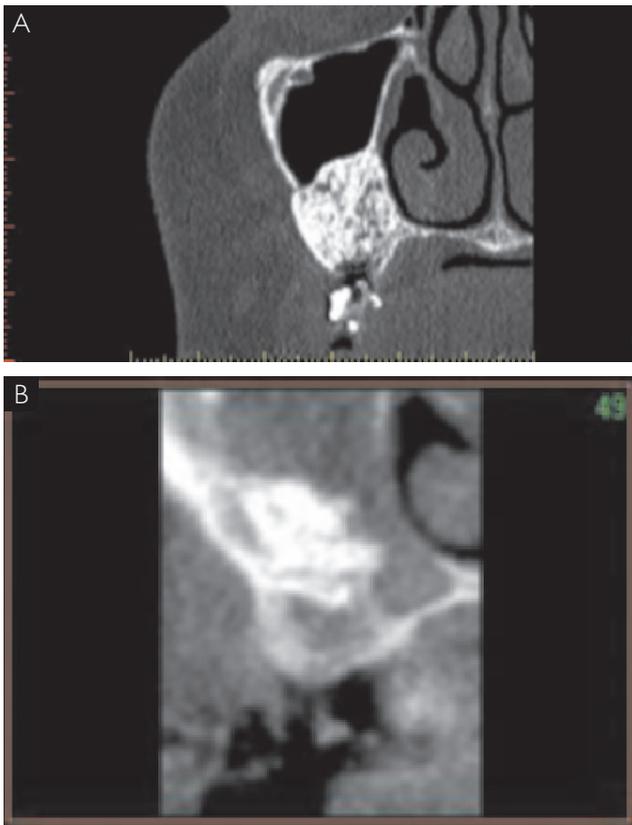
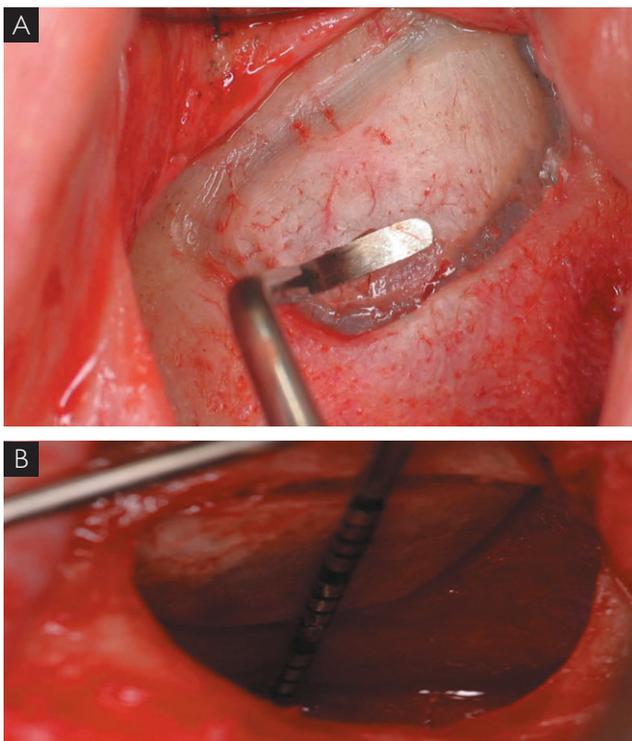


Figure 4. (A) Sinus membrane visible on all but superior antrostomy cut (the hinge). (B) Hinge osteotomy. Note elevation of the membrane up the medial wall.



facilitate grafting to that height without having to release the membrane farther in the superior direction (Fig. 2). It is understood that the vascular supply to the newly placed graft comes mostly from the bony walls of the sinus and not from the Schneiderian membrane. It is therefore imperative that the membrane be elevated across the sinus floor and up the medial wall to the level of the proposed graft placement. Further, this elevation usually must extend anteriorly to reach and extend up a portion of the anterior sinus wall to allow for graft placement in the future receptor site for the most anterior implant. This will enable a vascular supply from the medial wall to reach the graft. As vascular ingrowth occurs at a rate of 1 mm per month, graft maturation time can be substantially reduced with this dual blood supply, especially in wide sinuses. Thorough grafting from lateral to medial walls is also of importance when considering implant placement. The maxilla resorbs in an upward and inward direction, which in many instances requires the apex of the implant to be angled toward the medial wall to achieve a proper prosthetic positioning. A graft falling short of this end point may ultimately compromise implant placement (Fig. 3, A and B).

Figure 5. Complete osteotomy. Window is removed before elevation of the membrane.

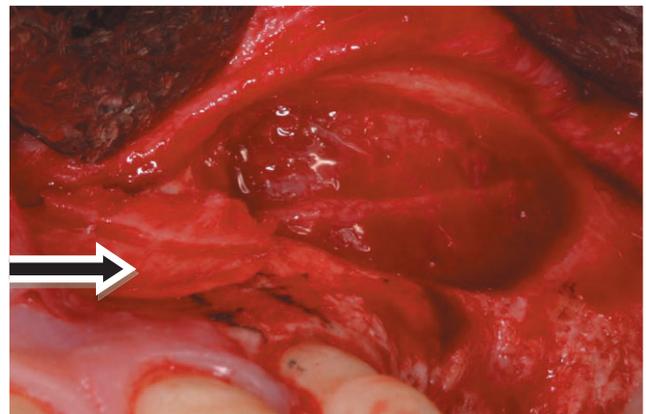


Figure 6. Particulate xenograft in place.

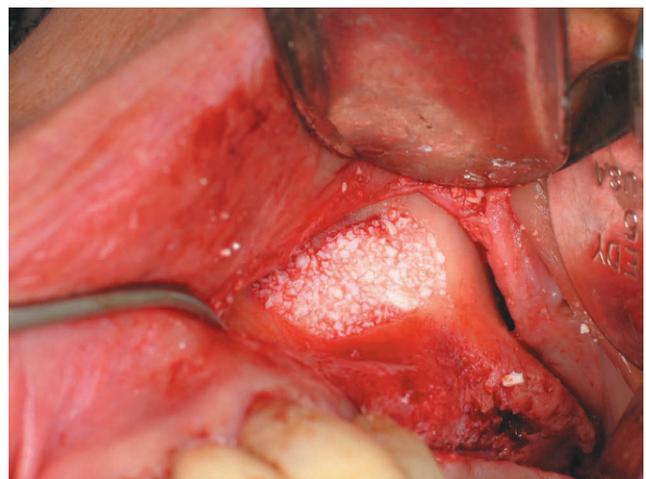


Figure 7. Collagen barrier membrane (BioGide) over window. A supple membrane that adapts to the irregular bony surface requires no stabilization.

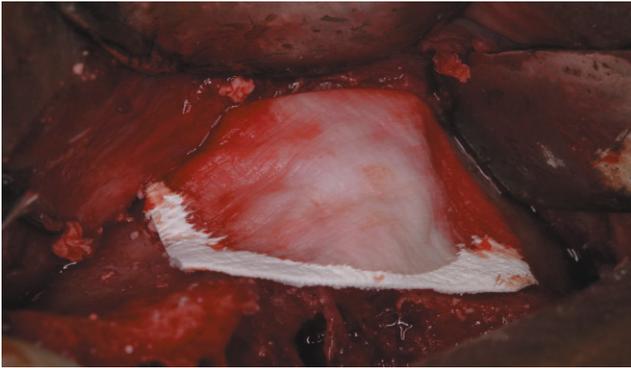
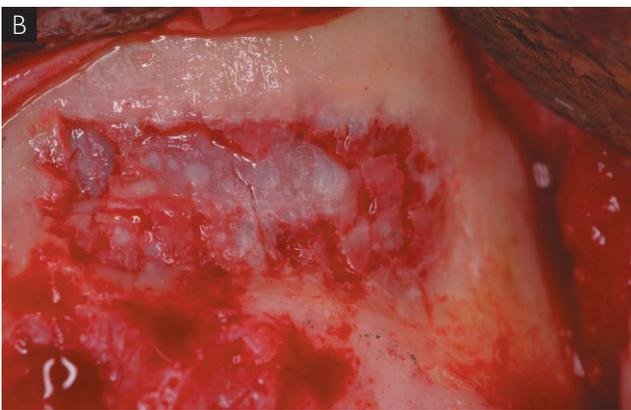
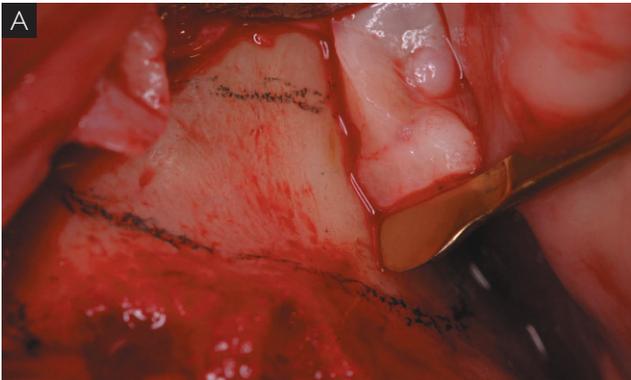


Figure 8. (A) Piezoelectric osteoplasty insert in place. (B) Bone removal following osteoplasty.



ROTARY TECHNIQUE

Once the window location is determined or outlined, a high-speed hand piece or surgical motor with external irrigation is used with a round diamond bur (safer than carbide) to create a “window” in the lateral sinus wall. The cutting motion should be with a lateral motion rather than an up-and-down motion, the latter being more likely to result in membrane perforation. The sinus membrane, usually visualized as a dark shadow, is approached carefully until it is possible to observe movement of the window. The hinge technique keeps the superior osteotomy cut partially incomplete and the lateral

Figure 9. Piezoelectric osteotomy insert in place to refine antrostomy.

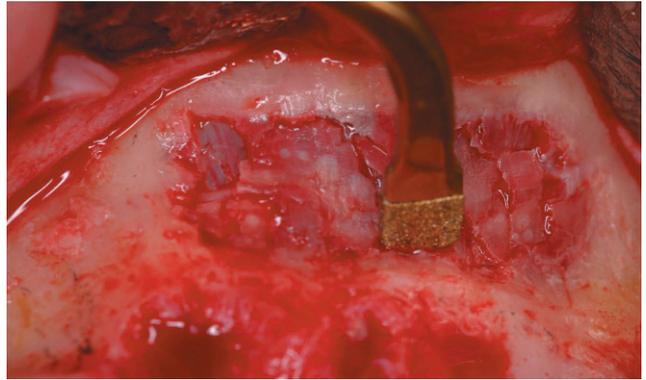


Figure 10. Artery isolated and left intact.

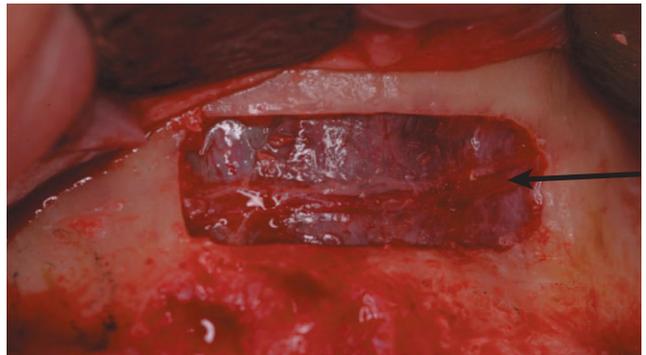


Figure 11. Initial piezoelectric elevator in position.



wall “window” is rotated (hinged) inward and upward to a horizontal position. Alternatively the osteotomy can extend 360° creating an “island” of bone in the center. This can remain attached to the membrane, being elevated with it, or it can be removed with the procedure now called a complete osteotomy. There are no published data to show that one approach is more favorable than another. In cases where the sinus is narrow, the window must be removed, as it may not be possible to hinge it inward without being obstructed by the medial wall. The elevation of the membrane is followed by the introduction of the graft material and the placement of a collagen barrier membrane extending a few mm over the lateral window (Figs. 4–7).

Figure 12. An 8-mm DASK drill on sinus wall.

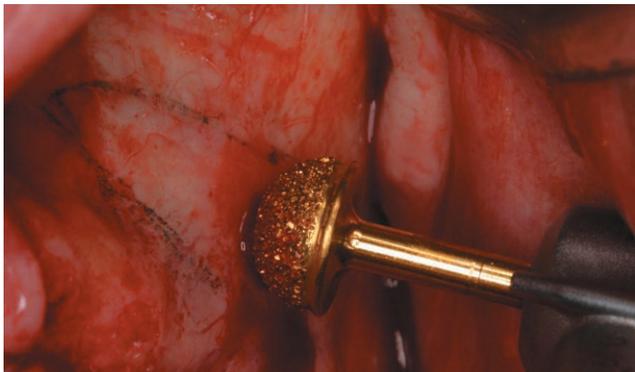


Figure 16. Membrane elevation completed.

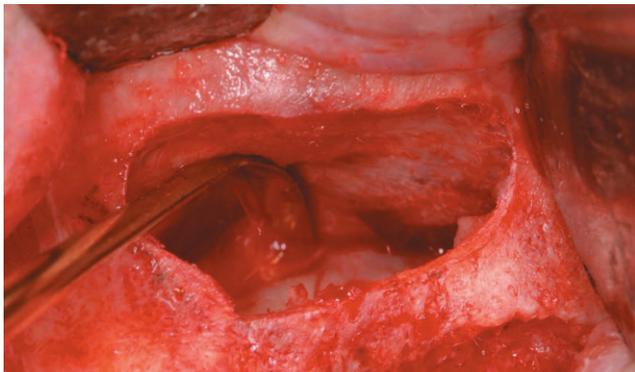


Figure 13. Thinning the lateral wall.

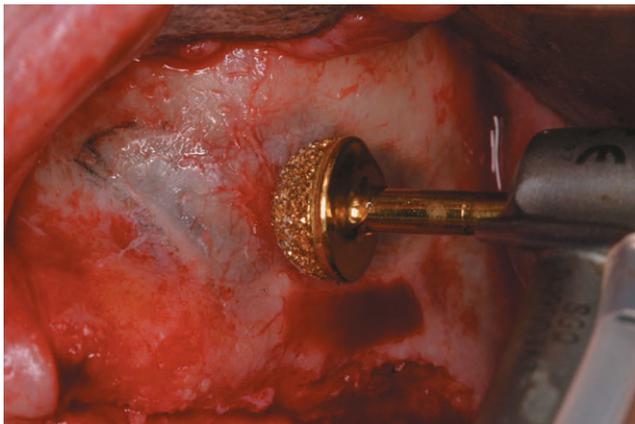


Figure 17. Bone replacement graft in place.



Figure 14. Window completed, leaving very thin layer of bone and microvasculature intact.

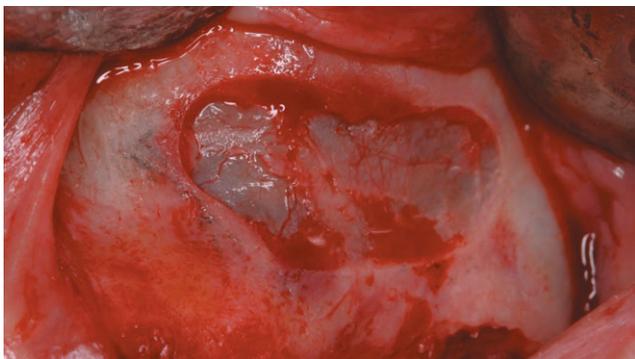
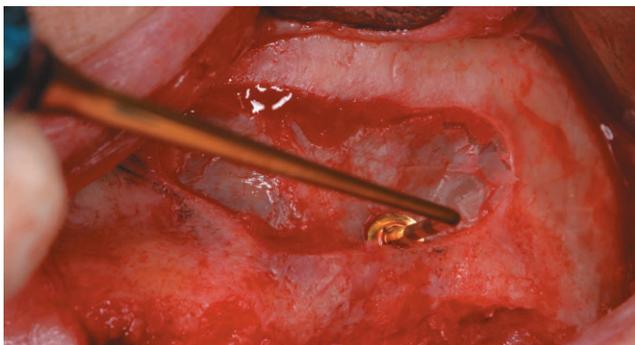


Figure 18. Collagen barrier membrane in place.



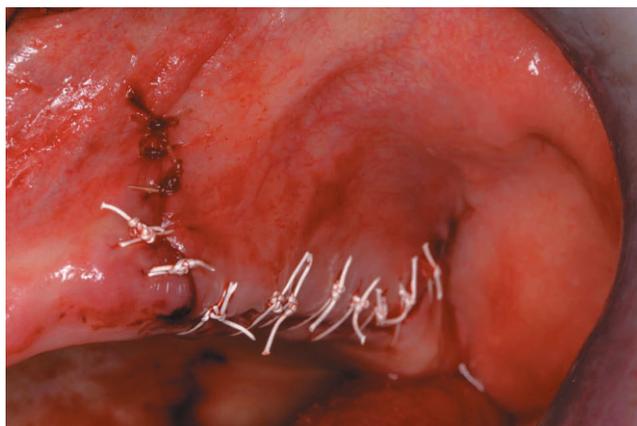
Figure 15. Initial membrane elevation.



PIEZOELECTRIC TECHNIQUE

Although the rotary technique has proven to be a very predictable technique over the past 30 years, it is subject to a pair of intraoperative complications, namely sinus membrane perforation and instances of profuse, usually intrabony, bleeding. In a study by Zijderfeld et al⁴⁹ reporting on intraoperative complications in 100 consecutive cases, membrane perforations were reported in 11% of cases and profuse bleeding in 2%. The perforation rate in this study using rotary instrumentation is quite low, as a review of the literature reveals an average perforation rate of 20% to 25%.

Figure 19. Primary intention closure with Gore-Tex and chromic gut.



Piezosurgery, a surgical technique invented by Dr Tomaso Vercellotti, and first published in the United States in 2001,⁴⁴ uses low-frequency ultrasonic vibration to create the lateral window and elevate the sinus membrane. This technique eliminates the “drag” created by rotary instrumentation and is therefore less likely to damage blood vessels or the Schneiderian membrane. Three studies⁵⁰⁻⁵² report perforation rates of 5.0%, 3.8%, and 3.6% when using piezoelectric surgery. Furthermore, blood vessels present in the lateral wall can be safely avoided and isolated, allowing bone removal to proceed without injury to these soft tissues. All previously described window techniques can be performed with piezoelectric surgery. Bone removal is accomplished with special inserts that can perform either osteotomy or osteoplasty procedures. The author’s (SSW) most commonly used technique is to perform an osteoplasty that removes all of the bone in the window area, resulting in direct access and vision of the sinus membrane. The consumed bone can be harvested and added to the graft material but the evidence-base shows that this is not necessary. A special trumpet-shaped elevation insert is then used at a low-power setting to safely begin the elevation of the sinus membrane (Figs. 8-11). Elevation can then be continued with either angled piezoelectric elevator inserts or hand elevators.

DASK TECHNIQUE

The DASK technique was developed to create an alternative nonpiezoelectric technique for maxillary sinus elevation that has the capability of reducing soft tissue complications for both the lateral and transcrestal approaches. The lateral window approach has been described by Lozada et al⁴² as a lateral bone-planing antrostomy technique. The membrane perforation rate in this study was 5.8%. DASK makes use of either a 6- or 8-mm diameter × 4-mm high dome-shaped drill with a nonaggressive diamond grit and both internal and external irrigation. The drills are operated at 800 to 1200 rpm and produce little or no “drag” when compared with

traditional rotary instrumentation. The drill is used with light pressure to plane or thin the bone of the lateral wall. As the bone is thinned, the blue shadow of the sinus membrane becomes more apparent. With proper technique, a very thin, movable, layer of bone remains attached to the sinus membrane. It is often possible to see the microvasculature of the lateral wall intact within this layer. The thin bony layer and membrane can be elevated as a unit or the bone fragments can be gently removed with a curette, creating a complete osteotomy, allowing for ideal access and vision to elevate the sinus membrane (Figs. 12-19).

CONCLUSIONS

The maxillary sinus elevation procedure is today considered to be the most predictable of the pre-prosthetic surgical techniques.⁶ Success rates, as determined by the secondary outcome measure of implant survival, are in the high 90th percentile when utilizing the proven evidence-based decisions to use rough-surfaced implants, xenogeneic bone replacement grafts, and a membrane over the window. With such high success rates, the developing technologies of bone graft enhancement factors (BMPs, growth factors, and stem cell products) are unlikely to result in any dramatic change. What they may do is reduce the time necessary for graft maturation. Studies using rh-PDGF_{ββ}³⁵ and OsteoCel³⁶ have shown this capability. The evolution of surgical technique is directed toward reducing the complications that may negatively affect the primary outcome of procedural success. A study by Becker et al⁴⁶ has shown that 10% of membrane perforations could not be repaired and resulted in termination of the sinus elevation procedure. Piezoelectric surgery, and recently the DASK technique, have demonstrated the capability to dramatically reduce the perforation rate and thereby reduce the number of procedure terminations.

Future clinical studies will likely substantiate these findings and possibly lead to further improvements in our ability to provide beneficial services to our patients.

REFERENCES

1. Tatum H Jr. Maxillary and sinus implant reconstruction. *Dent Clin North Am* 1986;30:207-29.
2. Boyne PJ, James RA. Grafting of the maxillary sinus floor with autogenous marrow and bone. *J Oral Surg* 1980;38:613-6.
3. Jensen OT, Shulman LB, Block MS, Iacono VJ. Report of the Sinus Consensus Conference of 1996. *Int J Oral Maxillofac Implants* 1998;13:11-5.
4. Wallace SS, Froum SJ. Effect of maxillary sinus augmentation on the survival of endosseous dental implants. A systematic review. *Ann Periodontol* 2003;8:328-43.
5. Del Fabbro M, Testori T, Francetti L, Weinstein R. Systematic review of survival rates for implants placed in the grafted maxillary sinus. *Int J Periodontics Restorative Dent* 2004;24:565-77.

6. Aghaloo T, Moy PK. Which hard tissue augmentation techniques are the most successful in furnishing bony support for implant placement? *Int J Oral Maxillofac Implants* 2007;22(Suppl):49-70.
7. Pjetursson BE, Tan WC, Zwahlen M, Lang NP. A systematic review of the success of sinus floor elevation and survival of implants inserted in combination with sinus floor elevation. Part I: lateral approach. *J Clin Periodontol* 2008;35(Suppl 8):216-24.
8. Del Fabbro M, Rosano G, Taschieri S. Implant survival rates after maxillary sinus augmentation. *Eur J Oral Sci* 2008;116:497-506.
9. Nkenke E, Stelzle F. Clinical outcomes of sinus floor augmentation for implant placement using autogenous bone or bone substitutes: a systematic review. *Clin Oral Implants Res* 2009;20(Suppl 4):124-33.
10. Jensen SS, Terheyden H. Bone augmentation procedures in localized defects in the alveolar ridge: clinical results with different bone grafts and bone-substitute materials. *Int J Oral Maxillofac Implants* 2009;24(suppl):218-38.
11. Esposito M, Grusovin MG, Rees J, Karasoulos D, Felice P, Alissa R, et al. Interventions for replacing missing teeth: augmentation procedures of the maxillary sinus. *Cochrane Database Syst Rev* 2010;(3):CD008397.
12. Del Fabbro M, Bortolin M, Taschieri S, Rosano G, Testori T. Implant survival in maxillary sinus augmentation. An updated systematic review. *J Osteol Biomat* 2010;1:69-79. Erratum in: *J Osteol Biomat* 2010;1:186.
13. Del Fabbro M, Wallace SS, Trisi P, Capelli M, Zuffetti F, Testori T. Long-term implant survival in the grafted maxillary sinus: a systematic review. *Int J Periodont Restorative Dent* (accepted for publication October, 2011).
14. Traini T, Valentini P, Iezzi G, Piattelli A. A histologic and histomorphometric evaluation of ABBM retrieved 9 years after a sinus augmentation. *J Periodontol* 2007;78:955-61.
15. Mordenfeld A, Hallman M, Albrektsson T. Histological & histomorphometrical analyses of biopsies harvested 11 years after maxillary sinus augmentation with 80% BioOss and 20 % autogenous bone. *Clin Oral Implants Res* 2010;21:961-70.
16. Chackartchi T, Iezzi G, Goldstein M, Klingner A, Soskolne A, Piattelli A, et al. Sinus floor augmentation using large (1-2 mm) or small (0.25-1 mm) bovine bone mineral particles: a prospective, intra-individual controlled clinical, micro-computerized tomography and histomorphometric study. *Clin Oral Implants Res* 2011;22:473-80.
17. Testori T, Wallace SS, Trisi P, Capelli M, Zuffetti F, Del Fabbro M. Effect of xenograft (ABBM) particle size on vital bone formation following maxillary sinus augmentation: A multi-center randomized, controlled, clinical histomorphometric trial in humans. *Int J Periodontics Restorative Dent*. (accepted for publication March 2012)
18. Froum SJ, Tarnow DP, Wallace SS, Rohrer MD, Cho SC. Sinus floor elevation using anorganic bovine bone matrix (OsteoGraf/N) with and without autogenous bone: a clinical, histologic, radiographic, and histomorphometric analysis—Part 2 of an ongoing prospective study. *Int J Periodontics Restorative Dent* 1998;18(6):528-43.
19. Valentini P, Abensur D, Wenz B, Peetz M, Schenk R. Sinus grafting with porous bone mineral (Bio-Oss) for implant placement: a 5-year study on 15 patients. *Int J Periodontics Restorative Dent* 2000;20(3):245-53.
20. Kolerman R, Samorodnitsky GR, Barnea E, Tal H. Histomorphometric analysis of newly formed bone after bilateral maxillary sinus augmentation using two different osteoconductive materials and internal collagen membrane. *Int J Periodontics Restorative Dent* 2012;32:e21-8.
21. Cha JK, Park JC, Jung UW, Kim CS, Cho KS, Choi SH. Case series of maxillary sinus augmentation with biphasic calcium phosphate: a clinical and radiographic study. *J Periodontal Implant Sci* 2011;41(2):98-104.
22. Boyne PJ, Marx RE, Nevins M, Triplett G, Lazaro E, Lilly LC, et al. A feasibility study evaluating rhBMP-2/absorbable collagen sponge for maxillary sinus floor augmentation. *Int J Periodontics Restorative Dent* 1997;17(1):11-25.
23. Boyne PJ, Lilly LC, Marx RE, Moy PK, Nevins M, Spagnoli DB, et al. De novo bone induction by recombinant human bone morphogenetic protein-2 (rhBMP-2) in maxillary sinus floor augmentation. *J Oral Maxillofac Surg* 2005;63(12):1693-707.
24. Triplett RG, Nevins M, Marx RE, Spagnoli DB, Oates TW, Moy PK, et al. Pivotal, randomized, parallel evaluation of recombinant human bone morphogenetic protein-2/absorbable collagen sponge and autogenous bone graft for maxillary sinus floor augmentation. *J Oral Maxillofac Surg* 2009;67(9):1947-60.
25. Tarnow DP, Wallace SS, Testori T, Froum SJ, Motroni A, Prasad HS. Maxillary sinus augmentation using recombinant bone morphogenetic protein-2/acellular collagen sponge in combination with a mineralized bone replacement graft: a report of three cases. *Int J Periodontics Restorative Dent* 2010;30(2):139-49.
26. Kao D, Kubota A, Nevins M, Fiorellini JP. The negative effect of combining rh-BMP-2 and Bio-Oss on bone formation for maxillary sinus augmentation. *Int J Periodontics Restorative Dent* 2012;32:60-8.
27. Carragee EJ, Ghanayem AJ, Weiner BK, Rothman DJ, Bono CM, et al. A challenge to integrity in spine publications: years of living dangerously with promotion of bone growth factors. *Spine J* 2011;11:463-8.
28. Carragee EJ, Hurwitz EL, Wiener BK. Critical review of rhBMP-2 trails in spinal surgery: emerging safety concerns and lessons learned. *Spine J* 2011;11:471-91.
29. Sánchez AR, Sheridan PJ, Kupp LI. Is platelet-rich plasma the perfect enhancement factor? A current review. *Int J Oral Maxillofac Implants* 2003;18(1):93-103.
30. Esposito M, Grusovin MG, Coulthard P, Worthington HV. The efficacy of various bone augmentation procedures for dental implants. A Cochrane systematic review of randomized controlled clinical trials. *Int J Oral Maxillofac Implants* 2006;21(5):696-710.
31. Boyapati L, Wang HL. The role of platelet-rich plasma in sinus elevation: a critical review. *Implant Dent* 2006;15(2):160-70.
32. Nevins M, Camelo M, Nevins ML, Schenk RK, Lynch SE. Periodontal regeneration in humans using recombinant human platelet-derived growth factor-BB (rhPDGF-BB) and allogenic bone. *J Periodontol* 2003;74(9):1282-92.
33. Camelo M, Nevins ML, Schenk RK, Lynch SE, Nevins M. Periodontal regeneration in human Class II furcations using purified recombinant human platelet-derived growth factor-BB (rhPDGF-BB) with bone allograft. *Int J Periodontics Restorative Dent* 2003;23(3):213-25.
34. Nevins M, Garber D, Hanratty JJ, McAllister BS, Nevins ML, Salama M, et al. Human histologic evaluation of anorganic bovine bone mineral combined with recombinant human platelet-derived growth factor BB in maxillary sinus augmentation: case series study. *Int J Periodontics Restorative Dent* 2009;29(6):583-91.
35. Froum SJ, Wallace SS, Ricci J, Bromage T, et al. A histomorphometric comparison of Bio-Oss alone vs. Bio-Oss and platelet-derived growth factor for sinus augmentation: a 4-9 month post-surgical assessment of vital bone formation. *Int J Periodontics Restorative Dent* (accepted for publication August 2012).
36. Gonshor A, McAllister BS, Wallace SS, Prasad H. Histologic and histomorphometric evaluation of an allograft stem cell-based matrix sinus augmentation procedure. *Int J Oral Maxillofac Implants* 2011;26(1):123-31.

37. Lundgren S, Andersson S, Gualini F, Sennerby L. Bone reformation with sinus membrane elevation: a new surgical technique for maxillary sinus floor augmentation. *Clin Implant Dent Relat Res* 2004;6(3):165-73.
38. Cricchio G, Sennerby L, Lundgren S. Sinus bone formation and implant survival after sinus membrane elevation and implant placement: a 1- to 6-year follow-up study. *Clin Oral Implants Res* 2011;22(10):1200-12.
39. Lin IC, Gonzalez AM, Chang HJ, Kao SY, Chen TW. A 5-year follow-up of 80 implants in 44 patients placed immediately after the lateral trap-door window procedure to accomplish maxillary sinus elevation without bone grafting. *Int J Oral Maxillofac Implants* 2011;26(5):1079-86.
40. Borges FL, Dias RO, Piattelli A, Onuma T, Gouveia Cardoso LA, Salomão M, et al. Simultaneous sinus membrane elevation and dental implant placement without bone graft: a 6-month follow-up study. *J Periodontol* 2011;82(3):403-12.
41. Mazor Z, Horowitz R, Del Corso M, Prasad HS, Rohrer MD, Dohan Ehrenfest DM, et al. Sinus floor augmentation with simultaneous implant placement using Choukron's platelet-rich fibrin as the sole grafting material: a radiographic and histologic study at 6 months. *J Periodontol* 2009;80:2056-64.
42. Wood RM, Moore DL. Grafting of the maxillary sinus with intraorally harvested autogenous bone prior to implant placement. *Int J Oral Maxillofac Implants* 1988;3(3):209-14.
43. Smiler DG. The sinus lift graft: basic technique and variations. *Pract Periodontics Esthet Dent* 1997;9:885-93.
44. Vercellotti T, De Paoli S, Nevins M. The piezoelectric bony window osteotomy and sinus membrane elevation: introduction of a new technique for simplification of the sinus augmentation procedure. *Int J Periodontics Restorative Dent* 2001;21:561-7.
45. Lozada JL, Goodacre C, Al-Ardah A, Garbace A. Lateral and crestal bone planing antrostomy: a simplified surgical procedure to reduce the incidence of membrane perforation during maxillary sinus augmentation procedures. *J Prosthet Dent* 2011;105:147-53.
46. Becker ST, Terheyden H, Steinriede A, Behrens E, Springer I, Wiltfang J. Prospective observation of 41 perforations of the Schneiderian membrane during sinus floor elevation. *Int J Oral Maxillofac Surg* 2010;39(7):699-704.
47. Proussaefs P, Lozada J, Kim J, Rohrer MD. Repair of the perforated sinus membrane with a resorbable collagen membrane: a human study. *Int J Oral Maxillofac Implants* 2004;19(3):413-20.
48. Cote MT, Segelnick SL, Rastogi A, Schoor R. New York State ear, nose, and throat specialists' views on pre-sinus lift referral. *J Periodontol* 2011;82(2):227-33.
49. Zijdeveld SA, van den Bergh JP, Schulten EA, ten Bruggenkate CM. Anatomical and surgical findings and complications in 100 consecutive maxillary sinus floor elevation procedures. *J Oral Maxillofac Surg* 2008;66(7):1426-38.
50. Wallace SS, Mazor Z, Froum SJ, Cho S-C, Tarnow DP. Schneiderian membrane perforation rate during sinus elevation using piezosurgery. *Int J Periodontics Restorative Dent* 2007;27:413-9.
51. Blus C, Szmukler-Moncler S, Salama M, Salama H, Garber D. Sinus bone grafting procedures using ultrasonic bone surgery: 5-year experience. *Int J Periodontics Restorative Dent* 2008;28:221-30.
52. Toscano N, Holtzclaw D, Rosen P. Effect of piezoelectric use on open sinus lift perforation: evaluation of 56 cases. *J Periodontol* 2010;81:167-71.