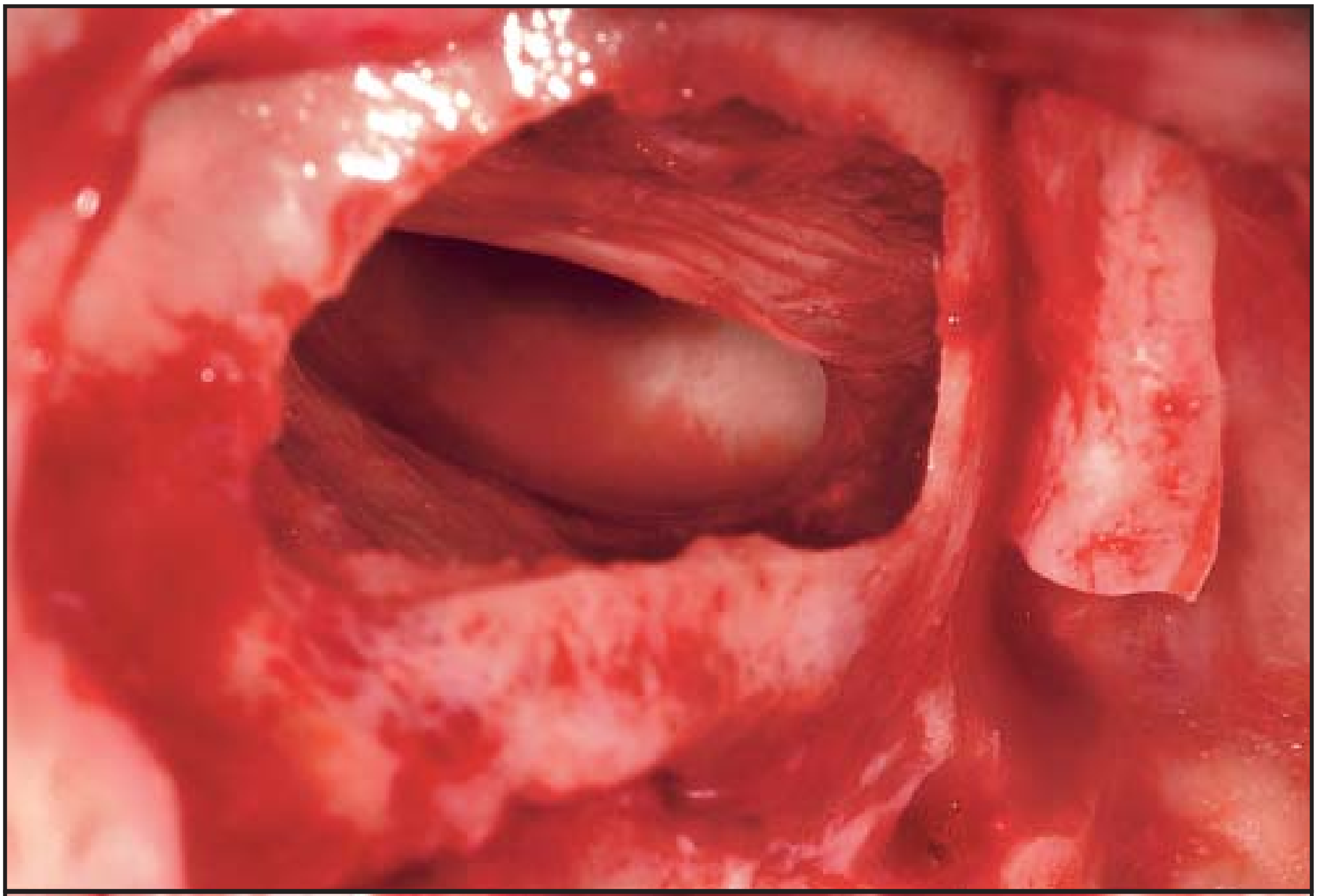

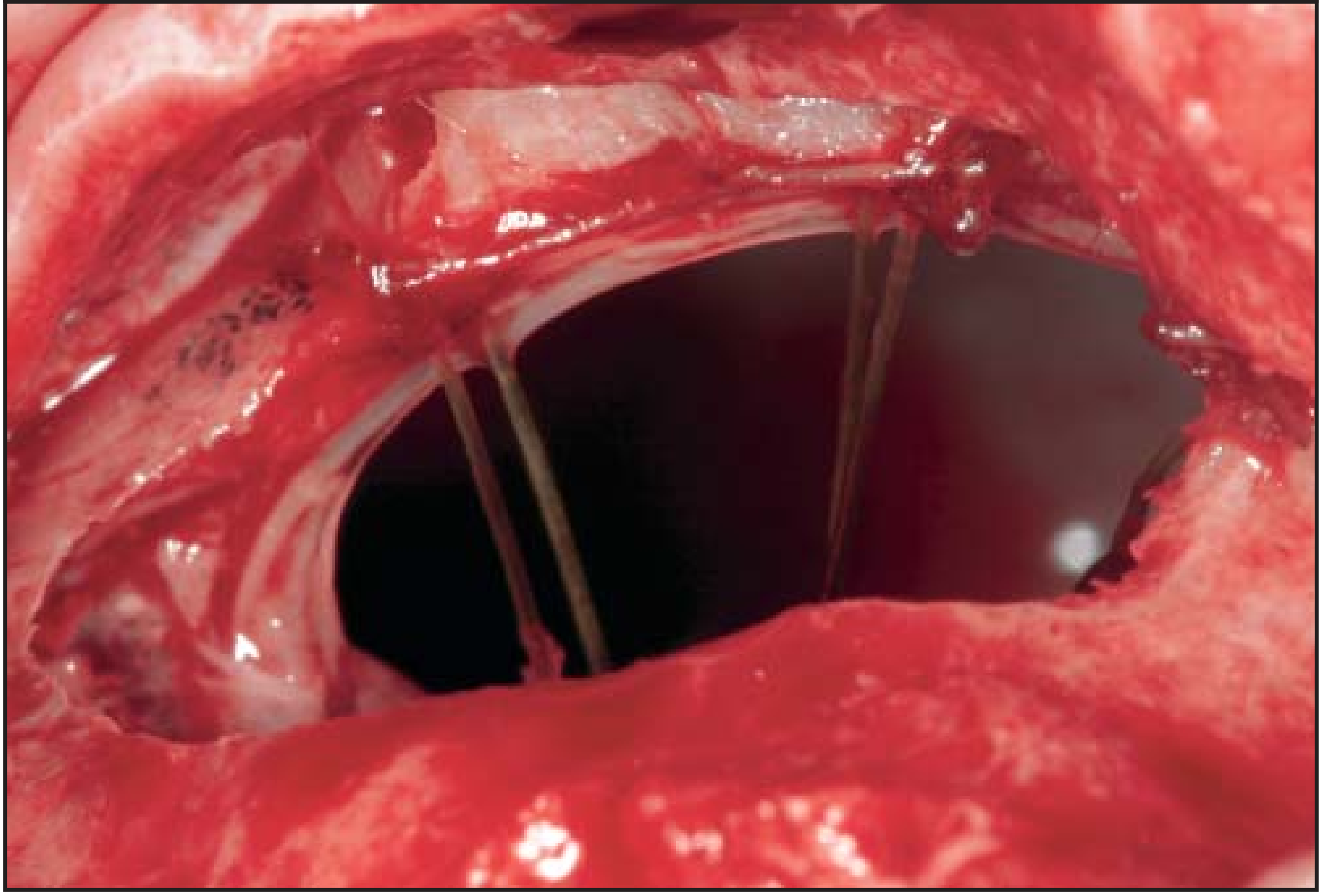

Repair of Large Sinus Membrane Perforations Using Stabilized Collagen Barrier Membranes: Surgical Techniques with Histologic and Radiographic Evidence of Success

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The most frequent intraoperative complication with sinus elevation is perforation of the schneiderian membrane. In most instances, the repair of this perforation is necessary to contain particulate grafting material and complete the procedure. New techniques are presented here for the management of large perforations of the schneiderian membrane. A bioabsorbable collagen membrane is stabilized outside the antrostomy and then folded inward to create either a new superior wall that can obliterate a large perforation or a "pouch" that can completely contain the particulate material. This can make it possible to complete a procedure that otherwise may have had to be aborted by preventing dispersion of the particulate graft within the sinus cavity. Clinical cases are shown, along with follow-up at 6 to 9 months, demonstrating histologic and/or radiographic evidence of success, continued sinus health, and superior vital bone formation. The authors have used this technique on 20 consecutive patients without experiencing any procedural failures. (Int J Periodontics Restorative Dent 2008;28:9–17.)

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A review of the sinus augmentation literature of the past 25 years reveals the evolution of sinus grafting techniques, with subsequent prosthetic rehabilitation, into a highly predictable discipline.[1–3] The lateral window technique uses many antrostomy designs, and the procedure can be performed with various forms of surgical instrumentation. These include electric or air-driven handpieces and piezosurgical devices. In most cases the elevation of the schneiderian membrane, performed prior to the placement of the bone graft, is performed with hand instrumentation.

The most frequent intraoperative complication with this type of surgery is the perforation of the schneiderian membrane.[4–6] A review of the literature reveals perforation rates that vary from 11% to 56%.[5–20] Vlassis and Fugazzotto[21] classified perforations based on their location and size and have proposed appropriate repair techniques for each classification. The same authors later simplified their classification into just three types with respect to size and location and recommended repair techniques for each.[22]

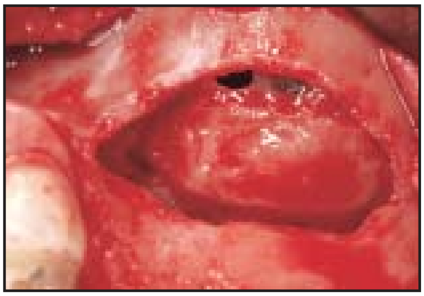

Fig 1a (left) *The sinus membrane perforation is visible on the superior border of the antrostomy.*

Fig 1b (right) *Repair membrane (BioMend, Zimmer) is in place, with a portion outside the sinus window and the remainder folded into the sinus to make a new roof.*

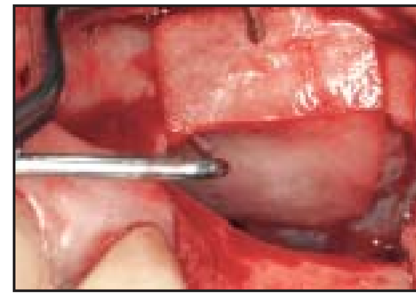

Fig 1c (left) *Particulate graft material (Bio-Oss) in place.*

Fig 1d (right) *Histology at 9 months. Bio-Oss particles* (yellow) *are in direct contact with newly formed vital bone* (red). *Osteoid* (green) *lines many surfaces (Stevenel's blue and van Gieson picric fuchsin; original magnification ×10).*

Solutions proposed to treat the problems associated with sinus membrane perforations include the following:

1. Abort the procedure and attempt after the perforation has healed.
2. Use a stabilized block graft without attempting to repair the perforation.
3. Repair the perforation with collagen membranes or lamellar bone.

The repair of perforations with bioabsorbable collagen barrier membranes has been previously documented.[14,17,21–25] However, certain problems may occur when using the barrier membrane repair technique. These include the shifting of the barrier away from the perforation during graft placement and the possibility of an unstable repair membrane falling through a large perforation, with subsequent loss of containment of the graft material.

This paper presents surgical techniques for the management of perforations of the schneiderian membrane that result in mechanical stabilization of the repair membrane, thereby preventing the aforementioned adverse events.

Perforation repair techniques

Whether the perforation occurs during antrostomy procedures or during elevation of the schneiderian membrane, it is first necessary to complete the elevation of the membrane from the internal sinus walls. Every attempt should be made to complete this task without increasing the size of the perforation. Once schneiderian membrane elevation is complete, the size and location of the perforation will dictate the need for, and the location of, devices to stabilize the repair membrane(s).

Two techniques for repair are presented. The first technique creates a stabilized roof for the damaged graft material compartment. The second technique creates a stabilized pouch that will completely contain the graft material.

Patient reports

Patient 1

The perforation in this case was moderate in size and located near the superior antrostomy cut. A problem can occur when using a nonstabilized membrane if the membrane shifts medially in position during the placement of the graft material. Placement of a portion of the repair membrane outside the sinus window will keep the membrane from shifting (Figs 1a to 1c). Histomorphometric analysis of a core taken through the former lateral

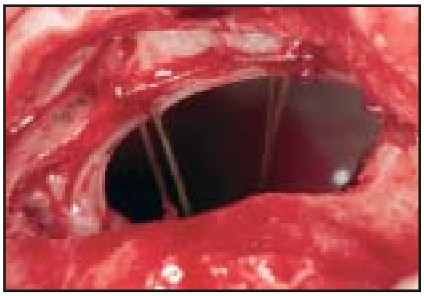

Fig 2a (left) *Large tear above superior antrostomy with suture "struts" in place. Note holes through lateral wall above lateral window for suture stabilization.*

Fig 2b (right) *Repair membrane (BioMend) in position.*

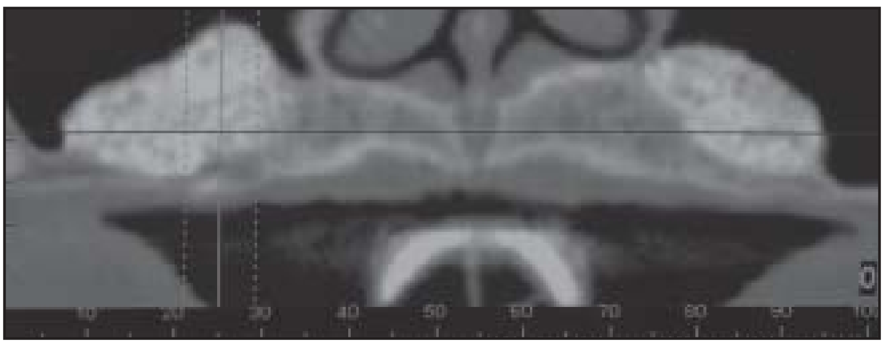

Fig 2c *Nine-month postoperative CT scan.*

Fig 2d *Histology at 9 months. Bio-Oss particles* (yellow) *are in direct contact with newly formed vital bone* (red). *Osteoid* (green) *lines many surfaces (Stevenel's blue and van Gieson picric fuchsin; original magnification ×20).*

window area at the time of implant placement (9 months) revealed 26% vital bone formation (Fig 1d).

Patient 2

A bilateral sinus elevation was performed using anorganic bovine bone (Bio-Oss, Geistlich). The preoperative scan revealed the presence of a very thin membrane. The left-side surgery was completed without complications, but a very large tear occurred on the right side (Fig 2a). The remaining portion of the schneiderian membrane was elevated up the medial wall to the height required for future implant placement. After the membrane was freed for a few millimeters above the superior antrostomy cut, a series of holes was made in the lateral wall with a small round carbide bur. Resorbable sutures (4-0 Vicryl, Ethicon) were used to gently engage the torn membrane on the medial wall to create a series of suture "struts" along the superior aspect of the window by tying the sutures through the holes made in the lateral wall. The repair membrane was then cut, folded, and stabilized superiorly with two titanium tacks (Fig 2b). After the graft was placed, an additional barrier membrane (BioGide, Geistlich) was placed over the lateral window.

An immediate postoperative panoramic radiograph was obtained to confirm graft containment, and a second was obtained at 6 weeks to confirm continued containment. At 9 months, a computerized tomograph (CT) was obtained to confirm three-dimensional graft containment, and a histologic core was taken to evaluate vital bone formation. The CT demonstrated complete containment of the particulate graft on both sides and showed no signs of sinus inflammation (Fig 2c). Histologic evaluation revealed newly formed vital bone surrounding residual Bio-Oss particles (Fig 2d). Histomorphometric analysis of the repaired site revealed 22% vital bone, 30% residual xenograft, and 48% marrow. Direct contact was seen between the graft particles and the newly formed vital bone. This is consistent with previously published data on xenografts.[26–28]

Patient 3

The preoperative scan, as in the previous case, revealed the presence of a thin sinus membrane. After appropriate anesthesia was administered, a full-thickness mucoperiosteal flap was elevated to expose the lateral wall of the maxillary sinus. The antrostomy was then performed by means of piezoelectric inserts followed by elevation with hand instruments. During the course of membrane elevation, a 5 × 2–mm perforation occurred in the region of the coronal osteotomy cut. During further elevation, the perforation became larger, finally extending over most of the antrostomy lumen (Fig 3a). A collagen barrier membrane (BioGide) was placed over the perforation and stabilized with titanium tacks externally near the coronal limit of the antrostomy. (If possible, resorbable tacks should be used.) The repair membrane was then folded into the sinus, creating a pouch to contain the graft material (Fig 3b). The sinus was subsequently grafted with anorganic bovine bone (Bio-Oss spongiosa, 0.25 to 1 mm) mixed with 5 mL of the patient's blood to improve its consistency (Fig 3c). The graft was then covered externally with a second bioabsorbable collagen barrier membrane. The repair technique is shown schematically in Fig 3d. Tension-free primary closure was achieved with all incisions distant from the external barrier membrane.

A postoperative panoramic radiograph and a 6-month CT scan were obtained; these showed no signs of hypertrophy of the sinus membrane (Fig 3e). At implant placement, after informed consent was obtained, a trephine bone core biopsy was performed through the former lateral window from a site distal to the most posterior implant site. The specimen was sent to the BioCRA Laboratory, where it was processed according to a previously published technique.[29]

Histologic specimens (Fig 3f) showed newly formed bone connecting the particles of anorganic bovine bone in a mosaic pattern. It was also possible to note a newly formed cortical wall of composite bone in the area of the former lateral window. The xenograft appeared in direct contact with the newly formed bone, providing evidence of the osteoconductivity of the graft material. The combination of residual graft material and newly formed bone resulted in considerable bone density. Bone remodeling with osteoclastic resorption was observed. Resorption of the graft particles is also visible.

Second-stage surgery was performed 4 months after implant placement. A provisional prosthesis was placed at that time, and the definitive prosthesis was placed 6 months later.

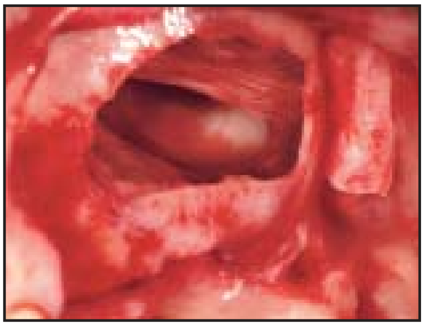

Fig 3a *View of large sinus membrane perforation.*

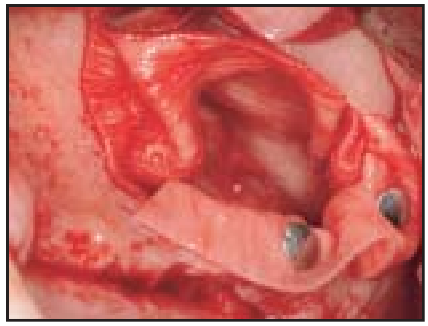

Fig 3b *Repair membrane is folded into the sinus, creating a pouch.*

Fig 3c *Xenograft is placed into the pouch.*

Fig 3d *Schematic drawing of the repair shown in Figs 3a to 3c.*

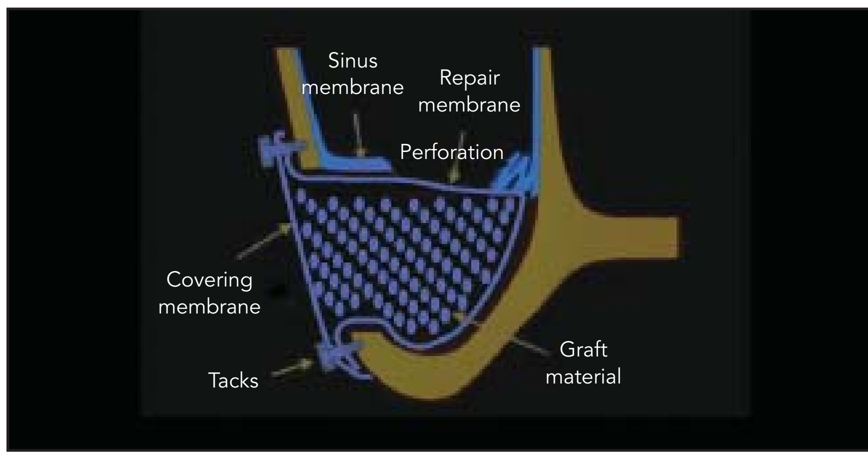

Fig 3e *CT scan at 6 months shows graft containment and no hypertrophy of the sinus membrane.*

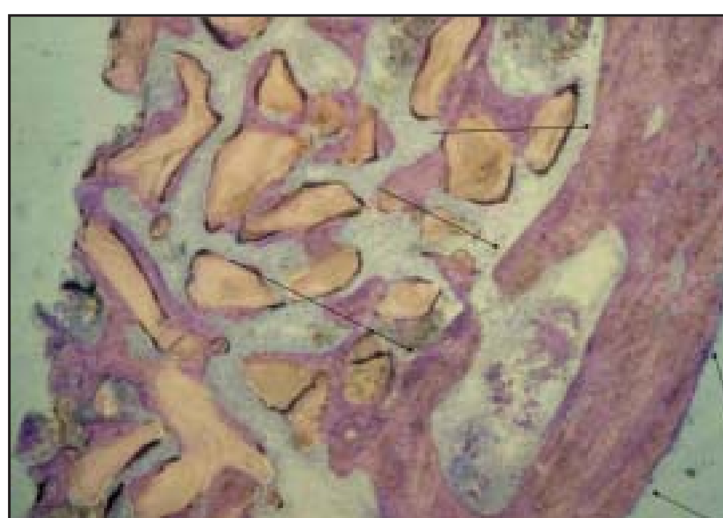

Fig 3f *Histology at 6 months. A newly formed cortical layer of immature composite bone is evident on the outer layer of the biopsy specimen* (arrows). *Newly formed bone trabeculae bridge the xenograft particles (toluidine blue; original magnification ×25).*

Discussion

The incidence of sinus membrane perforations, as reported in the literature and referenced in this report, varies from 11% to 56%. Most of these studies further report that adequately repaired perforations have no effect on the ultimate survival of the implants placed in the affected sinuses. Two noteworthy exceptions are the studies by Khoury[13] and Proussaefs et al.[24] Khoury reported that half (14 of 28) of his implant failures occurred in sinuses with perforated membranes, while the incidence of perforations was only 24% of the treated sinuses.[13] The study by Proussaefs et al compared results in 12 bilateral cases in which only one side had a perforation.[24] They found significant differences between the nonperforated and perforated sinuses in both vital bone formation (33.6% and 14.2%, respectively) and in implant survival (100% and 69.6%, respectively). They also reported significant hypertrophy of most perforated sinus membranes after surgery. According to the authors, the poor results were caused by (*1*) bacterial colonization of the graft material and the membrane used to seal the perforation and (*2*) lack of containment of the graft material.[24] The repair technique used in their study involved the placement of a nonstabilized bioabsorbable collagen membrane over the perforation. Further, a barrier membrane was not placed over the lateral window, a procedure that has been shown in three controlled trials to increase vital bone formation.[28,30,31]

In the patients presented in the current paper, no signs of sinus membrane inflammation or hypertrophy were detected after repair procedures. This may also be ascribed to the particular attention paid to performing an aseptic procedure that involved avoiding any contact of the graft material with saliva or other possible sources of contamination. If graft material was dispersed in the mouth during the filling of the sinus cavity, it was recovered and discarded. Further, the barrier membranes were shaped prior to placement of the graft material so that they could be placed without allowing the cheek to come into contact with the graft material. At this point in the procedure, the graft is unprotected and is susceptible to contamination and possible infection.[32]

Proussaefs and Lozada[33] later developed a technique to resolve the problem of loss of graft containment, known as the Loma Linda pouch technique. It consists of using a large membrane that is folded into the sinus to completely contain the graft material, which is placed in its center. The membrane is then folded over the graft at the lateral wall to create an external barrier.

When 100% bone replacement grafts are used, the only source of cells and growth factors comes from the vascular supply in the sinus walls. It thus becomes imperative during a repair procedure to contain the graft material and maintain the source of blood supply. It is appropriate to place a repair membrane over the torn schneiderian membrane, as studies by both Hürzeler et al[34] and Haas et al[35] have shown that the sinus membrane lacks osteogenic potential once it has been elevated from the sinus walls and therefore is of limited significance in the formation of new bone. It would appear that every effort should be made to limit the coverage of significant portions of the internal bony walls with the repair membrane. The Loma Linda pouch technique, however, completely isolates the graft material from the blood supply in the sinus walls (infraorbital, posterior superior alveolar, and posterior lateral nasal arteries). This technique was originally presented without any confirming histologic or histomorphometric evidence of vital bone formation. The present article validates this technique, with limited histologic evidence. The collagen repair membrane placed in contact with the bony walls may slow down the remodeling process of the graft by temporarily isolating it from the blood supply. The mean time for collagen repair membranes to be degraded has not yet been determined with precision. A study by Rothamel et al[36] in rats reported that the thickness of BioGide and BioMend membranes was significantly reduced after about 4 and 8 weeks, respectively. In humans, this period may be somewhat longer. It should also be considered that a reduction in membrane thickness does not necessarily imply a loss of the barrier function, which would occur only after interruption of membrane continuity. In the present report, the period of isolation from the blood supply, as well as the presence of the metabolites produced by membrane biodegradation, did not appear to negatively affect the generation of new bone.

Movement or shifting of the membrane may occur because of the physical act of placement of the graft material. This is most often observed when the perforation is close to the superior part of the osteotomy cut (type I). As the graft is placed, the repair membrane continuously shifts medially, increasing the risk of reopening the perforation. The membrane stabilization techniques presented in this article show how to avoid this problem by using tacks and/or sutures to stabilize the membrane.

A few simple rules have evolved through the performance of many successful perforation repairs by our multinational clinical team:

1. Small perforations may "self-repair" when the sinus membrane folds over itself as elevation is continued.
2. The sinus membrane should not be elevated close to a laceration, as this generally will increase the size of the tear.
3. If possible, the antrostomy should be enlarged to obtain easier access to complete the membrane elevation and perform the repair.
4. Membranes used for repairs should cover the perforation and the surrounding area and have sufficient stiffness, even when wet, to prevent collapse through the perforation.
5. Large repairs should be stabilized to prevent shift and loss of graft containment.
6. When using particulate grafts, one has the option of mixing the graft either with autologous venous blood or with a platelet concentrate to improve its consistency and cohesion. As no clinical evidence has been published to show an improved outcome of implant survival using platelet-rich plasma,[2,37,38] this can only be recommended as an adjunctive procedure to facilitate graft containment.
7. Care must be taken to work under aseptic conditions to avoid graft material contamination, as contamination may negatively affect the outcome of the procedure.

The elevated schneiderian membrane forms two walls (superior and distal) of a box or container into which the particulate graft material is placed and confined. In the patients described in this paper, a bioabsorbable collagen membrane was placed inside the maxillary sinus to repair large perforations (greater than 10 mm) and thereby contain the graft material. Although similar techniques have already been described in the literature,[23,24,33] there are to date no histologic reports assessing the effects on the maturation of bone grafts after the use of stabilized collagen to repair torn membranes. In this report, bone biopsies were obtained 6 to 9 months after the augmentation of the sinus to acquire histologic and histomorphometric data on bone graft maturation.

The follow-up radiographs and CT scans taken of the patients in this report showed complete containment of the graft material following repairs with stabilized membranes. In addition, the sinuses showed no evidence of inflammation or thickening of the repaired schneiderian membrane. In addition, implants could be placed in all proposed sites within the expected time frame of cases without perforations, and implant survival rates, while short term, were consistent with those reported in the most current evidence-based reviews.[2,3]

Conclusions

Based upon the clinical and radiographic outcomes of the cases presented in this report, the following may be stated:

1. Bioabsorbable membranes can be used to repair large perforations, allowing for the completion of sinus augmentation.
2. Histologic evidence revealed that vital bone formation is not affected by the occurrence and proper repair of a perforation.
3. Radiographic evidence revealed that 100% graft containment can be achieved with a properly stabilized perforation repair.
4. Clinical and radiographic examination revealed that normal sinus health was present following grafting of a repaired perforation.
5. Limited short-term implant survival was not negatively affected by the presence of large perforations in the cases presented in this report.
6. Further studies are needed to confirm the results achieved in this limited presentation of clinical cases.

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