Maxillary Autogenous Bone Grafting

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Reconstruction of the atrophic maxilla for dental implant placement has many unique considerations (\textbf{Figs. 1–20}). After tooth extraction, the greatest loss of bone in the maxilla occurs facially. Horizontal bone resorption can approach 50\% of the ridge width at 12 months.\textsuperscript{1} The use of a soft tissue borne–prosthesis causes continued medial resorption and loss of vertical bone height.\textsuperscript{2} As a result, the atrophic residual ridge may be significantly palatal to the prosthetic tooth position. Efforts to reconstruct the atrophic maxilla to its original form usually require buccal bone augmentation. The surgeon must also contend with the maxillary sinususes and nasal cavity as anatomic limitations that may need bone grafting. The maxillary bone is often less dense than the mandible, especially in the posterior regions below the sinuses.\textsuperscript{3} Aesthetic zone reconstruction in the partially edentulous anterior maxilla can be especially challenging when a high lip line exposes gingiva.

There are several methods available to augment the atrophic maxilla, including onlay bone grafting, sinus/nasal bone grafting, guided bone regeneration, interpositional grafting, ridge splitting, and distraction osteogenesis. The choice of a particular technique depends on the need for horizontal or vertical augmentation, degree of atrophy, type of prosthesis, and clinician or patient preference. Autogenous bone grafting offers a well-proven predictable method for ridge augmentation and defect repair for dental implant placement. There are several advantages to using autogenous bone grafts.\textsuperscript{4} Autogenous block bone grafts have a shorter healing period than other approaches such as guided bone regeneration using bone substitutes. This graft usually requires only 4 months of healing before implants may be inserted. On incorporation, the quality of the graft often exceeds the density of the native maxillary bone. This enhanced quality improves implant stability and can shorten healing time. The

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cost of autogenous bone is obviously much less than using bone substitutes, membranes, and/or recombinant growth factors. Block bone grafts may be preferred to osteotomy techniques (ridge splitting, interpositional grafts) because they can 3-dimensionally reconstruct the lost anatomic ridge contour. Autogenous bone grafts have proven to be most effective in managing larger bone defects. Although sinus bone grafting may not require the routine use of autogenous bone, autogenous bone use may be beneficial when treating large pneumatized sinuses with minimal remaining bone. This article primarily focuses on the use of autogenous onlay bone grafts to reconstruct the atrophic maxilla.

PROSTHETIC TREATMENT PLANNING

It is important to define the prosthetic goals before the maxillary reconstruction. The design of the final prosthesis determines the number of implants required and the ideal
positions of implants. If there is inadequate available bone for implant placement in the desired locations, then bone augmentation is considered. This concept has been termed prosthetic guided bone augmentation. Computed tomography (CT) is extremely useful in assessing the ridge deficiency and volume of bone augmentation required. Radiographic templates allow the clinician to evaluate the ideal prosthetic tooth position in relationship to the atrophic ridge. In addition, an implant planning software can be used with the scan to precisely evaluate the reconstructive needs of the patient. It is difficult to provide absolute guidelines for the number and distribution of implants to support a particular type of prosthesis. However, generalizations may be made based on biomechanical support, long-term studies, and clinical experience. When only the minimum number of implants are used, the prosthesis may be at risk if complications occur. The philosophy of “protect the prosthesis” is a prudent guideline in treatment planning and design of the implant support system.

The planning for posterior implant support in the edentulous maxilla has been simplified with sinus bone grafting techniques and zygoma implants. The residual ridge anterior to the sinuses is therefore the key region to evaluate for implant placement. From a prosthetic perspective, anterior abutments are necessary for proper load distribution and mechanical support. Ignoring the atrophic anterior maxilla and only placing posterior implants can have undesirable prosthetic consequences. One must keep in mind that the maxilla resorbs medially such that the residual ridge is palatal to the position of the teeth. Functional use of the anterior teeth, for incising
and anterior guidance, can cause a tripping action on an upper overdenture. A continuous connecting bar across the anterior maxilla acts as a vertical stop to resist overdenture displacement. A lack of anterior abutments for a fixed prosthesis creates a cantilever effect that can lead to complications such as screw loosening, screw breakage, marginal bone loss, and implant fracture.\textsuperscript{12–15} These problems are magnified in patients with biomechanical risk factors such as strong masticatory dynamics, parafunctional habits, or opposing natural dentition/fixed implant prosthesis.\textsuperscript{16–18} Therefore, when the residual ridge is deficient in the anterior maxilla, autogenous block

![Fig. 5. A CT scan of the healed graft, showing minimal resorption and favorable bone volume for implant placement.](image)

![Fig. 6. Removal of the fixation screws through a mucosal incision for implant placement after a 4-month healing period.](image)
bone grafts can be used to predictably develop sites for implant placement. This site development using implants is accomplished in a staged manner with implant placement following graft incorporation.

EDENTULOUS MAXILLA

Implant-Supported Overdenture

Clinical studies have found that implant failure rates are often significantly higher for maxillary overdentures than any other type of implant prosthesis.\textsuperscript{19,20} This higher failure rate may be because of less bone volume and poorer bone quality as well as implant distribution, prosthetic design, and opposing occlusion. Although the use of 2 implants for overdenture support is a well-documented option in the mandible, this approach is less recommended in the maxilla.\textsuperscript{21} Many patients with minimal atrophy of the upper jaw are able to tolerate a maxillary complete denture. It is not until the maxilla becomes more resorbed that the patient experiences problems with stability and retention of the prosthesis. With increased atrophy, there is less available bone for implant placement and less residual ridge for prosthetic support. Higher loads are placed on 2 independent implants in soft-quality bone.\textsuperscript{22} Studies have found higher implant failure rates and greater levels of marginal bone loss around independent maxillary implants supporting overdenture prostheses.\textsuperscript{20,23-25} Although the cost is higher, the mechanical advantage of implant splinting with a connecting bar is preferred.\textsuperscript{26}

Fig. 7. Placement of the implants into the incorporated bone graft.

Fig. 8. Provisional tooth replacement using an immediate provisional bridge.
The minimum number of implants for support of a maxillary overdenture is 4. Two implants are typically positioned on each side of the maxilla anterior to the maxillary sinuses. The midline area is usually avoided to provide space for positioning denture teeth, minimize bulky palatal contours, and allow placement of anterior prosthetic attachments. The 4 implants should be splinted with a connecting bar. This splinting requires preoperative planning in cases with less atrophy because greater inter-arch space is needed. The palate and posterior areas of the maxillary ridge may be used for additional prosthetic support.

A maxillary overdenture with 6 implants may be removable yet completely implant supported. Sinus bone grafting is often required to place the 2 additional posterior implants. As previously mentioned, avoiding implant placement in the midline area is preferred. Reduction of palatal coverage is a desired benefit of additional implant support. The 6 implants are cross-arch splinted with a connecting bar. Although 2 separate connecting bars have been proposed, this design is mechanically unfavorable because the overdenture has a tendency to rock from the lack of anterior support.

**Fixed Implant Prosthesis**

The minimum number of implants proposed for support of a maxillary fixed prosthesis is 4. Although the early Swedish literature documented maxillary cases with as few as
4 implants, they more often recommended 6 placed anterior to the maxillary sinuses. A higher failure rate was noted when only 4 implants were used. More recently, the All-on-Four concept was introduced for treatment of the edentulous maxilla using 4 implants for a fixed prosthesis. In this approach, the posterior implants are placed in a tilted manner to follow the anterior sinus border, extending the distal position of the implants. Although early results have been favorable, the obvious significant disadvantage is that loss of one implant will result in complete prosthetic failure. A more prudent approach is to consider a minimum of 6 implants for a maxillary fixed prosthesis. Implants should be evenly distributed across the maxilla, avoiding long pontic spans. Sinus bone grafting may be required to place the posterior implants. Greater numbers of implants (7–12) are recommended when mechanical risk factors are higher, bone volume is compromised, and/or bone density is poor. Bone augmentation is often required in the atrophic maxilla, including sinus and/or onlay grafting, to provide the preferred number and distribution of implants. A greater number of implants (>6) are also advised when immediate loading with a fixed prosthesis is planned.

The Aesthetic Zone

Bone remodeling following tooth loss can have a significant effect on the ability to properly place dental implants in the aesthetic zone. When the anterior maxilla is

Fig. 11. Splinting of the 4 maxillary implants for support of an overdenture using an implant connecting bar.

Fig. 12. Preoperative view of an alveolar defect after a failed attempt at repair using guided bone regeneration techniques.
planned for grafting, an aesthetic zone evaluation is necessary. The surgeon should plan on providing adequate bone volume for implant placement as well as a proper soft tissue profile for the implant restoration. The amount of tooth and gingival exposure with a high smile is accessed. The need for lip support is evaluated when multiple teeth are missing. A diagnostic wax up helps determine the ideal tooth length and need for vertical augmentation to develop the proper tooth size. If the upper lip covers the defect, it may be an option to prosthetically replace the missing hard and soft tissues with gingival colored porcelain.

The soft tissue in the graft recipient site should be evaluated, including the amount of keratinized tissue and gingival biotype. It is often better to plan the correction of soft tissue problems before bone grafting. This correction will help reduce soft tissue complications (ie, wound dehiscence) and improve graft incorporation. Autogenous free gingival grafts from the palate may be used to increase the amount of keratinized tissue. Connective tissue grafts from the palate can be used to enhance mucosal thickness and improve graft coverage. Soft tissue corrective surgery must be performed at least 8 weeks before bone grafting. The surgeon should be aware that facial flap advancement over a bone graft moves the mucogingival junction palatally.

When failed maxillary incisors have significant facial bone loss, the osseous repair is usually not performed at the time of extraction. The normal gingival anatomy is disrupted by the flap advancement over the socket because primary soft tissue closure is

Fig. 13. Repairing the soft tissue defect before bone graft surgery using a gingival graft from the palate.

Fig. 14. Exposure of the ridge for onlay bone grafting after 2 months of soft tissue grafting.
necessary for bone grafting or membrane repair. The reconstruction of the alveolar defect is performed approximately 6 to 8 weeks after extraction to allow epithelialization over the socket, which allows the surgeon to perform the bone graft and adapt the flaps to maintain the soft tissue architecture.

The teeth adjacent to the graft site should also be evaluated before grafting. It is often preferred to extract compromised teeth before the bone graft surgery and allow the soft tissue to heal over the site. The marginal bone height on the teeth bordering the ridge defect determines the level that may be achieved with vertical bone augmentation. In some cases, it may be preferred to remove teeth with marginal bone loss to improve the ability to reconstruct the ridge.

**BONE GRAFT DONOR SITES**

Onlay bone grafts can be used to increase horizontal ridge width and/or vertical ridge height. The degree of jaw atrophy and amount of bone augmentation required for implant placement determines the preferred donor site for graft harvest. For the management of moderate ridge atrophy, bone grafts can be procured from intraoral donor sites, such as the symphysis and ramus of the mandible. These donor sites are desirable because the surgery may be performed in the office. Intraoral bone grafts are primarily cortical and used for veneer grafting narrow ridges or modest vertical augmentation.

![Fig. 15. Harvesting a cortical bone graft from the mandibular ramus using a piezoelectric saw.](image15)

![Fig. 16. Fixation of the cortical bone graft to the maxilla with a titanium alloy lag screw.](image16)
The symphysis donor site offers the greatest volume of intraoral bone. The ease of surgical access is another advantage of this region. Large blocks of bone can be harvested as well as significant quantities of particulate graft. However, the symphysis is associated with a greater incidence of postoperative complications. These complications include neurosensory changes (lip, chin, anterior teeth), pulpal injury, concern for altered facial contour, and significant postoperative pain.

The posterior mandible is an excellent donor site, and this area offers several advantages over the symphysis. A cortical block graft approximately 4 mm in width may be harvested from the buccal aspect of the ramus region. The rectangular graft may extend up to 40 mm in length and more than 10 mm in height. This morphology is well suited for width augmentation of the narrow maxillary ridge. Both sides of the mandible may be used when significant veneer grafting is needed. The posterior mandible is also an excellent area for harvesting particulate bone with a scraper device. The particulate bone can be used for sinus bone grafting and/or placed around the periphery of the bone block. The mandibular ramus has less morbidity than the symphysis and has become the preferred donor site of many clinicians. Although there is a low risk of inferior alveolar nerve injury, this complication can be avoided by knowledge of mandibular canal anatomy and a strict adherence to the recommended osteotomies. Compared with chin graft surgery,
ramus grafting in patients seems to result in fewer difficulties with managing postoperative pain and also lesser concern with bone removal from this area.\textsuperscript{33,36}

When treating large defects and advanced maxillary atrophy, larger bone grafts may be harvested from the iliac crest. Corticocancellous block bone grafts from the ilium are especially useful for reconstructing the atrophic anterior maxilla. Severe horizontal and vertical deficiencies can be managed with this approach. When thicker pieces of bone are needed for significant vertical bone augmentation, a tricortical bone graft may be harvested using the entire width of the iliac crest.\textsuperscript{4} The use of a pain pump with a long-acting local anesthetic (bupivacaine) has dramatically reduced the level of postoperative pain from the hip area.\textsuperscript{42} Although the proximal tibia is an attractive donor site for harvest in an office setting, the bone is mostly cancellous; so, titanium mesh or membrane techniques are needed for graft stabilization and protection.

**BONE GRAFT INCORPORATION**

Bone graft resorption is a necessary biologic aspect of graft healing and incorporation to the osseous recipient site. Cortical bone grafts undergo creeping substitution with replacement by new bone over time.\textsuperscript{43} Although the embryologic origin of the bone graft was suggested as a predictor of resorption, more recent studies emphasize the importance of the osseous microarchitecture.\textsuperscript{43–46} Denser cortical bone grafts resorb less than more porous cancellous bone grafts.\textsuperscript{46} Cortical bone grafts from
the mandible exhibit minimal resorption and maintain their dense quality, making them ideal for onlay augmentation before implant placement. The volume loss of cortical bone grafts used for onlay augmentation has been measured as less than 25%.\textsuperscript{38,47} Corticocancellous bone grafts from the ilium are associated with greater resorption because of the thinner outer cortex and more porous cancellous component.\textsuperscript{48,49} Although some studies have reported higher rates of graft resorption, they still conclude that onlay bone grafting is a predictable technique for implant placement.\textsuperscript{58,48,50,51} It is prudent to slightly overbuild the reconstructed ridge in anticipation of some volume loss on healing.

The use of a barrier membrane has been suggested as a strategy to reduce resorption of block bone grafts. Although some studies have found that membranes have a positive influence on graft healing, others dispute the benefit of this practice.\textsuperscript{52} Cortical bone grafts exhibit minimal resorption and do not typically require membrane protection.\textsuperscript{32,38,46,47,53} Although the routine use of membranes over onlay bone grafts is questionable, a barrier membrane may improve the incorporation of the peripheral particulate graft around the block.\textsuperscript{54}

It is imperative that the onlay bone graft remains immobilized during healing. In the partially edentulous patient, a fixed provisional prosthesis, such as a temporary bridge or bonded prosthesis, is preferred for tooth replacement over the grafted site. Transitional implants have been used successfully to support fixed interim prostheses for patients less tolerant of complete or partial dentures.\textsuperscript{55} The transitional implants should be placed in native bones and not within the bone graft. A removable Essix retainer is another excellent option for cosmetic tooth replacement during graft healing because it does not place any pressure on the site. The use of a soft tissue–borne removable prosthesis is discouraged for the first few weeks until the incision has healed. Removable prostheses should then be adjusted to minimize any contact with the grafted site. A metal base removable partial denture, with rest seats on the abutment teeth, is preferred over an acrylic soft tissue–borne prosthesis because there is less potential for loading of the graft under function. The major connector of the partial denture should be designed, so there is no metal framework over the graft site. For patients wearing a complete denture, the flange should be removed over the graft area. The internal surface of the prosthesis should also be generously relieved over the graft site. The denture may be relined with tissue conditioner after suture removal. Patients are instructed to use their removable prosthesis for cosmetic appearance and minimize function. Patients wearing removable prostheses over larger bone grafts should maintain a softer diet for at least 2 months after surgery. After this period, the onlay graft has formed a union to the host bone and relies less on the fixation screws for immobility.

Smoking has been associated with a high rate of wound dehiscence and graft failure.\textsuperscript{56} Unless a patient commits to not smoke during the early postoperative course, onlay bone grafting is discouraged. A smoking cessation protocol is followed, including the use of prescription medications, such as bupropion, and the nicotine patch. Patients are instructed to quit smoking 1 week before surgery and told not to smoke at least until the incision is completely closed (2 weeks).\textsuperscript{4}

**IMPLANT PLACEMENT**

Reconstruction of the atrophic jaws for implant placement is usually staged with implant placement after graft healing. Enough time should elapse for graft incorporation, but implants should be inserted early enough to stimulate and maintain the regenerated bone.\textsuperscript{48} Autogenous block grafts should heal for approximately 4 months
before implant placement. The placement of implants into healed bone grafts is similar to their use in sites that have not been grafted. However, the implant site is often at the junction between the block and host bone. The surgeon should be careful not to displace the block from the ridge during the implant osteotomy and placement. Fixation screws are usually removed before implant insertion but may be left in place if they are remote. Elevation of large flaps for screw removal is discouraged because this disrupts the vascular supply to the healed graft. A small mucosal incision over the screw head allows for easy retrieval.

The integration period of implants placed into healed bone grafts is based on the resulting bone quality. Stable implants in dense cortical bone grafts (type 1–2) may only require 2-month healing. Implants placed into softer corticocancellous grafts (type 3) may need up to 4-month healing. Early Swedish studies on implants placed in iliac bone grafts found low survival rates, which was attributed to the use of machined implants, simultaneous graft-implant placement, and a developmental learning period. Much higher implant survival can be achieved in maxillary iliac bone grafts with staged surgery and use of microtextured implants (94.5%–100%). Studies on intraoral bone grafts for localized defect repair have also found very high implant survival rates (96.9%–100%). Implant loading stimulates the healed bone graft and maintains the volume. Additional graft resorption following implant placement and delayed loading has not been noted radiographically.

REFERENCES


