

# Maxillary Sinus and Ridge Augmentations Using a Surface-Derived Autogenous Bone Graft

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**Purpose:** The purpose of this article is to describe a new technique and the anatomic sites for cutting and harvesting bone for grafting applications. A handheld instrument is described that cuts and collects thin shavings of bone from cortical surfaces.

**Materials and Methods:** This study included 193 consecutive patients who needed bone augmentation and simultaneous implant placement in the severely atrophic posterior maxilla and in the anterior maxilla with acquired defect of alveolar bone as a result of local trauma. A total of 477 implants were placed. Clinical criteria for evaluation at time of implant exposure included stability in all directions, crestal bone resorption, and any reported pain of discomfort.

**Results:** There were no failures of the anterior maxilla group, and no signs of bone resorption were noted at the second stage surgery or during the follow-up. During initial and late healing, there was no dehiscence of the soft tissue flaps and no membranes were exposed. Core biopsies typically showed immature, newly formed bone and, on average, 27% to 36% vital bone.

**Conclusion:** From this research, it appears that excellent implant success rates can be achieved in grafted sinuses or ridges when a locally harvested autogenous bone graft with a ribbon geometry is used.

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The reconstruction of bone in the maxillofacial region has become prevalent with the expanded use of osseointegrated implant-supported prosthetics. Autogenous bone continues to be the "gold standard" for bone grafting applications.<sup>1-7</sup> However, the use of intraoral autogenous particulate bone has been limited because of time constraints, donor site morbidity, and a limited number of intraoral sites available for harvesting particulate bone. An important goal of the clinician is to provide these bone grafts for dental

implant placement in such a way as to minimize donor site morbidity, to minimize costs, and to minimize the patient's perceived complexity of the procedure. To address these problems, clinicians have turned to alternative sources of graft material such as allogenic, xenogenic, and alloplastic materials.<sup>8</sup> Although these sources are more convenient, the predictability of healing and long-term capabilities for remodeling are questionable because normal lamellar bone is not the same as for autogenous bone.<sup>9-11</sup> However, when these materials are used, their success and predictability can be increased with the addition of autogenous bone to create a composite graft.<sup>8,12-15</sup>

Traditional approaches to harvesting bone intraorally involve the removal of blocks or sections of bone through the use of trephines, saws, burs, and osteotomes. The symphysis and lateral body of the mandible are the most common sites available for harvesting blocks of bone.<sup>7,16</sup> Most other intraoral sites are not candidates for harvesting blocks of bone because of their proximity to tooth roots, neural structures, and the thin bones overlying the maxillary sinus and nasal antrum. The harvested bone graft has been used as blocks by some<sup>17</sup> but is most often rendered into a particulate form by means of rongeurs

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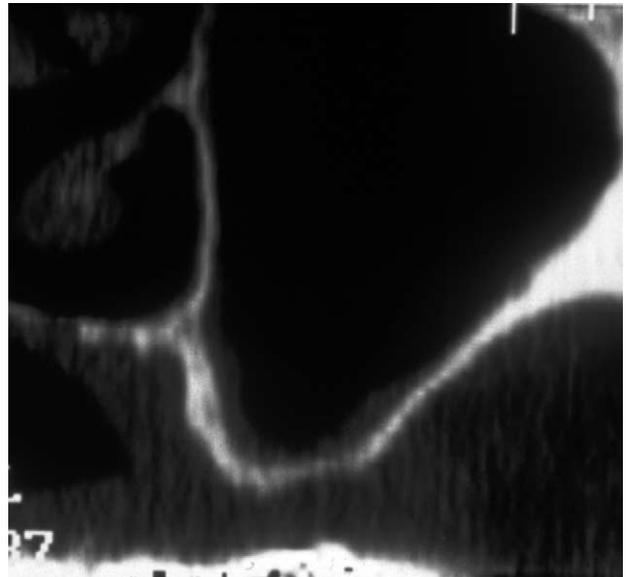
or a bone mill. The particulate form of the graft, which can be adapted to the site being reconstructed, increases the density of the graft and enhances the rate of graft healing.<sup>10,18-20</sup> Other approaches (eg, involving the use of burs to grind and collect the dust with filters from surface sites<sup>21,22</sup>) are limited by concerns of graft contamination, by the effect of heat on cells and proteins, and by desiccation of cellular elements.

In contrast, if only the superficial layers of bone are to be harvested, there are abundant bone surfaces in the maxillofacial region available as donor sites. Many large surfaces (such as the lateral mandibular ramus, the posterior mandibular body, anterior and lateral walls of the maxilla, and the zygomaticomaxillary buttress) are easily accessible through relatively small incisions and elevated mucoperiosteal flaps. Others indicate the use of trephine bur on a straight hand-piece to harvest bone from the zygomatic bone.<sup>23</sup> However, of the 3 cases reported, 1 had perforation of the maxillary sinus. Moderate amounts of bone of membranous origin are available in the maxillofacial region if the graft is harvested from the superficial layers of cortical bone. Membranous grafts seem to be less prone to resorption than grafts of endochondral bone origin.<sup>24-26</sup> Additionally, membranous bone graft healing time (4 months) is shorter than bone grafts of endochondral origin (6 to 9 months).<sup>27</sup> Cellular bone regeneration occurs in the area of the bone graft and initially produces a disorganized woven bone that is structurally sound but not to the degree of mature bone. This bone will undergo an obligatory resorption and replacement remodeling, eventually replaced by phase-2 (lamellar) bone, which is less cellular, more mineralized, and structurally more organized. Histologically, such grafts enter a long-term remodeling that is consistent with normal skeletal turnover. A periosteum and endosteum develop as part of this long-term remodeling cycle.<sup>28</sup>

The purpose of this article is to describe a new technique and the anatomic sites for cutting and harvesting bone for grafting applications. A handheld instrument is described that cuts and collects thin shavings of bone from cortical surfaces. The principles and application of this instrument are illustrated using the lateral mandibular ramus and the zygomaticomaxillary buttress as donor sites to harvest moderate amounts of bone.

## Materials and Methods

This study included 193 consecutive patients who needed bone augmentation and simultaneous implant placement in the severely atrophic posterior maxilla and in the anterior maxilla with acquired defect of alveolar bone as a result of local

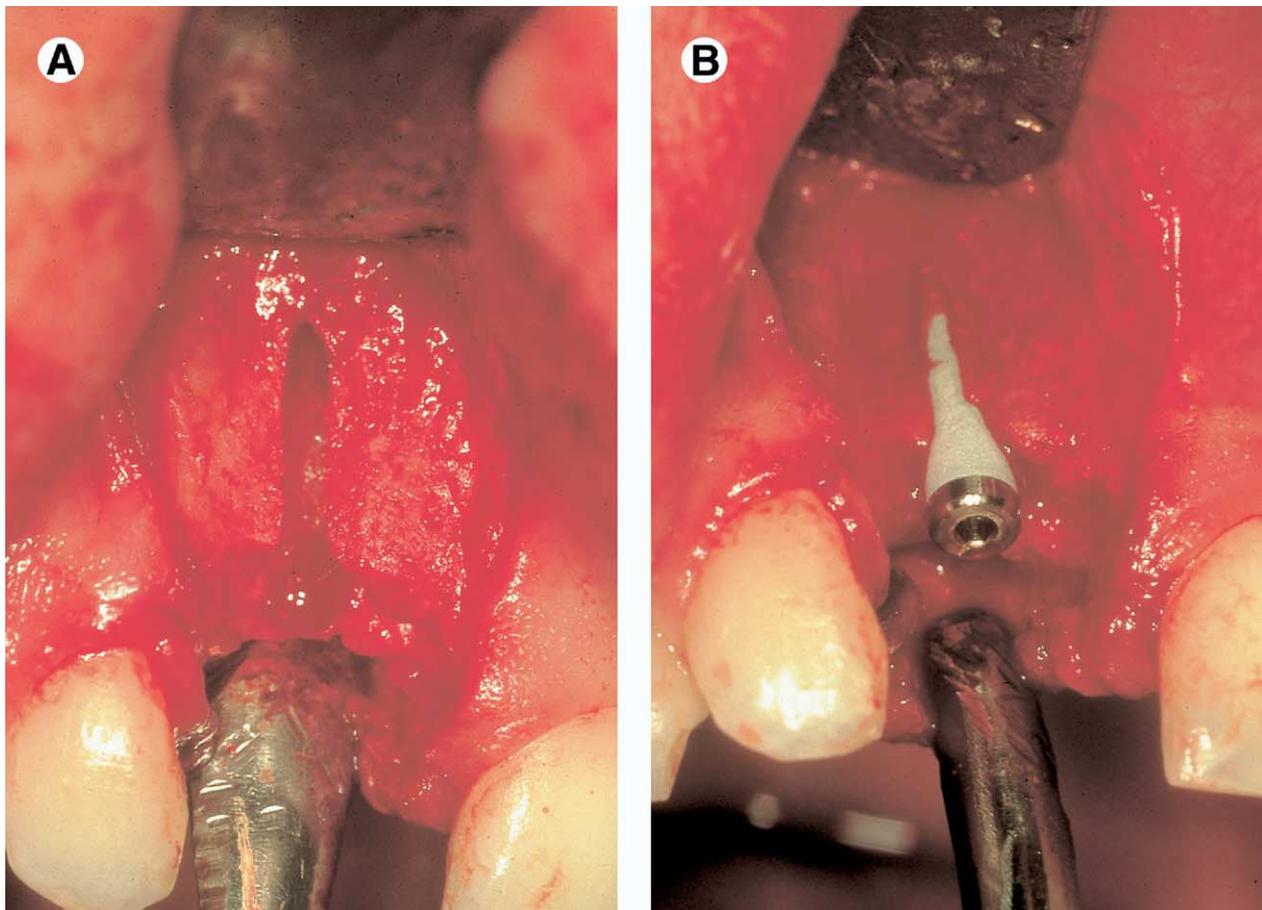


**FIGURE 1.** Patient with a severe atrophic posterior maxilla with 1 mm of bone height.

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trauma. One hundred fifty-six patients with a severe atrophic posterior maxilla no greater than 5 mm of residual crestal height (Fig 1) and 37 patients with dehiscence/fenestration of the buccal aspect of the implant placed were included (Figs 2, 3). Of the 156 patients with severely atrophic posterior maxilla, 38 patients had bilateral sinus floor augmentation procedures, and 118 had unilateral sinus floor augmentation procedures. Half of all the sinus floor augmentation patients were grafted with a composite graft that consisted of 50% autogenous bone and 50% Bio-Oss (Osteohealth, Shirley, NY). In the bilateral sinus lifts, 1 side was grafted with a composite bone graft and the other side with autogenous bone. The other half of patients were augmented with autogenous bone alone. The autogenous bone was harvested with the Mx-Grafter bone grafting system (Maxilon Laboratories, Inc, Hollis, NH). For a large grafted compartment that was grafted with autogenous bone alone, the amount of bone was harvested from the anterior maxillary wall, the zygomaticomaxillary buttress, and the lateral mandibular body and ramus. An average of 5 to 6 cc of autogenous bone was required for 1 sinus from the autogenous bone group. For the composite graft group, an average of 2 to 3 cc of bone was required. In this group, bone was harvested from the anterior maxillary wall, from the zygomaticomaxillary buttress, and from the tuberosity.

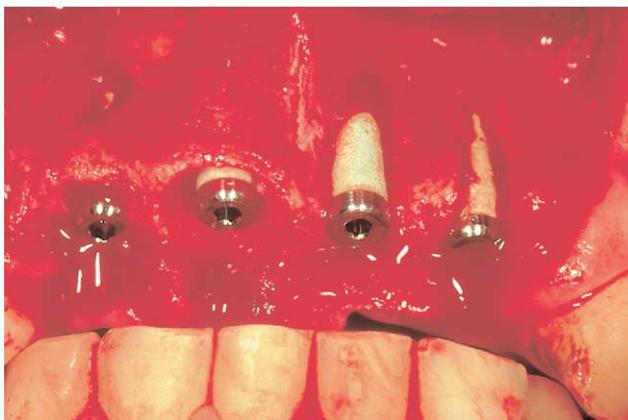
All patients received 15 mm length implants. The diameters were 3.25 or 3.75 mm. However, only 13% were 3.25 mm in diameter (Zimmer Dental, Carlsbad,



**FIGURE 2.** A, Dehiscence/fenestration of the buccal aspect of tooth number 8. B, Dehiscence on buccal aspect with implant in place.

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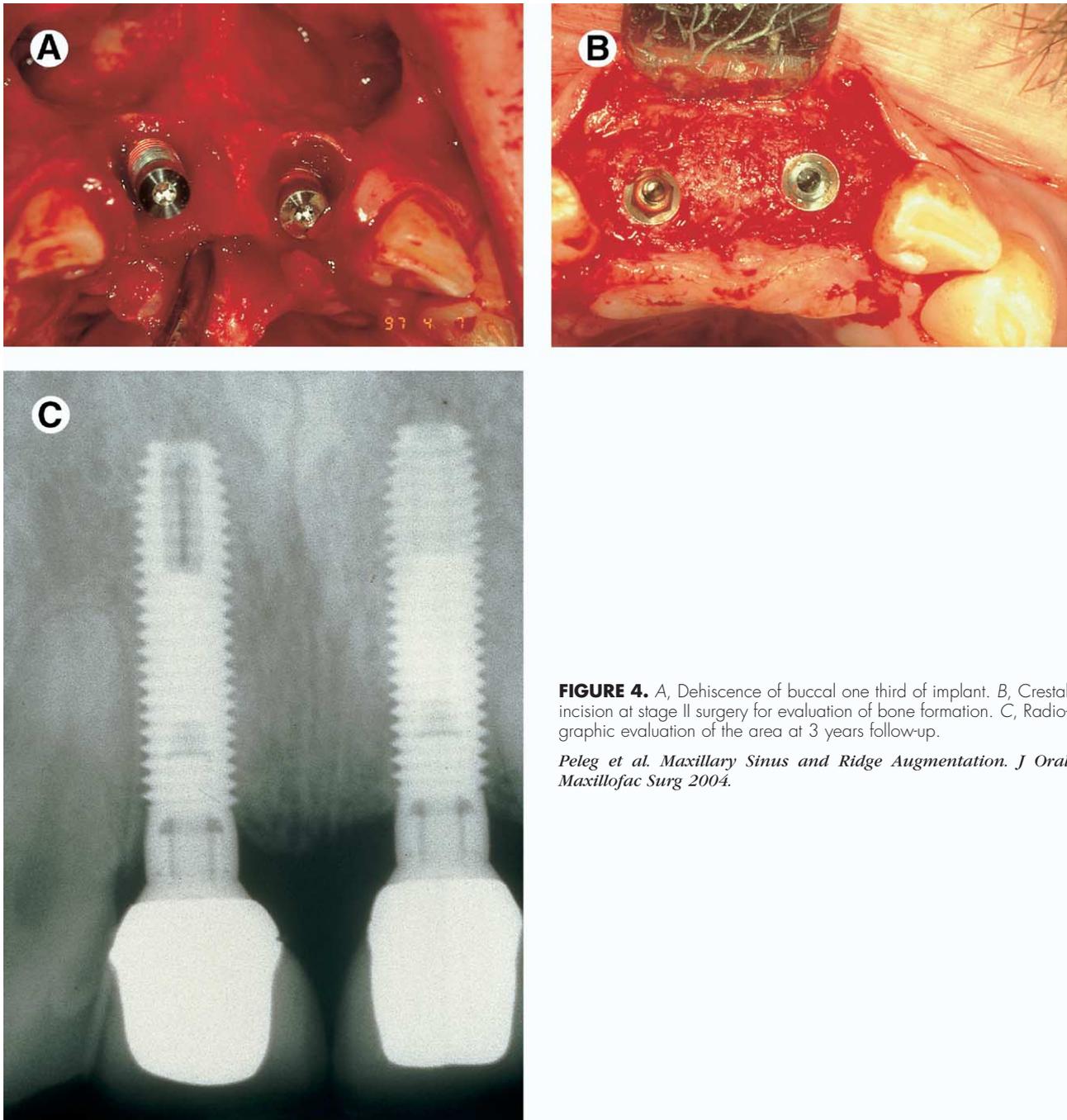
CA). A total of 436 implants were placed in the sinus floor augmentation group. In 28 patients of the bilateral and 18 of the unilateral sinus augmentation (a total of 38.9%), the procedures were performed un-



**FIGURE 3.** Dehiscence/fenestrations of the buccal aspect of implants placed in position of 2 left maxillary incisors.

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der intravenous sedation and local anesthesia. For the remainder of the patients treated in this study, surgical treatment was performed under local anesthesia alone. For 37 patients with dehiscence/fenestration of the buccal aspect of the implant placed in the anterior maxilla, the autogenous bone graft was harvested from the zygomaticomaxillary buttress or the tuberosity with an average of 1 to 1.5 cc required. The implant length for this group was 15 mm while the diameter was 3.75 or 3.25 mm (Zimmer Dental). A total of 41 implants were placed in the anterior maxilla group. For all bone grafts and for the 477 implants placed in this study, a resorbable membrane (BioMend Extend; Zimmer Dental) or Lyophilized Dura Mater (University of Miami tissue bank)<sup>29</sup> was placed over the graft according to the principle of guided bone regeneration. A second-stage surgery was performed 4 to 8 months after implant placement. Before implant exposure, patients were evaluated radiographically. Panoramic and periapical radiographs and computed tomography scans were used for assessment of the newly formed bone and its close relation to the implants. Clinical criteria for evaluation



**FIGURE 4.** A, Dehiscence of buccal one third of implant. B, Crestal incision at stage II surgery for evaluation of bone formation. C, Radiographic evaluation of the area at 3 years follow-up.

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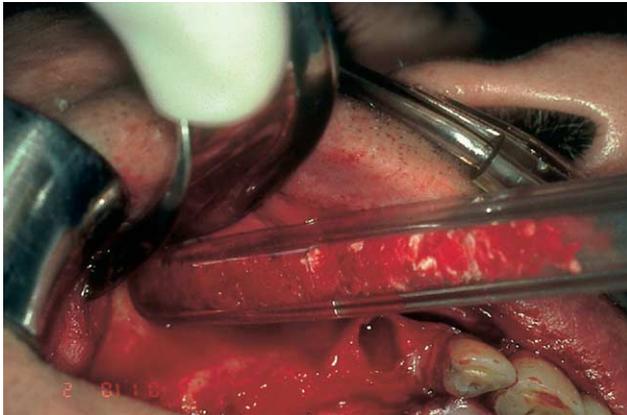
at time of implant exposure included stability in all directions, crestal bone resorption, and any reported pain or discomfort.

For the anterior maxilla alveolar bone dehiscence/fenestration group, panoramic and periapical radiographs were taken at second stage surgery and for follow-up. The new bone formation was assessed clinically at the second stage surgery (Fig 4). A crestal incision was used for this purpose rather than a punch technique. Implants were placed simultaneously with the grafting procedure in all cases. To

assess the new bone formation, core biopsies were taken from the lateral window at 4 to 5 months for the autogenous bone and at 7 to 8 months for the composite bone graft.

### Surgical Technique

The instrument's hardened hollow ground blade is curved, and when held at an angle of approximately 5° to 50° to the bone surface, it makes a point contact with the relatively flat bone surface. With light down-



**FIGURE 5.** Harvesting bone from the zygomaticomaxillary buttress. Peleg et al. *Maxillary Sinus and Ridge Augmentation. J Oral Maxillofac Surg* 2004.

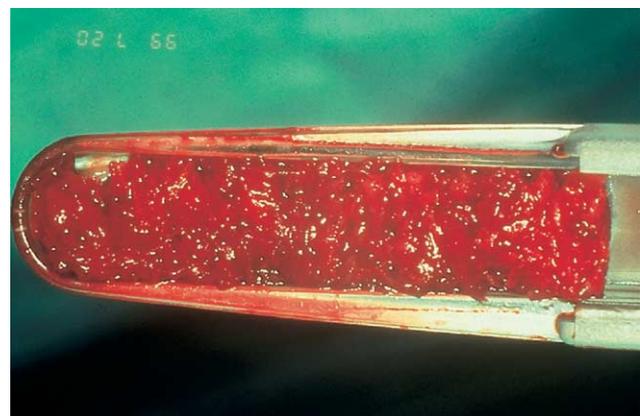
ward pressure, forces much greater than the tensile strength of bone are generated, enabling the blade to penetrate the bone surface. As the blade penetrates more deeply into the surface, it reaches an equilibrium depth that is a function of the downward pressure, of the surface area of the bone engaging the blade edge, and of the bone tensile strength. As the instrument is pulled, the blade maintains its depth and planes a shaving of bone from the cortical surface. The curved shaving passes through a narrow aperture adjacent to the blade edge and flows into the handle of the instrument, where it can be collected and stored.

The most convenient bone-harvesting site can be from areas adjacent to the recipient site. For amounts of bone up to 2 to 3 cc as needed for the composite graft group in the sinus floor augmentation, the anterior maxillary wall, the zygomaticomaxillary buttress, and the tuberosity donor sites are accessed through the same full-thickness mucoperiosteal flap either by a crestal incision (in cases of edentulous ridge) or by intra-sulcular incision.

In this case, the minimum donor site surface area should be approximately 10 mm × 15 mm and accessible with the instrument at an angle between 5° and 50°. In sinus augmentation procedures, the buccal window is mainly prepared with the grafter. For the zygomaticomaxillary buttress harvest, the flap is raised superiorly to the point at which the origin of the masseter muscle is visualized at its junction with the zygomatic process of the maxilla. This flap design will expose the entire buttress (Fig 5). Access to the zygomaticomaxillary buttress can also be gained by an incision made through the alveolar mucosa about 5 cm above the mucogingival junction, starting between the first and second molars and proceeding to the first premolar area.

The lateral aspect of the mandibular body and the lateral mandibular ramus donor sites is accessed through an incision over the external oblique ridge in a manner similar to the approach for oblique vertical ramus osteotomy. The incision, approximately 2.5 to 3.0 cm long, extends into the free mucosa from the third molar to the first molar region, and vertically along the external oblique ridge. Local anesthetic with vasoconstrictor (lidocaine 2% with 1:100,000 epinephrine) is infiltrated along the external oblique ridge, the lateral aspect of the mandibular ramus, and inferolaterally in the molar region of the mandible. Infiltration of the periosteum and a mandibular block are required for sufficient anesthesia. To facilitate closure, a cuff of at least 2 to 3 mm of free mucosa lateral to the attached gingiva is preserved. It is important to stay lateral with the incision to allow the instrument to achieve the proper cutting angles to the lateral mandible. A Minnesota, Langenback, or vertical ramus osteotomy retractor for the mandibular ramus is used to retract the tissues laterally and provide good visibility. This technique provides the instrument's optimal 15° to 20° cutting angle to the lateral bone surface.

Initially, dipping the instrument into saline lubricates it. The instrument cuts shavings from the bone surface with an elliptical raking motion, with 1 to 2 cm strokes at an angle of 5° to 50° to the bone surface. The semicircular blade cuts flat, convex, and concave bone surfaces. As the bone shavings flow into the handle, the instrument is occasionally tapped on a table surface to advance the bone into the chamber. The instrument storage chamber holds approximately 2 cc of graft material. Typically, approximately 5 to 10 minutes are required to harvest 2 cc of bone. Routinely, 4 cc of graft material can be harvested from the lateral ramus site, and the instrument will stay



**FIGURE 6.** Graft is stored in the handle of the instrument until delivered to the recipient site.

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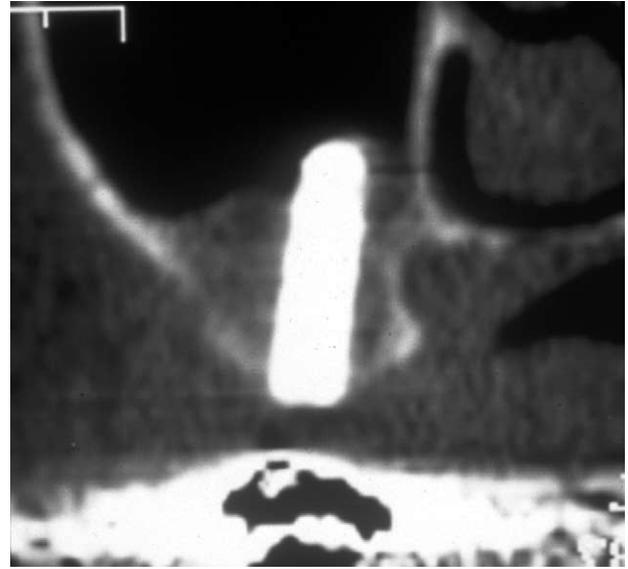
sharp for harvesting a total of approximately 8 cc of bone.

If a graft of more than 2 cc is required, the bone shavings are emptied into a sterile bowl and covered with a moist, lint-free sponge.

After irrigation, suctioning, and inspection of the perimeter of the flap for remnants, an attempt is made to invert wound edges by using interrupted vertical mattress sutures to optimize healing and minimize dehiscence. The recipient site should be prepared to accept the bone graft. This process includes removing any soft tissue remnants and the preparation of fenestrations in the bone surface. An alternative is to use the grafting instrument to plane a thin layer of bone off the recipient site surface to open and expose the bone's blood vessels. This technique helps to promote revascularization of the graft and provides a source of osteoprogenitor cells that line the endosteum and vascular channels of the Haversian systems and Volkmann's canals.

The graft is stored in the handle of the instrument until delivered to the recipient site (Fig 6). The blade lock is released and the integrated plunger is advanced to consolidate the graft and to move it to the forward end of the chamber. The blade is then retracted to gain access to the graft. The instrument provides a convenient carrier to deliver the graft to the recipient site. The hoop-shaped blade also cuts when drawn in a lateral motion, helpful for accessing the medial and lateral aspects of the anterior mandibular ramus.

The flap can be pulled over the site, and, with palpation through the flap, the contour can be formed. After the periosteum has been released to achieve a tension-free closure, the flap is positioned for closure either with tooth forceps or a temporary traction suture. The flap is then held in place for 20 to 30 seconds with gentle pressure, thus assisting the flap to adhere to the graft and taking much of the tension off the closure line. The closure should be water tight with slight outward eversion of the wound edges, accomplished with a vertical mattress suture. Ice application and a semiupright position help to reduce swelling. Pressure with moist gauze is applied directly over the site for about 1 hour to promote attachment of the flap and to minimize hematoma formation. Postoperative care should include a semiupright position and ice to both the donor and recipient sites for 24 hours. Broad-spectrum antibiotics are commonly given as an initial preoperative dose 1 hour before the procedure and for 10 days postoperatively. An oral antiseptic rinse, such as chlorhexidine gluconate, is started on the seventh postoperative day. In most patients, NSAIDs can provide adequate comfort.



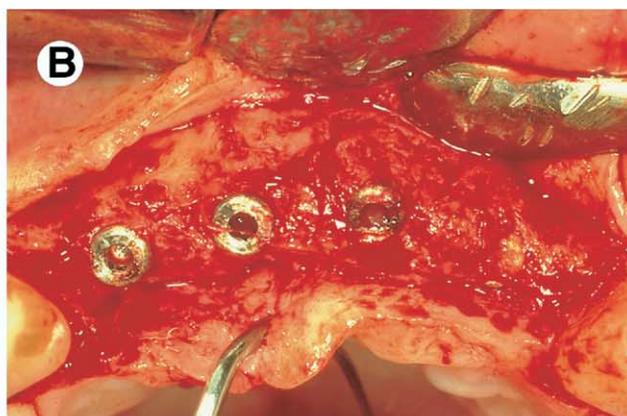
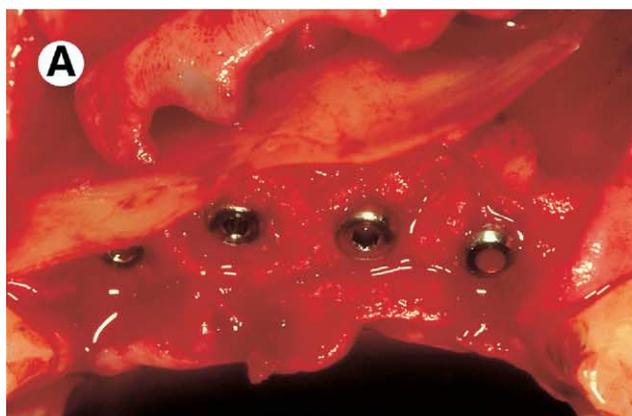
**FIGURE 7.** Implants were successful and were fully surrounded by bone as revealed by computed tomography scan.

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## Results

In our 156 sinus floor augmentation procedures and 37 alveolar augmentations, none of the patients had any complication related to the bone harvesting site and technique. A minimum of 1 cc and a maximum of 5 cc of bone were harvested for these procedures. For the unilateral sinus floor grafting procedures, where only autogenous bone was used, an average of 4 to 5 ccs were harvested. An average of 2 to 3 ccs of bone graft was harvested for the composite bone group, and 1 to 1.5 ccs were the average amounts of bone harvested for the anterior maxilla alveolar bone dehiscence/fenestration. Between 10 and 15 minutes were required to harvest 4 to 5 cc of bone from the lateral mandibular body and ramus, zygomaticomaxillary buttress, and lateral maxillary wall. No nerve injuries, dental injuries, or tears of the Schneiderian membrane were noted from the harvesting procedure in any of these cases. An average of 1 Mx-Grafter bone grafting system was used per side.

Patient follow-up has ranged from 8 to 24 months, with an average of 16 months. For the sinus floor augmentation group, computed tomography scans were taken at the second stage surgery. All implants were successful as per the Albrektsson criteria<sup>30</sup> of success and were fully surrounded by bone as revealed by computed tomography scan (Fig 7). All donor sites for the bone healed without immediate or delayed complications. At the second stage surgery, 2 implants from the autogenous group and 1 implant from the composite bone graft group failed to integrate. There were no signs of infection during the



**FIGURE 8.** A, Patient from Fig 3, with graft and membrane in place. B, Stage II surgery showing good new bone formation and good ridge width. C, Uneven soft tissue healing after stage II surgery.

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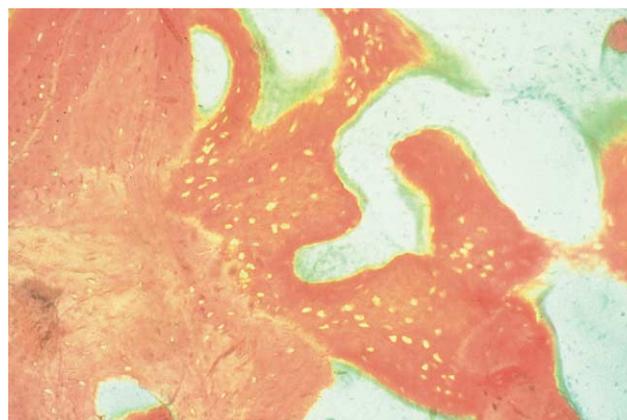
healing period. The implants were successfully replaced with a 5.0 mm diameter implant at the time of exposure without any need for additional bone grafting.

There were no failures of the anterior maxilla group, and no signs of bone resorption were noted at the second stage surgery or during the follow-up (Fig 8). During initial and late healing, there was no dehiscence of the soft tissue flaps and no membranes were exposed. Core biopsies showed on average immature, newly formed bone and on average 27% to 36% vital bone. (Figs 9, 10).

## Discussion

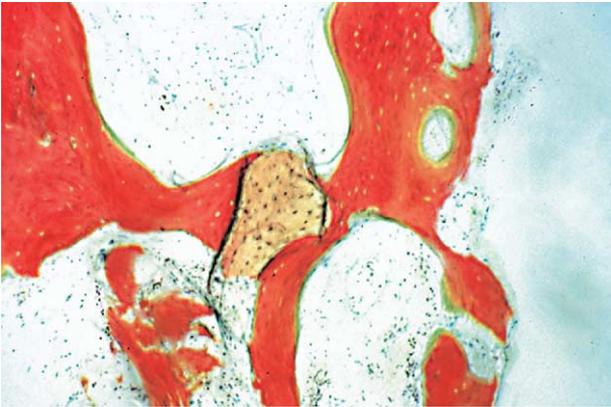
Autogenous bone continues to be the “gold standard” for bone grafting applications.<sup>1-7</sup> It is common to find significant defects of the alveolar bone at sites to be used for implant reconstruction. Frequent causes of alveolar deficiency in younger patients include traumatic avulsions and anodontia. In older patients, chronic periodontitis and iatrogenic causes are common, including aggressive surgical techniques for removal of bone at extraction sites and the persistent salvage of compromised carious and periodontally involved teeth despite poor long-term prognosis. Furthermore, once the tooth has been extracted, re-

sorption of the alveolar bone ensues to a variable extent. In the maxillary sinus region, this resorption can be significant, with nearly the entire region of alveolar bone replaced by the maxillary sinus. Long-term soft tissue borne prosthetics, especially when opposed by natural teeth, commonly lead to severe



**FIGURE 9.** This high power photomicrograph (all autogenous bone graft) at 4 months' healing shows immature but newly formed bone. Green staining osteoid can also be seen around the newly formed bone.

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**FIGURE 10.** This high power photomicrograph (Bio-Oss and autogenous bone) at 7 months' healing shows a piece of Bio-Oss in the center surrounded by actively growing trabeculae of cancellous bone. The green-staining osteoid rims around the trabeculae.

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atrophy. Clearly, alveolar bone is present to provide endosseous support for teeth. Alveolar bone can be conserved by re-establishing endosseous loading using osseointegrated implants.

Most patients undergo implant therapy as an outpatient procedure, which uses local anesthesia with or without sedation. This option helps not only to minimize patient costs for procedures frequently not covered by insurance but also to lessen the patient's perception of the complexity of the procedure. One limiting factor in the treatment of patients requiring bone grafts has been how to acquire an adequate amount of bone in a minimally invasive manner.

The bone supporting a functional osseointegrated implant should be viable lamellar bone capable of normal remodeling in response to the biomechanical requirements of the site. Autogenous bone continues as a preferred solution for reconstruction of the alveolus in preparation for osseointegrated implants.<sup>18-20</sup> Nonautogenous preparations are still being used because of limitations in acquiring adequate amounts of autogenous bone or simply because of the convenience of using packaged preparations. However, healing and remodeling of these nonautogenous grafts is less predictable.<sup>9-11</sup>

There are many accessible bone surfaces available in the maxillofacial region. Large areas of periosteum can be elevated in this region without disrupting major muscle attachments or neurovascular structures. However, only a limited number of intraoral sites are available for harvesting of bone (eg, the symphysis) in the traditional surgical technique of removing blocks or sections of bone or cores of bone. This technique has been limited by difficulties such as donor site morbidity, close anatomic relation to vital structure (eg, tooth roots, neural structures, and the

thin bones overlying the maxillary sinus and nasal antrum), management of the patient, and the relative complexity of the procedure. Typically, bone is cut with power-driven instruments, either by drilling holes or creating an osteotomy or trephine bur. Chisels and osteotomes are used to make or complete cuts in areas that are not easily accessible or that are not safe for power-driven tools. Usually, intravenous sedation or general anesthesia is required for the bone-harvesting procedure, and narcotic pain medications are needed postoperatively.

Although dermatomes are commonly used to harvest sheets of skin, there was no equivalent to harvest bone. The Mx-Grafter bone grafting system is a hand-held instrument that planes ribbon-like shavings of bone from cortical surfaces. In addition, it directly collects the bone shavings, stores them, and then delivers them to the recipient site. The curved blade can plane shavings from flat, convex, and concave surface donor sites. Working angles between 5° and 50° enable the instrument to cut bone from most intraoral bone surfaces. The blade, shaped in a semi-circular loop, can cut by being drawn straight back or laterally. The small, streamlined profile of the instrument's nose provides access to constricted areas under the soft tissue flaps. Several similar devices have recently appeared on the market.

The matrix of ribbon-like bone shavings and blood has a mortar-like consistency that enables it to be easily handled and positioned. It can be molded with any flat surface instrument, such as a plugger or curette, and it stays where positioned. This form of graft has more consistency than other materials that are difficult to keep in place, such as pellets, dust, or chip-like particles. Bone planed off the cortical surface forms narrow, ribbon-like shavings. As the bone is harvested, blood from the cut bone surface is also passively collected and mixes with the bone to form a moldable composite matrix. The graft volume subtended by the 3-dimensional ribbon-like elements is greatly expanded by this process in comparison to the bone's volume at the donor site. This process is similar to the increase in volume seen when a wood plane removes a very thin layer of wood with the large volume of shavings that results. This composite matrix of ribbon-like shavings, with the patient's blood occupying the interconnecting porosity, has several potential advantages to promote a rapid healing response.<sup>31</sup> Because only a thin layer of bone is planed from the surface, the defect and subsequent morbidity at the donor site are minimized, and only minimal blood oozing is noted. The graft is kind to the flap with no sharp edges, and the flap seems to adhere to this bone-blood matrix. Adherence of the flap assists in taking the tension off the incision line and helps to minimize the chance of wound dehiscence.

In all 193 patients treated in this study, there was no wound dehiscence.

Typically, hard bone rapidly dulls cutting instruments with narrow inclusion angles, such as scalpel blades. The apparent hardness of the bone and therefore the rate of bone harvest varied between patients. This variance may have been a function of bone mineral content (about 76% mineral), the orientation of the lamellar structure, or other unidentifiable effects such as is seen with long-term treatment with tetracycline. The blade edge dulls prematurely if it frequently strikes against the sides of the teeth. However, an average of 1 Mx-Grafter bone grafting system was used per side to collect 4 cc of bone.

The grafts can also be mixed with bone substitute materials such as Bio-Oss to expand the volume of graft material; furthermore, platelet-rich plasma can also be added to the graft matrix to enhance the growth factors in the graft and to further improve the handling characteristics.

The use of the cortical surface as a source of graft material greatly increases the number of intraoral sites available for harvesting bone. Many intraoral sites are accessed through relatively small incisions to the subperiosteal plane, developing mucoperiosteal flaps that can be raised easily and safely to expose large surfaces of bone. Such sites are not constrained by concerns of deeper elements, such as tooth roots and neurovascular structures. Furthermore, patient morbidity is minimized if only a small thickness of bone is removed passively from the donor surface.

The shavings are collected passively without the use of suction, greatly minimizing the chance of graft contamination. The potential for cell survival is also enhanced by the minimal cutting temperatures generated with a manual instrument and also by no desiccation of the graft with a suction collection process. The bone is already in a particulate form, thus saving time from a secondary operation with a bone mill or rongeurs. The high porosity of cortical bone in the form of these curved ribbon-like shavings should enable the graft to be revascularized much more rapidly than cortical blocks, similar to that seen with particulate preparations. Success rates may have been so high because of the high surface area of the bone graft harvested in this manner. Minimal trauma to the harvested bone may also have been a factor.

From this research, it appears that excellent implant success rates can be achieved in grafted sinuses or ridges when a locally harvested autogenous bone graft with a ribbon geometry is used. It also appears when a composite bone graft is used in the sinus for dental implants, with at least 50% autogenous bone in a ribbon geometry, similar implant success rates can be achieved as with 100% autogenous bone graft. It also appears that a composite bone graft consisting of

50% autogenous bone can provide excellent success rates for implant support. This can avoid distant or additional graft donor sites. Further research is in progress to fully understand the unique properties of this high surface area graft with expanded volume and interconnecting porosity.

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