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Minimally Invasive Sinus Augmentation

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Sinus lift surgery has become more common as patients choose dental implants for tooth replacement. The recent development of a graft material that stimulates osteogenesis coupled with the application of tissue engineering principles has allowed for refinement of this surgical modality. A simple nontraumatic subantral sinus lift microsurgery is presented. This sinus lift microsurgery resulted in a 97% implant success rate.

Key Words: sinus augmentation, Regen Biocement, dental implants

INTRODUCTION

The application of tissue engineering principles has led to the development of a minimally invasive surgical procedure for subantral sinus augmentation. The goal of tissue engineering is to control the healing process to produce a normal tissue or organ. Tissue engineering is the practice of replacing lost tissue or organs by introducing biologically active components to orchestrate regeneration in a synthetic matrix designed to organize tissue growth. The biologic components used in tissue engineering may be implanted cells or biologically active compounds that direct host cells. The synthetic matrix is a porous structure made of fibers or a matrix of calcium phosphate compounds. The function of the synthetic matrix is to provide a surface for cell growth. In addition, the synthetic matrix is often designed to provide for the controlled release of biologically active molecules that selectively orchestrate and stimulate specific host cells.

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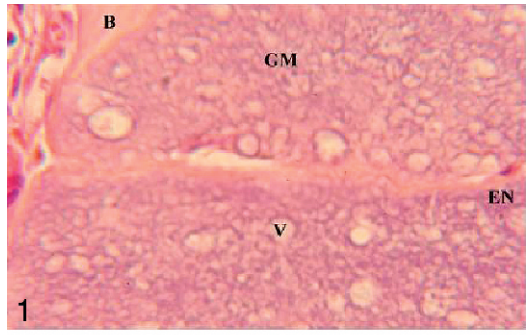
The chemical agents that influence cell migration, differentiation, and growth in tissues are extensive and are not completely understood. Growth factors are produced by cells and reside in extracellular fluid.[1] Growth factors stimulate cell growth by attaching to a receptor on the target cell surface.[2] As this event occurs, the growth factor and the receptor are degraded.[3] It is this process of growth factor binding to a specific membrane receptor and their combined degradation that stimulate the target cell.[4]

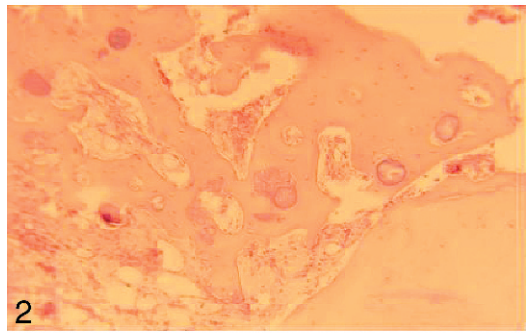
For tissue engineering to successfully produce a 3-dimensional and functional tissue, careful orchestration of a remarkable number of signaling molecules is required.[5] Important intercellular (autocrine) and intracellular (paracine) signaling molecules include the following: transforming growth factor (TGF), fibroblast growth factors (FGFs), platelet-derived growth factor (PDGF), hedgehogs (HHs), bone morphogenic proteins (BMPs), morphogenic signaling molecules (WNTs), and Runx2.[5]

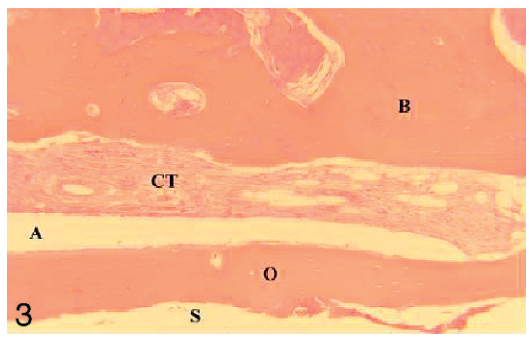
Because growth factor molecules are degraded after each receptor linkage, and because a complex mixture of molecules is needed to produce cell growth, the application of a single growth factor for tissue engineering has resulted in limited success.[6,7]

For these reasons, the graft material used in this article does not use growth factors but contains SL Factor (Steiner Laboratories Factor, Steiner Laboratories, Kapolei, Hawaii). SL Factor is time released as the matrix is degraded. SL Factor enters the osteoblast and stimulates the osteoblast to produce the required signaling molecules and growth factors for bone organization and production. In addition, SL Factor is stored in the osteoblast and continues to stimulate bone growth after the synthetic matrix has been resorbed (Steiner Laboratories, unpublished data). Unlike growth factors, SL Factor is transported across the cell membrane and into the nucleus and has been shown to modify the activity of more than 300 genes, producing an up-regulation in genes known to stimulate bone formation and the down-regulation of genes that result in bone loss (Steiner Laboratories, unpublished data). SL Factor stimulates mesenchymal stem cells to differentiate into osteoblasts and increases the production of alkaline phosphatase, in addition to creating a 2-fold increase in BMP2 and Runx2 production (Steiner Laboratories, unpublished data). Osteoclast formation is also reduced by inhibiting the production of RANK ligand (Steiner Laboratories, unpublished data).

The tissue engineering matrix of Regen Biocement (Steiner Laboratories) was developed to provide timed release of SL Factor as the matrix is resorbed. The matrix is a dual-phase calcium phosphate biocement. In physiologic conditions, the first phase sets in the first 24 hours to provide body for the graft material. The second phase of the matrix sets over the following days as the first phase washes out, resulting in a porous matrix. The matrix is resorbed as cells populate the matrix and provide calcium and phosphate compounds for the mineralization process. The matrix is nonceramic; therefore it does not inhibit bone formation and is completely resorbed. As a biocement, the matrix bonds to bone and implant surfaces, thereby stabilizing the implant and facilitating the integration process.







Figures 1–3. Figure 1. The graft matrix is penetrated by an endothelial cell, as can be seen entering the graft matrix (GM) on the left with the endothelial nucleus (EN) on the far right. B indicates new bone; V, void. **Figure 2.** At 6 weeks, the matrix is largely resorbed, leaving isolated islands of graft matrix covered with new bone. **Figure 3.** Sinus bone anatomy. S indicates sinus; O, osteoid-like layer; A, artifact; CT, soft connective tissue; B, mineralized bone.

Shortly after grafting, the matrix of Regen Biocement is penetrated by endothelial cells from the surrounding vascular system (Figure 1). Vascular penetration of the graft matrix continues until the graft matrix is broken up into islands of graft material (Figure 2). As endothelial cells penetrate the matrix, SL Factor is released and directs

the differentiation of arriving cells along the osteogenic path. Bone formation occurs on the graft matrix until the matrix is completely resorbed at approximately 8 to 12 weeks, depending on the size of the graft.

The unique characteristics of Regen Biocement have enabled the development of new surgical procedures. In adults, the size of the maxillary sinus often needs to be reduced, allowing for increased bone volume and thereby permitting tooth replacement with dental implants. However, the cost, morbidity, and surgical complexity associated with maxillary bone augmentation have limited the use of this procedure. The Steiner Sinus Lift (Steiner Laboratories) addresses each of these issues with the intention of making maxillary bone augmentation in the floor of the sinus a simple and nontraumatic procedure. The Steiner Sinus Lift and the sinus lift pioneered by Tatum and described in detail by Misch is comparable in that both methods use a lateral wall osteotomy for graft placement.[8,9] The differences between the two methods are based primarily on the fact that the Steiner Sinus Lift is minimally invasive while using microsurgical instrumentation and hydraulic pressure to lift the sinus membrane. The soft tissue flap for the Tatam sinus lift exposes the lateral wall of the maxilla and a portion of the zygoma. The soft tissue flap for the Steiner Sinus Lift is reflected only to the base of the enlarged sinus. Most cases require exposure of the alveolar ridge only in the area of the lowest point of the sinus. The Tatum method utilizes an osteotomy of approximately 10 $\times$ 15 millimeters,[9] and the Steiner Sinus Lift utilizes an osteotomy close to the alveolar ridge of approximately 3 mm in diameter. This difference is more than just less invasive. Retaining the lateral wall of the maxilla preserves more regenerative tissue. Bone regeneration in the maxillary sinus has been found to originate primarily from the surrounding bone and not from the elevated sinus membrane or the periosteum covering the osteotomy.[10] Preserving the lateral wall of the maxillary sinus preserves this tissue to facilitate bone regeneration. Surgical cuts made through the maxilla to reach the sinus membrane and fracturing in the lateral wall or surgically removing the lateral wall increase the potential for sinus membrane perforation.[11,12] Following elevation of the sinus membrane using the Tatum sinus lift, it is common practice to routinely place a resorbable membrane soaked with antibiotics below the elevated sinus membrane. In addition, the graft material used for the Tatum sinus lift often includes ceramic granules mixed with antogenous bone harvested from the tuberosity and wetted with an antibiotic solution.[9] The ceramic granules are needed to maintain the graft shape, but they also delay bone regeneration and reduce the amount of bone in contact with implants placed before the granules are resorbed. Antibiotics are required because of the extent of the surgical wound in an environment that cannot be kept sterile.

The graft material used in the Steiner Sinus Lift is a dual-phase calcium phosphate biocement and does not require granules, membranes, or locally applied antibiotics. The graft material sets hard in the maxillary sinus and bonds to the implants. The graft material is completely resorbed in 3 months. The minimal osteotomy, the short time required to perform the surgery, and the placement of the graft material via a sterile syringe makes the Steiner Sinus Lift a potentially sterile technique. Normal sinuses are sterile, and any postoperative sinus infection can originate only from organisms introduced at the time of surgery.

Sinus lift procedures utilizing access through the implant osteotomy have been proposed and are in practice. These procedures utilize blind elevation of the sinus membrane through the alveolar crest and employ various methods of grafting the

sinus by condensing pliable or granular graft material. When this method of elevating the sinus membrane is used in cadavers with 4 to 8 millimeters of alveolar bone, 25% of sinus augmentation procedures resulted in sinus membrane perforation.[13] A multiclinical study of this technique resulted in only an 85.7% implant success rate when pretreatment bone height was 4 mm or less.[14]

The inability to determine whether the membrane has been perforated and the inability to effectively treat a perforated membrane were factors in choosing the lateral maxillary wall for access to the sinus membrane. The Steiner Sinus Lift permits the sinus membrane to be directly visualized.

When the alveolar ridge that separates gingiva from the sinus is 2.5 mm thick or greater, this area of the maxilla will contain trabecular bone in the remaining alveolar ridge. The bone lining the sinus wall will contain an osteoid-like layer. The osteoid-like layer of bone is firm, but flexible and lucent (Figure 3). This layer appears to have minimal mineralization, which accounts for its flexible nature. Histologically, this layer of bone is indistinguishable from cortical bone (Figure 3). When an osteotomy is prepared into the maxillary sinus from the lateral wall, hard bone is present until what appears to be a soft tissue separation is encountered between hard mineralized bone and the osteoid-like layer. Histology bears out this clinical finding (Figure 3). This structure may explain why sinus grafting is a very successful procedure. The sinus membrane is perfused with capillaries that penetrate the osteoid-like layer and anastomose with capillaries in the soft connective tissue layer immediately under the osteoid-like layer (Figure 3).

Materials and Methods

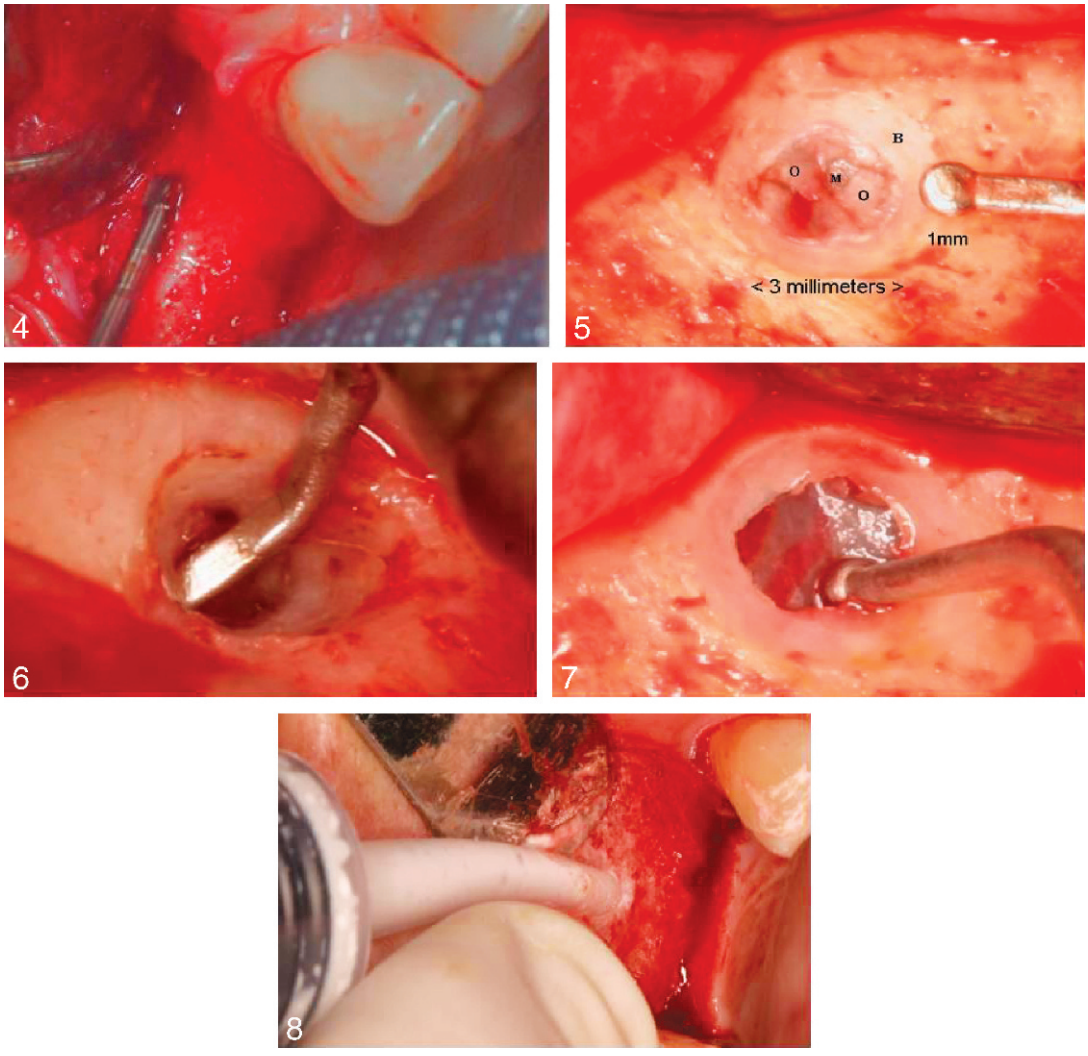
SL factor and sinus lift procedure study

A series of 30 implants were placed in 18 patients. Two of the patients were smokers. The number of cigarettes smoked per day was not documented. All patients were administered 500 mg amoxicillin by mouth for 7 days postoperatively. All sinuses were augmented using the Steiner Sinus Lift technique with Regen Biocement used as the graft material. The average age of the patient pool was 58 years, with an age range of 44 to 92 years. No screening was provided for various disease states or habits other than smoking and bruxism. A wide range of diseases were represented in the patient pool. No patients were excluded from the study for health reasons. At the end of the study, the average time since placement was 16 months, with a range of 6 to 33 months. In 15 of the 18 patients, the implants were placed at the time for sinus grafting. The range of pregraft alveolar bone was between 2.5 mm and 8 mm, with an average alveolar bone thickness of 4.6 mm.

Surgical procedure

To perform the subantral sinus augmentation, a crestal incision was made to accommodate implant placement and to expose the buccal alveolar ridge of the maxilla to the lowest point of the maxillary sinus (Figure 4). A presurgical panorex was used to evaluate all sinuses for general anatomy and pathology. Digital periapical radiographs were used to approximate the floor of the sinus. Because the Steiner Sinus Lift is minimally invasive and does not involve critical tissues, the information gained from a presurgical computerized tomography (CT) scan was not deemed to outweigh the cost and radiation exposure. The need for a presurgical CT should be determined by the individual practitioner on a case-by-case basis.

A No. 8 round bur in a high-speed handpiece was used to perforate the lateral wall of the maxillary sinus at the lowest point of the sinus. As the internal wall of the sinus was approached, the dark sinus was easily noted before perforation into the sinus.



Figures 4–8. Figure 4. A No. 8 round bur is used to prepare the osteotomy. **Figure 5.** O indicates osteoid-like bone lining; M, sinus membrane; B, bone. The micropaddle is approximately 1 mm in diameter. **Figure 6.** The micropaddle is used to dissect the sinus membrane in the immediate area of the osteotomy. **Figure 7.** After the micropaddle procedure, a microball is used to separate the membrane from the floor of the sinus until the medial wall of the sinus is reached. **Figure 8.** Regen Biocement is injected between the sinus membrane and the alveolar bone.

At this stage, the operator switched to a No. 8 multifluted round bur in a high-speed handpiece, which removes bone smoothly, thereby preventing damage to the sinus membrane. As discussed previously, a thin osteoid-like layer of bone separates mineralized bone from the sinus membrane. The osteoid-like layer of bone is not solidly fixed to the surrounding bone because a fine layer of soft connective tissue is present between the bone of the maxilla and the osteoid-like layer of bone supporting the sinus membrane. The osteoid-like layer does not have to be completely removed. In Figure 5, the osteoid-like layer presents with cracks and a small area of exposed membrane. This osteoid-like layer is pliable and can be displaced with hand instruments. The osteotomy is commonly between 3 and 4 millimeters in diameter and between 2 and 3 millimeters in depth.

A 1 mm micropaddle (Steiner Laboratories) was pressed onto the osteoid-like layer of the sinus membrane and was slipped between the membrane and the bone (Figure 6). The micropaddle was held in contact with bone as the membrane was released a few millimeters around the circumference of the osteotomy.

When the initial dissection of the membrane around the circumference of the osteotomy was complete, the sinus was entered with a microball (Steiner Laboratories) (Figure 7). Contact with bone was maintained as the membrane was dissected off the floor of the sinus until the medial wall of the sinus was reached. The membrane was dissected mesial and distal to the osteotomy as needed.

Regen Biocement is supplied in mixing syringes with dispensing tip for sterile delivery into the maxillary sinus. The properties of Regen Biocement make this surgical modality possible. As the graft material is injected, the sinus membrane rises under hydraulic pressure (Figure 8). The tip of the syringe is cut to develop a diameter that seals the osteotomy orifice. The syringe tip is manipulated to limit the amount of graft material that leaks between the maxilla and the syringe tip as it is injected. The amount of sinus lift is determined by the amount of graft material injected.

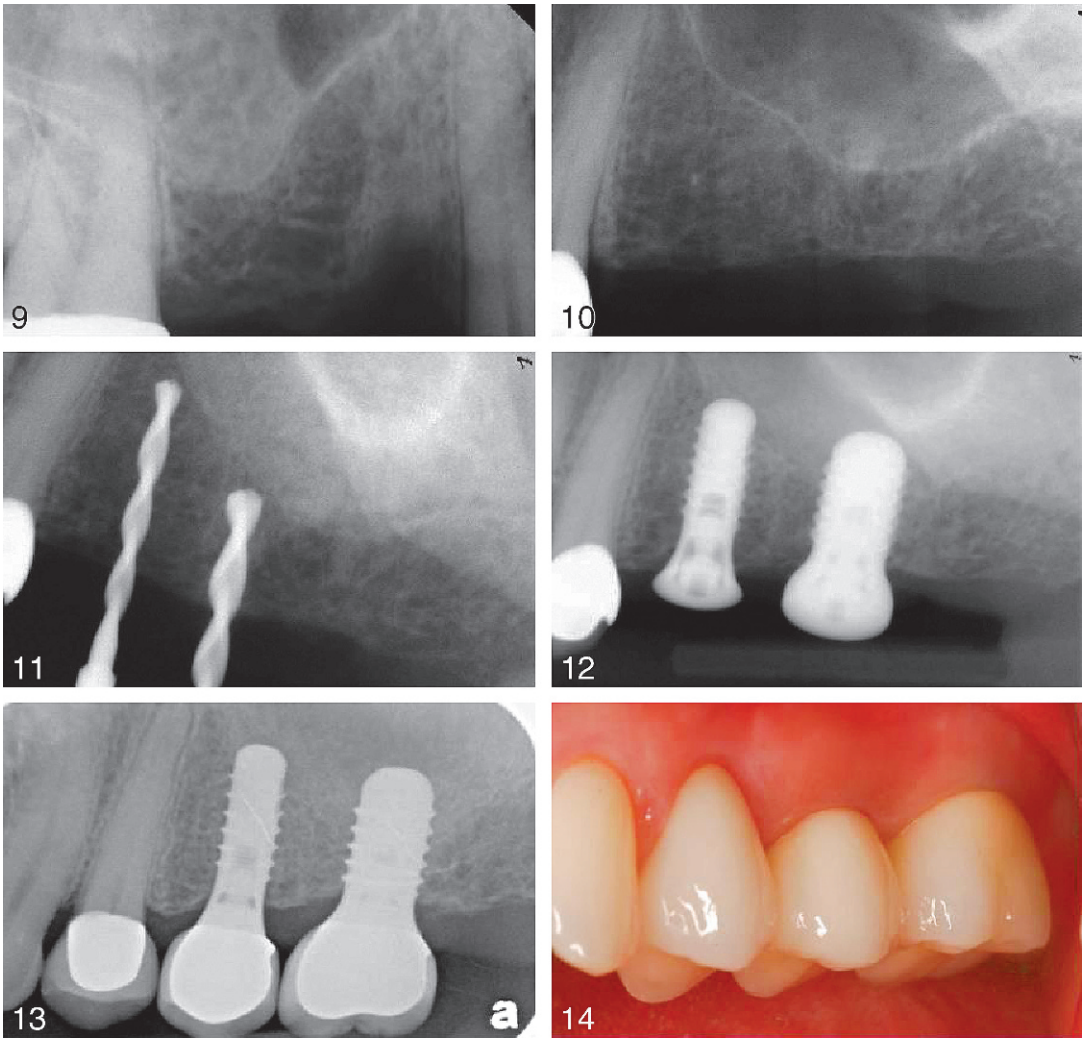
The graft material flowed freely until the void was filled where the membrane was detached mechanically. When this void was filled, an increase in resistance was felt as the membrane detached as it rose. With experience, a practitioner will know the proper amount of Regen Biocement to inject. When the sinus floor is smooth with no apparent septa or adjacent roots, 2 mL of the material can be injected. However, when adjacent roots or changes in the sinus floor occur nearby, approximately 1 mL should be injected and the lift of the membrane then can be assessed radiographically. Figure 9 demonstrates that when 1 mL of Regen Biocement was injected, radiographic evaluation revealed that the membrane remained attached in the mesial portion of the sinus lift area. The sinus was reentered with a microball and the sinus membrane was mechanically detached from this area before the lift procedure was completed.

Irregularities in the area of the osteotomy can complicate this method of subantral sinus augmentation. Large septum or graft material from a previous sinus surgery can be managed by this method, but extra care is needed to elevate the sinus membrane without perforation.

When 1 or 2 implants are to be placed and only a portion of the sinus is to be grafted, a single osteotomy is adequate. However, when the complete floor of the sinus is to be grafted and 3 or more implants are to be placed, prepare the lateral wall osteotomy for graft placement in the area of the mesial implant, and then prepare the osteotomy for the mesial implant. As the osteotomy for the mesial implant is prepared into the graft material, microinstruments can then enter this osteotomy to dissect the membrane in a distal direction. Seal the lateral wall osteotomy, inject Regen Biocement through the implant osteotomy, and the sinus membrane will rise for the next implant. Place the mesial implant, and continue the process for the next implant.

Many posterior maxillae present with poor bone density and a low maxillary sinus (Figure 10). This patient was a healthy 59-year-old woman. After grafting with Regen Biocement, implant osteotomies were initiated (Figure 11). During this part of the procedure, the injected Regen Biocement began to set. Subsequent drills to the final implant depth are used to remove the graft material in the area to be occupied by the implants. If the graft material is not removed, the graft material can be displaced coronally en masse when the implants are inserted. Internal irrigation cannot be used, as this would dilute the graft material.

Trabecular bone of the alveolus increases in thickness as bone growth occurs from the wall of the sinus. However, bone growth occurs throughout the grafted sinus as nutrient canals spread and cells migrate into the graft matrix. Bone that forms by surface growth from the wall of the sinus appears radiographically as trabecular bone. Bone that



Figures 9–14. Figure 9. The graft material fills the posterior portion of the graft site on the left, but the sinus membrane remains attached in the mesial portion of the sinus to the ring. **Figure 10.** A low sinus in the molar region. **Figure 11.** The sinus has been grafted and pilot holes started. **Figure 12.** Three months after sinus lift and implant placement. **Figure 13.** Four months post grafting and implant placement with the implants restored. **Figure 14.** Clinical photograph of restored implants.

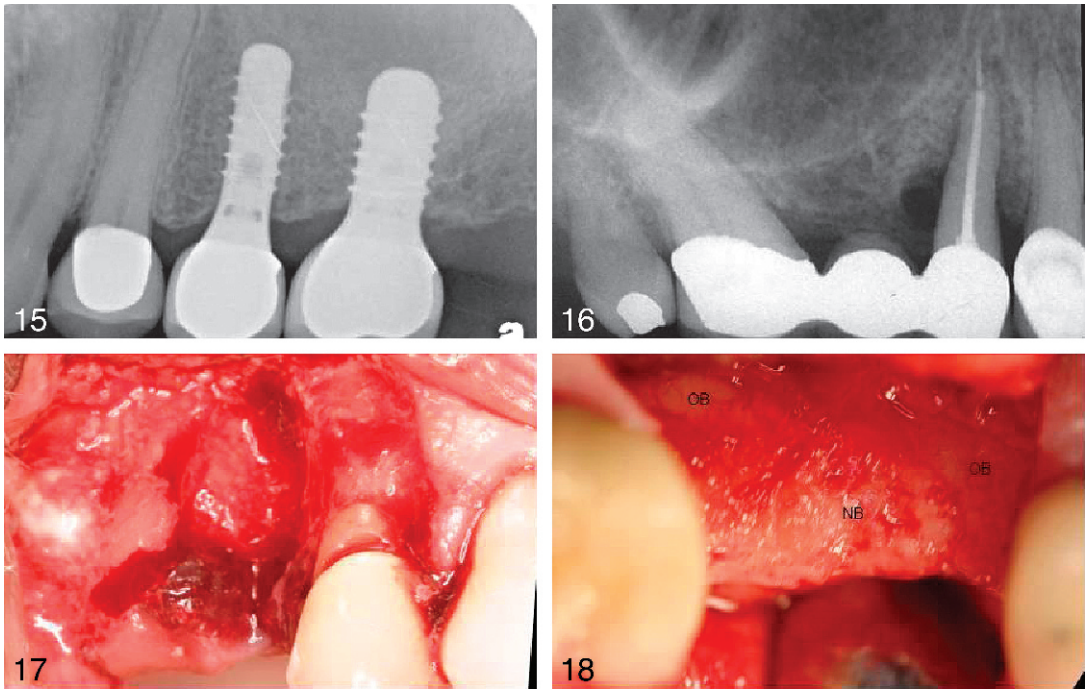
forms in the graft material after perfusion of nutrient canals has the radiographic appearance of cortical bone. Three months after grafting and implant placement, the original alveolus increases in thickness and the sinuses are filled with dense bone (Figure 12).

With this technique, implants should be placed at the time of sinus grafting. In the case pictured, implants were placed at the time of sinus grafting and were restored and loaded 3 months later (Figure 13).

The regeneration of bone and the placement of hygienic implants and crowns rival the esthetics and function of a natural dentition. For financial reasons, the patient in this series chose to have only 1 molar replaced. Widening the distance between implants permitted complete occlusion for the mandible and excellent esthetics. In addition, a significant cost savings was provided for the patient (Figure 14) (Restorative dentistry courtesy of Dr Ron Ask, Jackson, Calif).

At 20 months postoperatively, bone levels and density of the bone regenerated in the maxillary sinus remain unchanged from the 3-month postoperative radiograph (Figure 15).

Although this surgical technique calls for implant placement at the time of sinus



Figures 15–18. Figure 15. Twenty months after grafting and implant placement. **Figure 16.** Root fracture on tooth #5. **Figure 17.** Root fracture defect with sinus lift osteotomy in white to the left of the image. **Figure 18.** NB indicates new bone; OB, original bone.

grafting, not all cases in the study permitted implant placement at the time of grafting. In the following paragraphs, the steps taken in one of these cases, a case that presented with extensive bone loss around a fractured bicuspid (Figure 16), are detailed.

The patient was a healthy 59-year-old woman. The bridge was sectioned from tooth #2 and after the removal of tooth #5, a significant alveolar defect remained (Figure 17). As a result of the root fracture, complete loss of the buccal alveolar bone and partial loss of the lingual alveolar bone occurred, leaving only a shell of bone separating the lesion from the maxillary sinus. The osteotomy for the completed sinus lift was filled with Regen Biocement (Figure 17). The sinus was grafted with Regen Biocement, and the ridge was augmented with Regen Biocement followed by primary flap closure. No membranes were used.

Four months after the surgery, the site was ready for implant placement (Figure 18). On clinical examination, new bone in the area of the defect created by the fractured root is hardly distinguishable from the original bone (Figure 18).

The success of any reconstructive procedure requires consideration of the patient's regenerative potential and the lesion being treated. Maxillary sinus regeneration is very predictable. However, with ridge augmentation, it is significantly more difficult to achieve predictable results. In this case, Regen Biocement was the only material used to regenerate the sinus and the ridge. No membranes or granular graft materials were utilized.

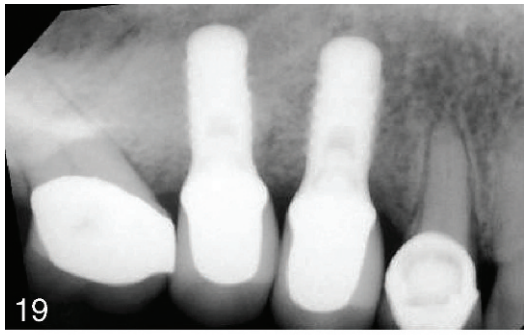
This particular case was determined to have high regenerative potential because of the following factors: The patient was a healthy middle-aged woman with no negative lifestyle habits; the patient presented with good alveolar structure in her maxilla and mandible, indicating a positive bone balance; the extraction site was filled with granulation tissue, and when the granulation

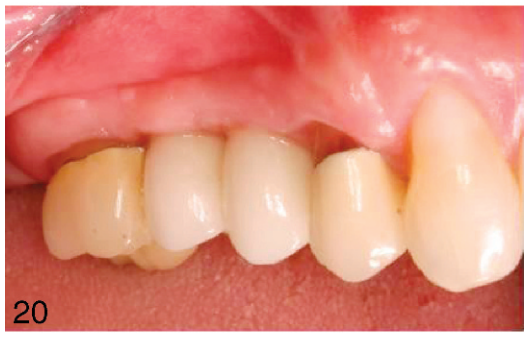
tissue was removed, the surface bone actively bled. After removal of granulation tissue, the porosity of the surface of the bone with the presence of blood vessels provided an efficient path for the migration of regenerative cells from surrounding bone. The same lesion in another patient might require a different surgical method.

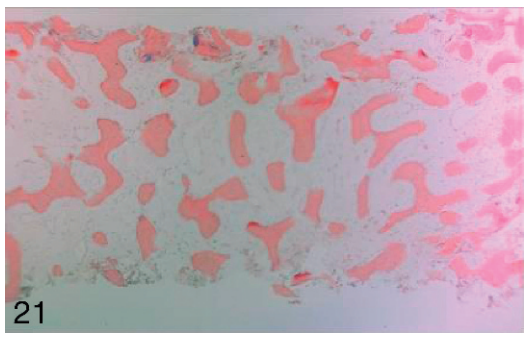
The implants were restored with hygienic abutments and crowns 7 months after grafting and 3 months after implant placement (Figure 19).

The health of the tissue around the implants was excellent with good esthetics (Figure 20).

A core sample taken from a sinus 15 weeks after grafting with Regen Biocement wetted with Hydrase (Steiner Laboratories) showed complete resorption of the graft material and significant bone growth (Figure 21).







Figures 19–21. Figure 19. Seven months, and grafting 3 months after restoration. **Figure 20.** Seven months after grafting. Three months after restoration. **Figure 21.** Bone core sample 15 weeks after sinus lift with Regen Biocement.

Results

No postoperative bleeding complications and no sinus membrane tears occurred. No postoperative sinus infections related to the sinus lift surgery were reported. In one patient, as a result of an undiagnosed endodontic lesion on a canine that drained into the maxillary sinus, a portion of the sinus graft material was lost. An apicoectomy was performed on the canine in combination with sinus debridement and regrafting, which resolved the infection. All 30 implants integrated, but 1 implant failed at 21 months. The single failure occurred in a patient with bruxism who wore a mandibular night guard. Over the time period of the study, the survival rate was 97%. All sinuses were grafted with Regen Biocement. Other graft materials, which consist of granules or putty, cannot exert controlled hydraulic pressure and cannot be used for this technique. For this reason, no comparison with other graft material was possible.

Performance of the Steiner Sinus Lift required between 30 minutes and 1 hour, and most patients reported no pain or sensation in the grafted sinus.

Discussion

Subantral sinus augmentation has proved to be a successful method of providing adequate bone for dental implants in the atrophic maxillae. Characteristics of the graft material presented in this paper have permitted the development of the Steiner Sinus Lift procedure. This surgical technique, which allows the sinus to be entered at its

lowest point through a 3 to 4 mm osteotomy, significantly reduces surgical trauma. The lift of the sinus membrane with hydraulic pressure while the graft material is injected helps to avoid membrane tears. Bonding of the graft material to the implant stabilizes the implant and facilitates implant integration.

Advantages of the Steiner Sinus Lift include the following:

- The procedure is minimally invasive.
- The osteotomy is minimal, being 1 to 3 mm deep and 3 to 4 mm wide.
- The dark sinus can be visualized easily before the membrane is reached.
- The membrane is easily visualized, ensuring detachment without damage.
- The amount of lift is determined by the volume of graft injected.
- Lifting the membrane with hydraulic pressure prevents membrane damage.
- The graft material sets hard and supports implants placed in minimal bone.
- The graft material bonds to the implant and the sinus bone, facilitating integration.
- The graft material stimulates osteogenesis and is quickly resorbed.
- Minimal instrumentation with closed grafting permits a sterile technique.
- Implants are placed at the time of sinus grafting.
- Implants are restored 3 months after grafting.
- The simplicity of the procedure requires less time and expertise.
- Cost-effective graft materials reduce cost to the patient.

Abbreviations

BMP: bone morphogenic protein
CT: computerized tomography
FGF: fibroblast growth factor
HH: hedgehog
PDGF: platelet-derived growth factor
TGF: transforming growth factor
WNT: morphogenic signaling molecules

References

1. Walsh-Reitz MM, Gluck SL, Waack S, Toback FG. Lowering extracellular Na+ concentration releases autocrine growth factors from renal epithelial cells. *Proc Natl Acad Sci U S A*. 1986;83:4764–4768.
2. Coutinho A, Larsson EL, Grönvik KO, Andersson J. Studies on T lymphocyte activation. II. The target cells for concanavalin A-induced growth factors. *Eur J Immunol*. 1979;9:587–592.
3. Cassel D, Glaser L. Proteolytic cleavage of epidermal growth factor receptor. A Ca2+-dependent, sulfhydryl-sensitive proteolytic system in A431 cells. *J Biol Chem*. 1982;257:9845–9848.
4. Sturani E, Zippel R, Toschi L, Morello L, Comoglio PM, Alberghina L. Kinetics and regulation of the tyrosine phosphorylation of epidermal growth factor receptor in intact A431 cells. *Mol Cell Biol*. 1988;8:1345–1351.
5. Huang Z, Nelson ER, Smith RL, Goodman SB. The sequential expression profiles of growth factors from osteoprogenitors to osteoblasts in vitro. *Tissue Eng*. 2007;13:2311–2320.
6. Yilgor P, Tuzlakoglu K, Reis RL, Hasirci N, Hasirci V. Incorporation of a sequential BMP-2/BMP-7 delivery system into chitosan-based scaffolds for bone tissue engineering. *Biomaterials*. 2009;30:3551–3559.
7. Chen FM, Chen R, Wang XJ, Sun HH, Wu ZF. In vitro cellular responses to scaffolds containing two microencapsulated growth factors. *Biomaterials*. 2009;30:5215–5224.
8. Tatum OH. Maxillary and sinus implant reconstruction. *Dent Clin North Am*. 1986;30:107–119.
9. Misch CE. *Contemporary Implant Dentistry*. 3rd ed. St. Louis: Mosby Elsevier; 2009.
10. Vlassis JM, Hurzeler MB, Quinones CR. Sinus lift augmentation to facilitate placement of nonsubmerged implants: a clinical and histological report. *Pract Periodontics Aesthet Dent*. 1993;5:15–23.
11. 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. *Clin Oral Implants Res*. 2008;19:1285–1289.
12. Hernández-Alfaro F, Torradeflot MM, Marti C. Prevalence and management of Schneiderian membrane perforations during sinus-lift procedures. *Clin Oral Implants Res*. 2008;19:91–98.
13. Reiser GM, Rabinovitz Z, Bruno J, Damoulis PD, Griffin TJ. Evaluation of maxillary sinus membrane response following elevation with the crestal osteotome technique in human cadavers. *Int J Oral Maxillofac Implants*. 2001;16:833–840.
14. Rosen PS, Summers R, Mellado JR, et al. The bone-added osteotome sinus floor elevation technique: multicenter retrospective report of consecutively treated patients. *Int J Oral Maxillofac Implants*. 1999;14:853–858.