Augmentation Grafting of the Maxillary Sinus for Placement of Dental Implants: Anatomy, Physiology, and Procedures

Arun K. Garg, DMD*

In patients with an inadequate amount of bone for implant placement, sinus lift surgery can be performed to restore a sufficient amount of alveolar bone to allow for successful implant placement and subsequent prosthetic reconstruction. In this article, the anatomy and physiology of the maxillary sinus, the mechanisms of bone grafting, bone grafting material, preoperative evaluation, surgical technique, and the grafting procedure, as well as intraoperative bleeding and postoperative complications, are discussed. (Implant Dent 1999;8:36–46)

Key Words: maxillary sinus, autogenous bone, sinus lift, augmentation, osteogenesis

Dental implant placement in patients who are edentulous in the posterior maxilla can be difficult for many reasons. These include an inadequate posterior alveolus, increased pneumatization of the maxillary sinus, and close approximation of the sinus to crestal bone.[1] The thickness of the maxillary sinus correlates with the degree of pneumatization. Sinus pneumatization will often minimize or completely eliminate the amount of vertical bone available for endosteal implant placement. Increased pneumatization combined with alveolar bone loss also reduces the chance of successful implantation. As the posterior bone resorbs, the amount of available alveolar bone necessary for supporting endosteal implants is reduced. To attain predictable implant support requires approximately 10 mm of vertical bone.[2] Associated anatomical limitations, such as a flat palatal vault and deficient alveolar height, can also compromise the treatment of these patients.[3–6]

In the past, it has been difficult to achieve satisfactory function and comfort in these patients with a conventional removable partial denture or complete denture prosthetics. Today, however, in many of these patients the problem can be overcome by increasing the alveolar height through bone grafting of the maxillary antral floors. This technique, known as sinus lifting, provides sufficient quantity and quality of bone for the placement of osseointegrated implants and subsequent prosthetic reconstruction. Sinus lift grafting and implant placement can be accomplished as either a one-step or two-step procedure.

If there is sufficient alveolar bone height present and only partial pneumatization of the sinus, bone grafting and implant placement can be performed at the same time (one-step method).[7] The implant can be placed through the crestal bone into the graft material if there is at least 5 mm of alveolus present to stabilize the implants during the healing period. Simultaneous grafting and implant placement can activate a coordinated consolidation of the graft around the implant.[1] However, if the available host bone is insufficient to mechanically maintain the endosteal implant (ie, is less than 5 mm in height), simultaneous placement of the implants is contraindicated and should be delayed approximately 4 to 6 months after the graft procedure.[8,9] In addition, an osseointegration and bonding period of 4 to 6 months is recommended before the site is uncovered and the abutments are placed.

Maxillary Sinus Anatomy

Maxillary bone is primarily medullary (spongy) in character and finely trabecular. It has less quantity and osseous density compared with premaxillary or mandibular bone. The adjacent cortices consist of compact bone. However, they are generally very thin, providing minimal strength compared with the cortices surrounding the mandible. Because of its spongy nature, medullary bone must establish a stress-bearing surface next to an endosteal implant for the functioning implant to remain stable and be able to transmit physiologic load to the supporting bone.[3,10]

Large areas of the posterior edentulous maxilla are occupied by the maxillary sinus, a pyramid-shaped structure located in the body of the maxilla.[11–13] The maxillary sinus is a 15-ml-volume airspace that resembles a sloped paperweight, with its largest and only flat side composing the medial wall (which is also the lateral wall of the nasal cavity).

*Associate Professor of Surgery, Division of Oral/Maxillofacial Surgery, Department of Surgery, University of Miami School of Medicine, Miami, FL.

ISSN 1056-6163/99/0801-036
Implant Dentistry
Volume 8 • Number 1

Septa may divide the sinus into two or more cavities that may or may not communicate. The sinus begins to form in early childhood (at about 2 to 3 years of age), and its formation is nearly complete by 8 years of age. It has a nonphysiologic drainage port high on the medial wall (maxillary ostium) that drains into the middle meatus of the nose. The ostium is considered nonphysiologic because it serves only as an overflow drain rather than as a dependent complete drainage system.

The bony walls of the sinus are thin, except for its anterior wall and the alveolar ridge in the dentate individual. In the edentulous person, the alveolar bone is atrophied and may be only 1 to 2 mm thick, making it unsuitable as an implant site. Thus, the purpose of sinus lift surgery is to restore a sufficient amount of alveolar bone so that implants can be successfully placed.

The maxillary sinus is lined with pseudostratified columnar epithelium, which is also called the Schneiderian membrane. Beneath the surface epithelium is a loosely cellular, but highly vascular, thin tissue. Beneath this, in all areas, is a periosteum. The delicate mucosa of the sinus attaches to the periosteum on its osseous surface. This feature is an important source of bone formation for sinus lift surgery. A thin layer of respiratory epithelium that lines the Schneiderian membrane cannot be differentiated from the periosteum of the bones to which it is firmly affixed.

The blood supply to the maxilla normally emanates from three parent arteries, the superior labial, anterior ethmoidal, and primarily the internal maxillary. The area of sinus lift surgery is mainly supplied by branches from the internal maxillary artery. The sinus floor receives some of its blood flow from the greater and lesser palatine vessels as well as the incisal artery, which is a terminal branch of the sphenopalatine artery (which is yet another portion of the internal maxillary artery). These vessels penetrate the bony palate and ramify within the sinus floor and its medial and lateral walls. Another vascular contribution arises from the posterosuperior alveolar artery, which enters the maxilla in the superior tuberosity area to supply most of the posterior and lateral walls. The infraorbital branch of the internal maxillary artery helps supply blood to the superolateral sinus area. The anterior ethmoidal artery, which is a terminal branch of the internal carotid system (via the ophthalmic artery), supplies the superomedial sinus area.

Maxillary Sinus Physiology

The functions of the maxillary sinus are purported to be to warm air and to provide resonance to the voice. More realistically, the sinus evolved, through natural selection, as an assistant to the scalp veins and intracranial venous sinuses that dissipate the intense heat produced by the metabolically active human brain. Additionally, it lightens the weight of the craniofacial complex.

The healthy maxillary sinus is self-maintained by postural drainage and actions of the ciliated epithelial lining, which propel bacteria toward the ostium. The sinus also produces mucous containing lysosome and immunoglobulins. The rich vascularity of the sinus membrane also helps to maintain its healthy state by allowing lymphocytic and immunoglobulin access to both the membrane and sinus cavity. The healthy sinus contains its own normal flora, of which *Hemophilus* species are the most common.

Mechanisms of Bone Grafting

Bone grafting is accomplished through osteogenesis, osteoinduction, and/or osteoconduction.[14–17] Osteogenesis refers to the formation and development of bone. Osteogenic graft material, which is derived from or composed of tissue involved in the growth or repair of bone, can encourage bone formation in soft tissues or stimulate quicker bone growth in bone implant sites. Osteoinduction is the act or process of activating osteogenesis. Osteoinductive grafts can enhance bone regeneration, resulting, sometimes, in the extension or growth of bone where it is not normally found. Osteoconduction provides a physical matrix (ie, a nonviable scaffolding) that is suitable for deposition of new bone. Osteoconductive grafts are conducive to bone growth and allow bone apposition from existing bone, but they do not produce bone formation when placed within soft tissue.

Bone-Grafting Material

Many materials have been recommended for sinus lift procedures. The attributes of the ideal graft are that it be nontoxic, nonantigenic, noncarcinogenic, strong, resilient, easily fabricated, able to permit tissue attachment, resistant to infection, readily available, and inexpensive.[18] To date, there is no consensus about which graft material or combination of materials is best for augmenting the sinus antral void created by the sinus lift operation.[19] Grafting materials that are currently being used for antral floor augmentation include autogenous bone,[7–9,20–22] bone allografts,[14,17,23–27] and alloplasts such as tricalcium phosphate and resorbable and nonresorbable hydroxylapatite (HA).[1,17,28–33]

Autogenous bone has long been considered the gold standard and remains the best grafting material because of its highly osteogenic, osteoinductive, and osteoconductive properties.[34] This allows bone to form more rapidly and in conditions where significant bone augmentation or repair is required. Autogenous bone can be harvested from the iliac crest (Figs. 1, 2) or from intraoral sites, such as the mandibular symphysis, maxillary tuberosity, ramus, exostoses, and extraneous bone from an implant osteotomy.[9,17,35–37] Resorption after transplantation of mandibular bone grafts has been reported to be less when compared to iliac crest grafts.[9,37] In addition, intraorally obtained bone grafts result in less morbidity than that associated with iliac crest grafts. The procedure can be easily accomplished in an office setting with the patient under parenteral sedation and local anesthesia so that there is no postoperative hospitalization, resulting in lower costs. A disadvantage is that intraoral donor sites

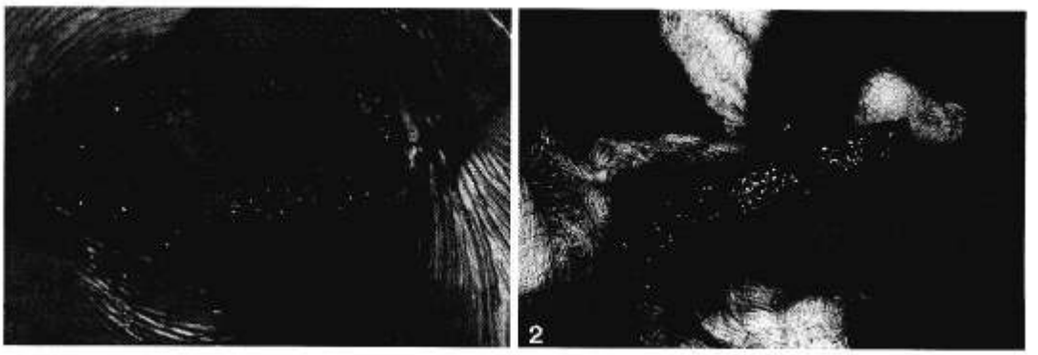


Fig. 1. The posterior iliac crest can provide a large volume of autogenous bone.
Fig. 2. Bone from the hip can be removed and used either as a block or in particulate form.

provide a smaller volume of bone than the iliac crest. The donor site is usually chosen on the basis of the volume and type of bone desired.

Bone allografts, which may be cortical or trabecular, may form bone by osteoinduction or osteoconduction. They are obtained from cadavers, living related persons, and living unrelated persons; processed under complete sterility; and stored in bone banks. Transplanted bone induces a host-immune response, with fresh allografts the most antigenic. However, this can be reduced considerably by first freezing or freeze-drying the bone.[23] Freeze-dried bone allografts can be used in either a mineralized or demineralized form. Demineralization removes the mineral phase and exposes the underlying bone collagen and growth factors (in particular, bone morphogenetic protein [BMP]).[14,24,25] Irradiated cancellous bone has also been used as a substitute graft material for autogenous bone.[26,27] Advantages of allografts include ready availability, elimination of the need to use a donor site in the patient, reduced anesthesia and surgical time, decreased blood loss, and fewer complications.[17] Disadvantages are primarily associated with the use of tissues from another individual and a donor's possibly questionable health status.[14,17,33] Cadaver bone also may be rejected like other transplanted tissues and organs. Technical problems include the precision required to insert bulk allografts, the need for rigid fixation to the host bone to obtain successful union, and the high rate of infection, nonunion, and graft fracture.[14,23] In addition, because allografts are not osteogenetic, bone formation takes longer and results in less volume compared with autogenous grafts.[17]

Alloplasts, which may be made of natural or synthetic materials, are osteoconductive only in action. Ceramics, such as HA, are safe and well tolerated but have minimal ability to encourage new attachments.[28] Recent advances in biomaterials, though, have greatly improved the use of synthetic bone substitutes in selected periodontal cases.[29–31] Augmentation materials can be incorporated in the modeling, remodeling, or healing process of bone to assist or stimulate bone growth in areas where resorption has occurred.[17] The most commonly used alloplasts are bioactive ceramics, which include synthetic calcium phosphate materials (eg, HA) and those derived from natural sources (eg, coralline or deorganified bovine bone). Calcium phosphate ceramics act as filler materials, with new bone formation taking place along their surfaces.[32,33] These materials are used in the reconstruction of bony defects and for the augmentation of resorbed alveolar ridges. The objective is to provide a scaffold for enhanced bone tissue repair and growth. Combining allograft or alloplastic grafting material with autogenous bone can decrease the amount of harvested bone necessary for procedures such as sinus lifts.[38]

Boyne[39] conducted a pilot study in monkeys to examine the effect of recombinant human BMP-2 (rhBMP-2) on bone regeneration after bilateral hemimandibulectomy. In three monkeys, a 0.8-mg dose of rhBMP-2 per milliliter in a collagen I sponge was applied to one mandibulectomy site, and 0.2 mg/ml was applied to the contralateral side. In four other monkeys, a dose of 0.4 mg of rhBMP-2 per milliliter was applied to one site, and an autogenous bone graft was used in the contralateral side. Complete regeneration of the alveolar ridge, with restoration of contour and cortical bone, was observed in all seven monkeys. Histomorphometric analysis showed excellent calcified bone matrix/marrow space ratios in animals that were killed at 5 months.

Recently, Nevins et al[40] studied the efficacy, safety, and technical feasibility of using an absorbable collagen sponge implant that had been impregnated with rhBMP-2 as a potential alternative to existing bone graft for inducing osteogenesis. Their maxillary sinus augmentation study was performed on an animal model. The investigators reported that delivery of rhBMP-2 in an absorbable collagen sponge resulted in significant new bone formation in the floor of the maxillary sinus and that the delivery system did not induce any significant immune or other adverse response.

Preoperative Evaluation

Panoramic and sinus radiographs and computed tomography scans are taken to help determine the available maxillary alveolar bone height, the location of sinus floor convolutions (septi), and the surgical entry site. The interdental space is evaluated for the available space between the gingiva and the proper plane of occlu-

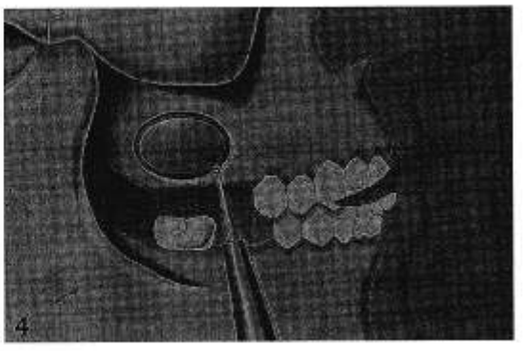


Fig. 3. A No. 8 round diamond bur is used in a slow-speed, high-torque handpiece to create the osteotomy in the lateral wall of the maxilla.
Fig. 4. An oval outline is created in the lateral wall of the maxillary sinus.

sion, which should be greater than 5 mm. If there is less than 5 mm of vertical space present for prosthetic reconstruction, gingivectomy, vertical osteotomy of the maxillary posterior alveolar process, and/or mandibular plane correction is indicated.[2,3] It is also important to determine whether any active disease or disorders (eg, acute sinusitis, retained root tips, polyps, tumors, or cysts in the antral cavity) exist in the sinus. It has been shown that patients with periodontal disease have an increase in maxillary sinus disease, which may have an impact on implantation.[41] The presence of any of these entities contraindicates performance of the procedure until they are corrected. After the relevant patient workup has been completed, the surgical procedure can be performed.

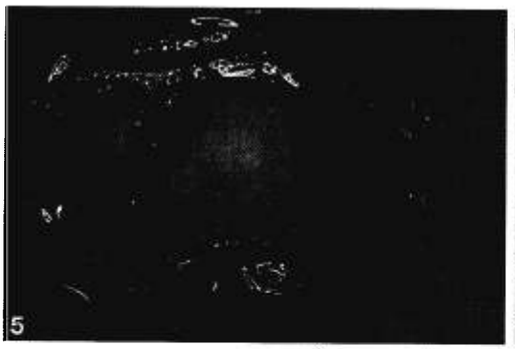
Surgical Technique

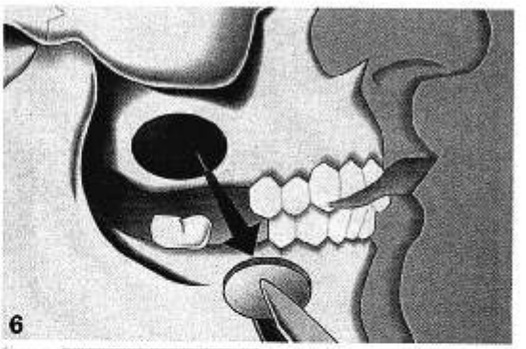
Appropriate antibiotics are administered preoperatively and continued postoperatively for 5 to 7 days.[42,43] Antibiotics that are effective against both aerobic and anaerobic bacteria should be prescribed. The patient's oral/facial area should be prepared and draped. The surgery can be performed with the patient sedated with intravenous medication unless the graft material is procured from the iliac crest, in which case general anesthesia is used. A local anesthetic, with a vasoconstrictor for hemostasis, is infiltrated into the maxillary surgical site and the maxillary or mandibular donor sites (if autogenous bone will be harvested from an intraoral site). The surgery can be performed with local anesthesia and posterosuperior alveolar and greater palatine nerve blocks combined with infiltration. A second-division nerve block, entering from the greater palatine canal, can also be used.

A horizontal incision is made on the crest or palatal aspect of the edentulous ridge, with extensions beyond the areas of the osteotomy and with consideration to the amount of attached gingiva on the alveolar crest. The incision is carried forward beyond the anterior border of the sinus. A vertical releasing incision in the canine fossa will help to reflect the flap and expose the bone and will also ensure soft tissue closure over the bone. The lateral wall of the maxilla is exposed by reflecting the mucoperiosteal flap superiorly to the level of the malar buttress. Elevation of the periosteum adjacent to the implant site should be minimized to preserve the blood supply to the alveolar crest. The periosteum should be reflected superiorly only to the height of the anticipated lateral maxillary wall infracture. After the lateral maxillary wall has been completely exposed, a No. 8 round diamond bur should be used in an oval configuration at low speed (100 rpm) to make an oval osteotomy in the lateral wall of the maxillary sinus (Figs. 3, 4). Slight variations have been described, with some investigators[7] creating a U-shaped osteotomy with the vertical arms of the osteotomy parallel to facilitate infracturing, whereas others[1] create a rectangular osteotomy with a No. 6 round bur. An oval osteotomy is recommended instead of a rectangular or trapezoidal osteotomy to minimize sharp edges on the bony window, which can cause tears in the underlying Schneiderian membrane.[44] A brush-stroke type of touch is used to penetrate through the bone but not the Schneiderian membrane (Fig. 5). To ensure that the bone has been penetrated all the way around the oval osteotomy, it should be tapped gently and any movement noted (Fig. 6). This bone can be either pushed in to serve as the roof of the graft or removed to create a window for better visualization and access (Fig. 7).

At this point, the underlying Schneiderian membrane is exposed (Figs. 8, 9). Meticulous care should be taken to reflect the Schneiderian membrane superiorly without perforating it. A curet is gently introduced along the margin of the created access window, with the curved portion of the curet placed against the Schneiderian membrane and the sharp edges placed against the bone (Figs. 10, 11). The curet is slid along the bone completely (360°) around the margin of the access window. The Schneiderian membrane is then carefully elevated from the floor interiorly, anteriorly, and posteriorly through the osteotomy sites. It is important to release the periosteum without tearing it from the bone. The lateral wall of the maxilla can be rotated into the sinus to create a ceiling for the bone graft or lifted off for better visualization and added to the graft material.

The sinus floor septi (convolutions) are not altered. A variable number of septa (also referred to as Underwood's septa) divide the floor of the maxillary sinus into several recesses and may complicate sinus lift procedures.[45,46] Most of the septa





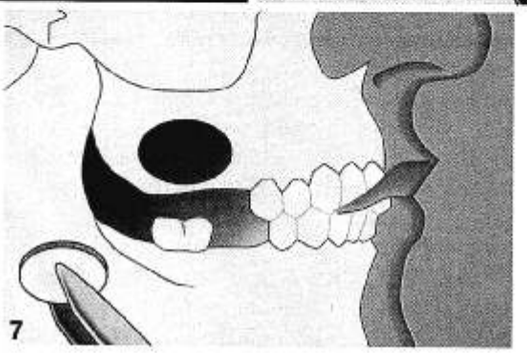


Fig. 5. After the access window is delineated, the bur is used to continue outlining with a brushstroke approach until a bluish hue is observed, indicating the approaching sinus membrane. This should be observed all around the access window.

Fig. 6. A blunt instrument is used to ensure that the island of bone is separated all around. This bone can then be either pushed in to serve as the roof of the graft or removed.

Fig. 7. Removing this window allows for better visualization and access.

are located in the region between the second premolar and the first molar. A possible cause of septal formation may be the different phases of maxillary sinus pneumatization of the empty alveolar process after tooth extraction. To minimize the chances of complications from septa, the inferior portion of the osteotomy should be created at least 3 mm above the sinus floor. If a septum is present and is more than 3 mm from the floor (something that should be noted preoperatively since it will affect the surgery), the oval osteotomy should be split into three by making vertical cuts through the bony window. This will create bony windows over the left and right compartments that are lifted off and a bony window over the septum that is not lifted off.

During surgery, the Schneiderian membrane may be perforated, so it must be handled with care. Perforation most often occurs when the lateral wall is being infractured, but it can also happen when the membrane is being elevated off the inferior and anterior bony aspects of the sinus. The most common areas of perforation are at the level of the inferior osteotomy, the level of the greenstick fracture if utilized, and the inferomedial portion of the membrane.[1] For small perforations in the membrane, a small piece of Gelfoam, Surgicel, collagen, or a resorbable cellulose membrane can be placed in the area to adapt to the perforation and occlude it. Another method used to cover antral lacerations is to place a resorbable collagen wound dressing below the laceration to provide a temporary interface superiorly between the antrum and the graft.[1] For larger defects, the lacerated membrane can be elevated off the medial wall, folded on itself to approximate the torn membrane of the lateral wall, and closed with a resorbable collagen wound dressing to cover the area.[1]

Intraoperative Bleeding

Because there are no major vascular structures in the area of the sinus lift surgery, any intraoperative bleeding that occurs is usually from capillary soft tissue or bony ooze. No doubt, all the interconnecting vascular contributions to the maxilla and maxillary sinus account for the "forgiving" nature and rapid healing of maxillary sinus surgery. However, the vascular system can produce a brisk intraoperative oozing, which is usually related to the patient's systemic blood pressure and/or the presence of local inflammation. Only rarely is it due to a bleeding disorder or coagulopathy. Most hemostatic disorders are already known by the time a patient reaches the age where he or she requires a sinus lift operation or are discovered by obtaining a good preoperative history. For patients who claim to be "bleeders" or who have a suspicious history of "bleeding problems," a simple battery of screening blood tests will identify 98.5% of bleeding disorders. This series of tests includes a complete blood count with platelet count and differential, bleeding time test, prothrombin time, and partial prothrombin time.

If brisk intraoperative oozing develops, the patient's systemic blood pressure should be checked. Hypertension control is usually established by reinforcing local anesthesia, verbally reassuring the patient, and using additional sedation if necessary. It is rare, but possible, that a procedure may have to be stopped because of uncontrollable hypertension. Locally, a brisk ooze is best controlled by temporarily packing the wound. Sometimes saturating the packing with epinephrine

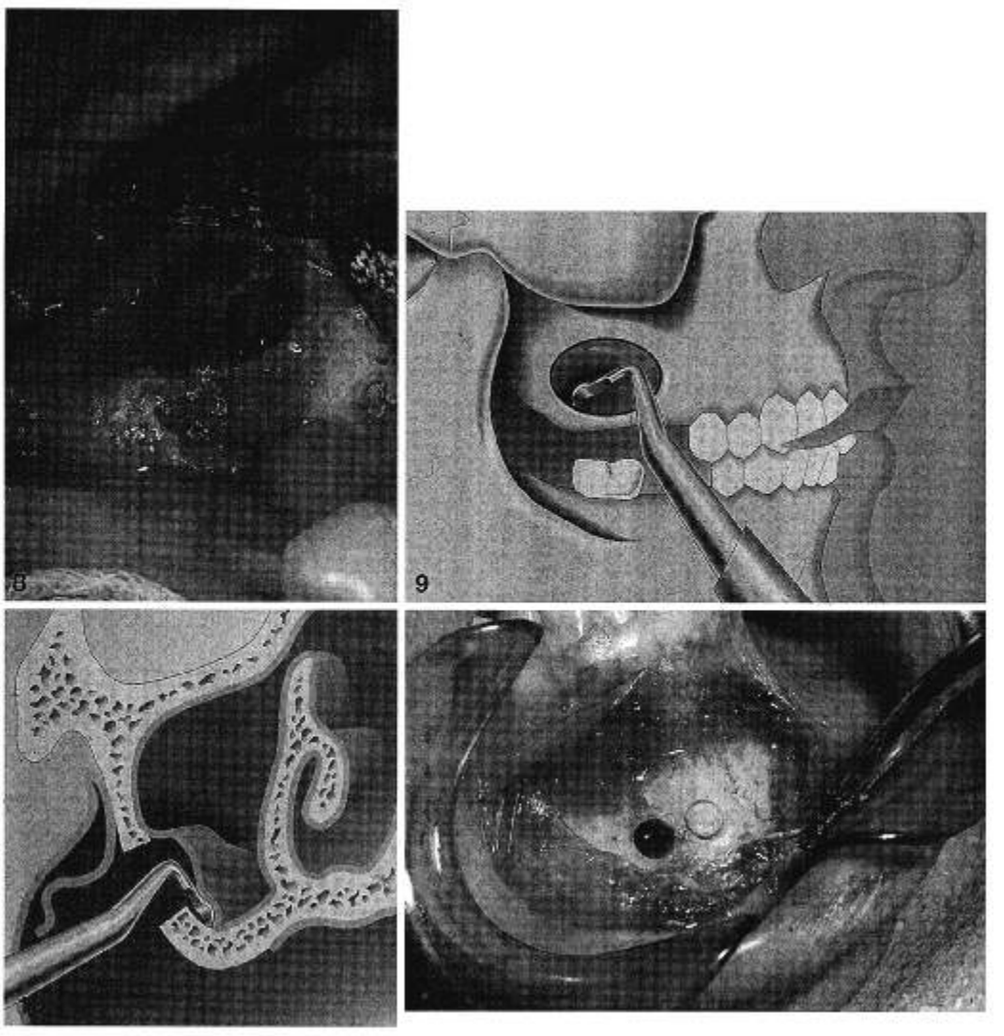


Fig. 8. The underlying Schneiderian membrane.
Fig. 9. A curet is introduced along the margin of the window. The curved portion is placed against the Schneiderian membrane and the sharp edges are placed against the bone.
Fig. 10. This procedure requires a gentle technique. The periosteum is released without tearing it from the bone.
Fig. 11. After a mandibular block local anesthesia, an intraoral bone graft is obtained below the apices of the mandibular incisors and canines. An incision is made in the alveolar mucosa 5 mm or more below the mucogingival junction between the premolars.

(1/100,000) or 4% cocaine will assist hemostasis, particularly if the oozing is coming from soft tissue. If the oozing is coming from bone and a temporary packing will not control it, pressing bone wax into the area will usually be effective. In addition, Avitene (microfibrillar bovine collagen) (Davol, Inc., a subsidiary of C.R. Bard, Inc., Cranston, RI) is an excellent resorbable and compatible agent that initiates clot formation. Gelfoam (Pharmacia & Upjohn, Kalamazoo, MI) and Surgicel (Johnson & Johnson Medical, Inc., Arlington, TX) (two additional "leave-in-place" agents) also assist in clot formation and hemostasis. However, the most effective means of control that permits completion of the sinus lift procedure is use of Avitene for slow bony oozing and bone wax for rapid oozing.

Grafting Procedure

Autogenous bone is harvested from the predetermined site and mixed with reconstituted freeze-dried bone in a 1:2 ratio. This mixture is then packed into 1-ml tuberculin syringes and set aside (Figs. 12-17).

If the patient has adequate residual bone on the alveolar crest to stabilize the implant initially (ie, 5 mm or more), a one-step procedure can be performed in which the graft and implant are placed simultaneously (Fig. 18). The implant sites should be drilled using a surgical template as a guide. During this procedure, it is important to protect the sinus membrane. After the implant sites are prepared, the top of the tuberculin syringes should be cut off with a No. 15 scalpel, and the mixture of autogenous bone and freeze-dried demineralized bone should be "injected" into the maxillary sinus and packed against the intact medial wall. After the medial portion of the sinus is grafted, the implants are placed.

Bone is then packed against the anterior and posterior maxillary walls to mold the bone against and over the implant to a height of 10 to 12 mm. During this part of the procedure, it is important to maintain the implant in the proper position so that subsequent prosthetic restoration is not compromised. Next, the lateral portion of the surgical site should be firmly packed with the bone graft. If

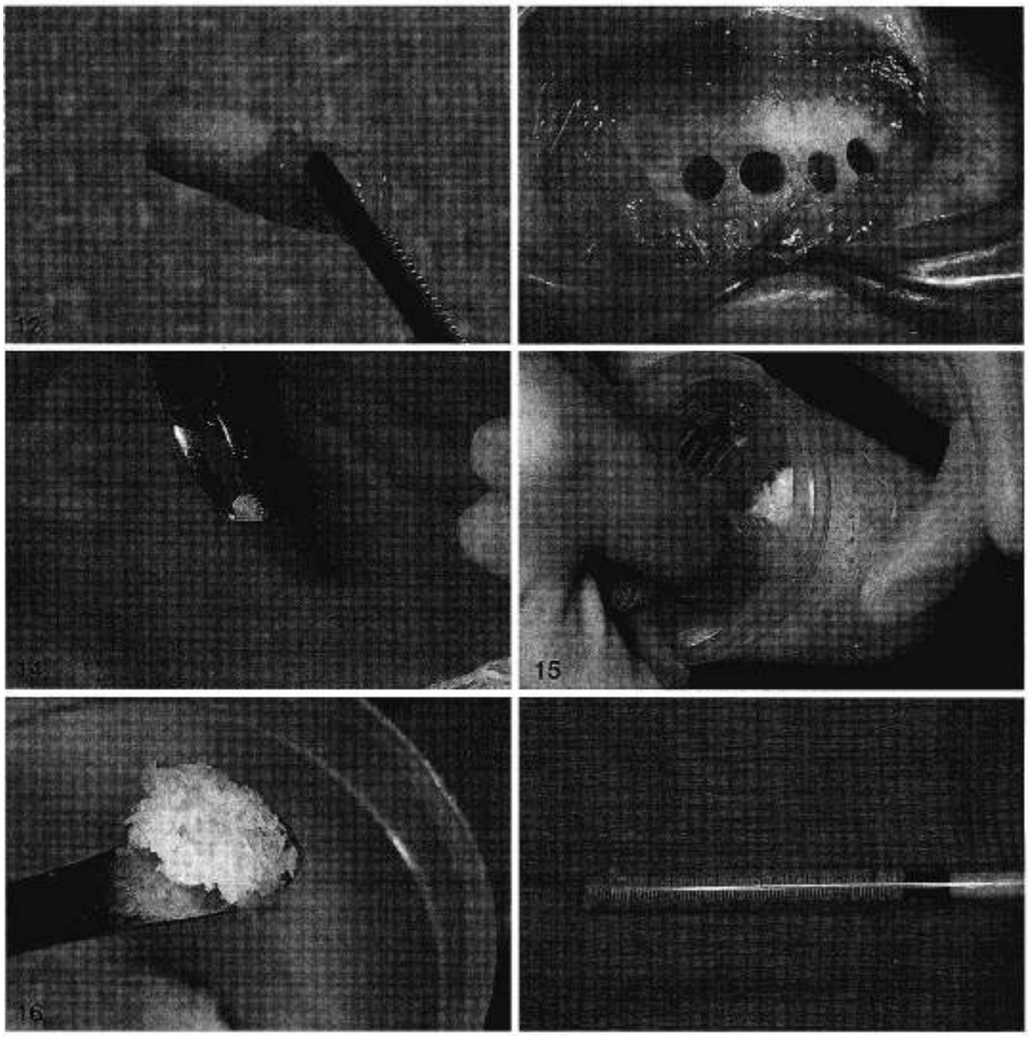


Fig. 12. A core of bone, the same diameter as the trephine bur used, is obtained. This can then be crushed or ground to the appropriate size. This bone is typically D1 bone.
Fig. 13. Up to 5 ml of bone can typically be harvested from the anterior mandible.
Fig. 14. The bone is crushed to the appropriate size either in a bone mill or with rongeurs.
Fig. 15. Autogenous bone can be mixed with other bone grafting materials in sterile saline. Excess saline is wicked away using a 4- × 4-inch gauze.
Fig. 16. Composite graft mix.
Fig. 17. This mixture can be placed into plastic syringes and then compacted with the plunger. The top of the syringe is then cut off to allow injection of the graft material into the maxillary sinus.

the diameter of the implant is greater than the alveolar crest, bone chips should be placed outside the sinus against the lateral surface of the implants. Then, the area of the access window should be covered with a membrane barrier, the mucoperiosteal flap repositioned, and the incisions closed with interrupted nonresorbable sutures. The graft can mature while the implant is integrating.

If the alveolar crest has less than 4 mm of bone available, then bone grafting and implant placement should be performed separately (two-step procedure), with implantation performed approximately 6 months after grafting. After the maxillary sinus is completely filled with the desired level of bone mixture, as above, the mucoperiosteal flap is repositioned and the incisions closed with interrupted nonresorbable sutures (Fig. 19). After the bone has matured, it is evaluated to ensure that there is a sufficient quantity for implant placement. The implants can then be placed in the mature graft material according to the surgical protocol for the particular implant system and allowed to integrate.

Postoperative Considerations

The postoperative considerations are similar to those for most oral surgery and sinus manipulation procedures. A chlorhexidine mouthrinse should be used twice a day for 2 weeks to reduce the chance of infection. Blowing the nose, sucking liquid through a straw (which creates negative pressure), and smoking cigarettes should be avoided for at least 2 weeks after surgery (smoking can also compromise healing). Coughing or sneezing should be done with an open mouth to relieve pressure. Other recommended postoperative care includes pressure at the surgical site, ice, elevation of the head, and rest. Analgesics (such as codeine, Tylenol 3 [McNeil Consumer Products Company, Fort Washington, PA], or Anaprox [Roche Pharmaceuticals, Nutley, NJ]) can be used to control pain and discomfort. An anti-inflammatory medication, as well as an antihistamine, can be used. Preoperative prophylactic antibiotic therapy, such as Augmentin (Beecham Products, Pittsburgh, PA) 500 mg twice a day for 7 to 10 days, is continued postoperatively for the appropriate period of time. Afrin

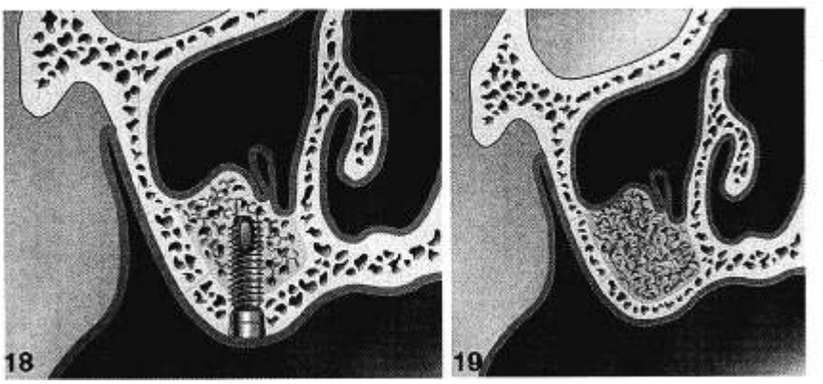


Fig. 18. In a one-step procedure, the graft and implant can be placed simultaneously and the incision sutured closed. In a two-step procedure, in which there is insufficient residual alveolar crest to maintain implant stability, the flap is repositioned and sutured closed after placement of the graft material. After the bone has matured, it is evaluated to ensure that there is sufficient quantity for implant placement.
Fig. 19. Implants can then be placed in the mature graft and allowed to integrate.

(Schering-Plough HealthCare Products, Liberty Corner, NJ) nasal spray and Sudafed (30 mg) (Warner-Lambert Consumer Healthcare, Morris Plains, NJ) can also be prescribed. Before the prosthodontic phase begins, 4 to 6 months should be allowed for the bone graft and implants to integrate. During this period, the patient can wear a conventional prosthesis that has been modified with a soft reline material. If an intraoral donor site has been used, it is usually well tolerated, and recuperation normally takes 1 to 2 weeks.

Potential Postoperative Complications

Possible complications that can occur after this procedure include sinus congestion, infection of the graft, poor would healing, insufficient quality or quantity of bone forming in the graft, and trauma or pathologic loading of the restoration.[47] Sinus congestion should be treated with decongestants and analgesics. If the graft becomes infected (a rare occurrence), the graft material should be completely removed, and the patient should be placed on antibiotic therapy. The sinus can be regrafted after the crestal soft tissue has healed and radiographs show the sinus to be clear. If the blood supply to the tissue is interrupted or impeded, there may be poor wound healing and an early loss of the bone graft or implant. If the incision does not close properly, the remaining graft should be removed, the membrane inspected for perforations, and the sinus void irrigated. The patient should be prescribed appropriate antibiotics, and the wound should be allowed to heal by secondary intervention. If the graft fails to produce sufficient quality or quantity of new bone to sustain implants, the sinus void can be regrafted. After the lateral aspect of the sinus has been exposed, the graft material is removed, the surgical defect inspected, and the sinus regrafted with a different combination of materials.[1] Trauma to an implant during the healing process or pathologic loading with the restoration can also cause premature loss. The loss of maxillary implants can create oral-antral openings, which may require surgery for closure.[36]

Discussion

Grafting of the antral floor was originally developed by Tatum in the early 1970s.[3–5] Initially, he used an alveolar crestal access to the maxillary sinus. Subsequently, a modified Caldwell-Luc procedure was developed in which the sinus was approached by infracturing the lateral wall of the maxilla and using the wall to elevate the maxillary sinus membrane. Autogenous bone was then added in the area previously occupied by the inferior third of the sinus. This technique provided adequate bone in the posterior maxilla, which permitted various implant placement options.

In 1980, Boyne and James[48] described a similar clinical procedure and demonstrated the potential of the maxillary antrum as a site of bone formation after the placement of autogenous marrow and cancellous bone in the maxillary sinus. In 1987, Misch[2] modified the technique and developed a combined sinus augmentation and blade-vent placement in the same procedure. Since then, a variety of techniques has been described for augmenting the maxillary sinus with grafting material for the placement of implants either in a one-step or two-step procedure.[1,7–9,20–22,36,37,49–55] The procedures differ in initial surgical approach, type or site of grafting material, and type of implant material.

Over the last decade, the success of sinus floor augmentation with graft material for the placement of implants has increased significantly, and the procedure has become an excellent one for treating patients with severely atrophic posterior maxillae.[38] Many investigators have reported good initial results with both the one-step and two-step procedures.[1,7–9,20–22,36,37,49–55] This option makes prosthetic rehabilitation with osseointegrated dental implants possible for people who were not implant candidates in the past.

Few risks are involved with sinus lift grafting surgery because few vital anatomical structures encroach upon the surgical site. Morbidity is low, and postoperative complications can usually be easily treated with either medical or surgical intervention. Bone response is excellent. Different graft materials produce bone that is demonstrable on histologic examination.[56] The graft and new bone appear to remodel in response to functional loading. The prosthetic alternatives are predictable. Fixed or

removable prosthetic reconstructions can be placed over implants within the sinus graft.[1]

Factors that influence the biocompatibility of the implant and bone formation within the graft will affect the success of implants placed within the graft. Important considerations include the design and composition of the implant material (ie, titanium and HA), the nature of the host tissue, and the interface reaction between the host tissue and implant. These factors help to determined what graft materials should be used to augment the sinus and what implant materials and design should be placed within the graft. As more long-term results with large patient populations are reported, dental practitioners will have a better idea about the best surgical approach for individual patients, the optimum graft material or combinations thereof, and the appropriate dental implant.

Conclusion

In patients with severe atrophy of the posterior maxilla, sinus floor augmentation with graft material for the placement of implants has been used with successful results over the past decade. Sinus lift grafting and implant placement can be accomplished by using either a one-step or two-step procedure, making prosthetic rehabilitation with osseointegrated dental implants possible for people who were not implant candidates in the past. Use of the proper surgical technique for sinus lifting and awareness of postoperative considerations can reduce or eliminate postoperative complications.

References

1. Smiler DG, Johnson PW, Lozada JL, et al. Sinus lift grafts and endosseous implants. *Dent Clin North Am.* 1992;36:151–186.
2. Misch CE. Maxillary sinus augmentation for endosteal implants: organized alternative treatment plans. *Int J Oral Implantol.* 1987;4:49–58.
3. Tatum H. Maxillary and sinus implant reconstructions. *Dent Clin North Am.* 1986;30:207–229.
4. Tatum H. Endosteal implants. *Calif Dent Assoc J.* 1988;16:71–76.
5. Tatum H. Maxillary implants. *Florida Dent J.* 1989;60:23–27.
6. Thomas GJ. Sinus lifts: A possible solution to the atrophic maxilla. *J Macomb Dent Soc.* 1990;29:9–11.
7. Kent JN, Block MS. Simultaneous maxillary sinus floor bone grafting and placement of hydroxylapatite-coated implants. *J Oral Maxillofac Surg.* 1989;47:238–242.
8. Jensen J, Simonsen EK, Sindet-Pedersen S. Reconstruction of the severely resorbed maxilla with bone grafting and osseointegrated implants: A preliminary report. *J Oral Maxillofac Surg.* 1990;48:27–32.
9. Raghoebar GM, Brouwer TJ, Reintsema H, van Oort RP. Augmentation of the maxillary sinus floor with autogenous bone for the placement of endosseous implants: A preliminary report. *J Oral Maxillofac Surg.* 1993;51:1198–1203.
10. Razavi R, Zena RB, Khan Z, Gould AR. Anatomic site evaluation of edentulous maxillae for dental implant placement. *J Prosthodont.* 1995;4:90–94.
11. Chanavaz M. Maxillary sinus: Anatomy, physiology, surgery, and bone grafting related to implantology—Eleven years of surgical experience(1979–1990). *J Oral Implantol.* 1990;16:2–12.
12. Cuenin MF, Pollard BK, Elrod CW. Maxillary sinus morphology in differential dental diagnosis. *Gen Dent.* 1996;44:328–331.
13. Ulm CW, Solar P, Gsellman B, Matejka M, Watzek G. The edentulous maxillary alveolar process in the region of the maxillary sinus—A study of physical dimension. *Int J Oral Maxillofac Surg.* 1995;24:279–282.
14. Lane JM. Bone graft substitutes. *West J Med.* 1995;163:565–566.
15. Frame JW. Hydroxyapatite as a biomaterial for alveolar ridge augmentation. *Int J Oral Maxillofac Surg.* 1987;16:642–655.
16. Pinholt EM, Bang G, Haanaes HR. Alveolar ridge augmentation in rats by combined hydroxylapatite and osteoconductive material. *Scand J Dent Res.* 1991;99:64–74.
17. Misch CE, Dietsh F. Bone-grafting materials in implant dentistry. *Implant Dent.* 1993;2:158–167.
18. Wagner J. A clinical and histological case study using resorbable hydroxylapatite for the repair of osseous defects prior to endosseous implant. *J Oral Implantol.* 1989;15:485–509.
19. Moy PK, Lundgren S, Holmes RE. Maxillary sinus augmentation: Histomorphometric analysis of graft materials for maxillary sinus floor augmentation. *J Oral Maxillofac Surg.* 1993;51:857–862.
20. Adell R, Lekholm U, Grondahl K, et al. Reconstruction of severely resorbed edentulous maxillae using osseointegrated fixtures in immediate autogenous bone grafts. *Int J Oral Maxillofac Implants.* 1990;5:233–246.
21. Kahnberg KE, Nystrom E, Bartholdsson L. Combined use of bone grafts and Brånemark fixtures in the treatment of severely resorbed maxillae. *Int J Oral Maxillofac Implants.* 1989;4:297–304.
22. Nystrom E, Kahnberg KE, Gunne J. Bone grafts and Brånemark implants in the treatment of the severely resorbed maxilla: A 2-year longitudinal study. *Int J Oral Maxillofac Implants.* 1993;8:45–53.
23. Editorial. Second-hand bones? *Lancet.* 1992;340:1443.
24. Rummelhart JM, Mellonig JT, Gray JL, Towle HJ. A comparison of freeze-dried bone allograft and demineralized freeze-dried bone allograft in human periodontal osseous defects. *J Periodontol.* 1989;60:655–663.
25. Mellonig JT. Decalcified freeze-dried bone allograft as an implant material in human periodontal defects. *Int J Periodontics Restorative Dent.* 1984;6:41–55.
26. Tatum OJ Jr, Lebowitz MS, Tatum CA, Borgner RA. Sinus augmentation: Rationale, development, long-term results. *NY State Dent J.* 1993;59:43–48.
27. Tatum OJ Jr. Osseous grafts in intra-oral sites. *J Oral Implantol.* 1996;22:51–52.
28. Fetner AE, Hartigan MS, Low SB. Periodontal repair using PerioGlas® in nonhuman primates: Clinical and histologic observations. *Compend Contin Educ Dent.* 1994;15:932–938.
29. Ashman A. The use of synthetic bone materials in dentistry. *Compend Contin Educ Dent.* 1992;13:1020–1034.
30. Ashman A. Clinical applications of synthetic bone in dentistry, part I. *Gen Dent.* 1992;40:481–487.
31. Ashman A. Clinical applications of synthetic bone in dentistry, part II: Periodontal and bony defects in conjunction with dental implants. *Gen Dent.* 1993;41:37–44.
32. Schepers E, DeClerco M, Ducheyne P, Kempeneers R. Bioactive glass particulate materials as a filler for bone lesions. *J Oral Rehabil.* 1991;18:439–452.
33. Schepers EJG, Ducheyne P, Barbier L, Schepers S. Bioactive glass particles of narrow size range: A new material for the repair of bone defects. *Implant Dent.* 1993;2:151–156.
34. Wheeler SL, Holmes RE, Calhoun CJ. Six-year clinical and histologic study of sinus-lift grafts. *Int J Oral Maxillofac Implants.* 1996;11:26–34.
35. Koole R, Bosker H, van der Dussen FN. Late secondary autogenous bone grafting in cleft patients comparing mandibular (ectomesenchymal) and iliac crest (mesenchymal) grafts. *J Craniomaxillofac Surg.* 1989;17:28–30.
36. Wood RM, Moore DL. Grafting of

the maxillary sinus with intraorally harvested autogenous bone prior to implant placement. *Int J Oral Maxillofac Implants.* 1988;3:209–214.

37. Jensen J, Sindet-Pedersen S. Autogenous mandibular bone grafts and osseointegrated implants for reconstruction of the severely atrophied maxilla: A preliminary report. *J Oral Maxillofac Surg.* 1991;49:1277–1287.

38. Chanavaz M. Sinus grafting related to implantology: Statistical analysis of 15 years of surgical experience(1979–1994). *J Oral Implantol.* 1996;22:119–130.

39. Boyne PJ. Animal studies of application of rhBMP-2 in maxillofacial reconstruction. *Bone.* 1996;19(Suppl 1):83S–92S.

40. Nevins M, Kirker-Head C, Nevins M, Wozney JA, Palmer R, Graham D. Bone formation in the goat maxillary sinus induced by absorbable collagen sponge implants impregnated with recombinant human bone morphogenetic protein-2. *Int J Periodontics Restorative Dent.* 1996;16:9–19.

41. Abraham JJ, Glassberg RM. Dental disease: A frequently unrecognized cause of maxillary sinus abnormalities? *AJR Am J Roentgenol.* 1996;166:1219–1223.

42. Misch CM. The pharmacological management of maxillary sinus elevation surgery. *J Oral Implantol.* 1992;18:15–23.

43. Peterson LJ. Antibiotic prophylaxis against wound infections in oral and maxillofacial surgery. *J Oral Maxillofac Surg.* 1990;48:617–620.

44. Garg AK, Quiñones CR. Augmentation of the maxillary sinus: A surgical technique. *Pract Periodontics Aesthet Dent.* 1997;9:211–219.

45. Betts NJ, Miloro M. Modification of the sinus lift procedure for septa in the maxillary antrum. *J Oral Maxillofac Surg.* 1994;52:332–333.

46. Ulm CW, Solar P, Krennmair G, Matejka M, Watzek G. Incidence and suggested surgical management of septa in sinus-lift procedures. *Int J Oral Maxillofac Implants.* 1995;10:462–465.

47. Regev E, Smith RA, Perrott DH, Pogrel MA. Maxillary sinus complications related to endosseous implants. *Int J Oral Maxillofac Implants.* 1995;10:451–461.

48. Boyne PJ, James RA. Grafting of the maxillary sinus floor with autogenous marrow and bone. *J Oral Surg.* 1980;38:613–616.

49. Keller EE, van Roekel NB, Desjardins RP, Tolman DS. Prosthetic-surgical reconstruction of the severely resorbed maxilla with iliac bone grafting and tissue-integrated prosthesis. *Int J Oral Maxillofac Implants.* 1987;2:155–165.

50. Loukota RA, Isaksson SG, Linner EL, et al. A technique for inserting endosseous implants in the atrophic maxilla in a single stage procedure. *Br J Oral Maxillofac Surg.* 1992;30:46–49.

51. Small SA, Zinner ID, Panno FV, Shapiro HJ, Stein JI. Augmenting the maxillary sinus for implants: Report of 27 patients. *Int J Oral Maxillofac Implants.* 1993;8:523–528.

52. Jensen OT, Perkins S, van de Water FW. Nasal fossa and maxillary sinus grafting of implants from a palatal approach: Report of a case. *J Oral Maxillofac Surg.* 1992;50:415–418.

53. Tidwell JK, Blijdorp PA, Stoelinga PJW, Brouns JB, Hinderks F. Composite grafting of the maxillary sinus for placement of endosteal implants. *Int J Oral Maxillofac Surg.* 1992;21:204–209.

54. Triplett RG, Schow SR. Autologous bone grafts and endosseous implants: Complementary techniques. *J Oral Maxillofac Surg.* 1996;54:486–494.

55. Zinner ID, Small SA. Sinus-lift graft: Using the maxillary sinuses to support implants. *JADA.* 1996;127:51–57.

56. Wallace SS, Froum SJ, Tarnow DP. Histologic evaluation of sinus elevation procedure: A clinical report. *Int J Periodontics Restorative Dent.* 1996;16:47–51.

57. Garg AK. *Practical implant dentistry*. Houston: Taylor Publishing Company; 1996.

Reprint requests and correspondence to:
Arun K. Garg, DMD
6633 Roxbury Lane
Miami Beach, FL 33141
Fax: (305) 865-1148
E-mail: arungarg@pol.net

Abstract Translations [German, Spanish, Portuguese, Japanese]

AUTOR: Arun K. Garg, DMD, *Gastprofessor für Chirurgie; Abteilung Kieferchirurgie; Fachbereich Chirurgie; Universität der Miami School of Medicine; Miami, Florida. Schriftverkehr: Arun K. Garg, DMD, 6633 Roxbury Lane, Miami Beach, FL 33141. Fax: 305-865-1148, E-mail: arungarg@pol.net.*

ABSTRACT: Bei Patienten, deren verbleibendes Knochenmaterial für die Implantierung im Kieferbereich nicht ausreicht, kann mittels eines chirurgischen Eingriffs zur Sinusanhebung die erforderliche Menge Alveolarknochens aufgebaut werden, um eine Implantation und eine somit folgende prothetische Wiederherstellung des Gebisses zu ermöglichen. Der Verfasser spricht in der vorliegenden Studie die physikalischen Gegebenheiten und den Aufbau des Kiefersinus an; er geht weiterhin auf die Abläufe bei der Knochentransplantation, die bei der Transplantation verwendeten Materialien, die vor dem Eingriff ergehende Beurteilung und die möglichen Operationstechniken ein. Des weiteren informiert dieser Artikel über die praktische Vorgehensweise bei der Transplantation, über die Problematik eventueller Blutungen während des Eingriffs und über mögliche postoperative Komplikationen .

SCHLÜSSELWORTE: Kiefersinus, autogenes Knochengewebe, Sinusanhebung, Knochenaufbau, Osteogenese

AUTOR: Arun K. Garg, DMD, *Profesor Asociado de Cirugía, División de Cirugía Oral/Maxilofacial, Departamento de Cirugía, Facultad de Medicina de la Universidad de Miami, Miami, Florida. Correspondencia a: Arun K. Garg, DMD, 6633 Roxbury Lane, Miami Beach, FL 33141. Fax 305-865-1148, Correo electrónico: arungarg@pol.net.*

ABSTRACTO: En pacientes con una cantidad inadecuada de hueso para la colocación del implante, se puede realizar una cirugía para levantar el seno para restaurar una cantidad suficiente de hueso alveolar para la colocación exitosa del implante y posterior reconstrucción protética posterior. El autor explica la anatomía y fisiología del seno maxilar, los mecanismos de injerto del hueso, material para injerto del hueso, evaluación preoperatoria, técnica quirúrgica, y el procedimiento de injerto, así como el sangrado intraoperativo y complicaciones postoperativas.

PALABRAS CLAVES: seno maxilar, hueso autogénico, levante del seno, aumento, osteogénesis

AUTOR: Arun K. Garg, DMD, *Professor Auxiliar de Cirurgia, Divisão de Cirurgia Oral e Maxilofacial, Departamento de Cirurgia, Universidade de Miami, Faculdade de Medicina, Miami, Flórida. Correspondências devem ser dirigidas a: Arun K. Garg, DMD, 6633 Roxbury Lane, Miami Beach, FL 33141. Fax: 305-865-1148, E-mail: arungarg@pol.net.*

SINOPSE: Em pacientes com uma quantidade inadequada de osso para colocamento do implante, pode ser efetuada uma cirurgia do tipo *sinus lift* para restaurar uma quantidade suficiente de osso alveolar visando permitir a inserção exata de implante e uma subseqüente reconstrução prostética. O autor discute a anatomia e a fisiologia dos *sinus* maxilar, os mecanismos de enxerto ósseo, materiais para enxerto ósseo, avaliação pré-operatória, técnica cirúrgica e o procedimento de enxerto, bem como o sangramento intra-operatório e complicações pós-operatórias.

PALAVRAS-CHAVES: *sinus* maxilar, osso autógeno, procedimento *sinus lift*, aumento, osteogênese

デンタルインプラント設置のための上顎洞増高移植：その解剖学、生理学と処置法

著者：アルン・K・ガーグ、DMD*

概要：

インプラント設置に際して骨容量が不足する場合、歯槽骨容量を十分に再建しインプラント設置とその後の補綴形成術を可能にするために、上顎洞増高術が行われる。著者は、上顎洞の解剖学・生理学、骨移植の手法と素材、術前の評価、手術技法、移植の手順、術中出血、術後合併症について説明する。

キーワード：

上顎洞、autogenous bone、上顎洞増高術、増高、骨生成

**マイアミ・スクール・オブ・メディシン（フロリダ州マイアミ）外科学部口腔顎顔面外科科外科准教授*

連絡先：Arun K. Garg, DMD, 6633 Roxbury Lane, Miami Beach, FL 33141

ファックス：(305) 865-1148　e-mail: arungarg@pol.net