

# The Use of Particulate Bone Grafts From the Mandible for Maxillary Sinus Floor Augmentation Before Placement of Surface-Modified Implants: Results From Bone Grafting to Delivery of the Final Fixed Prosthesis

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**Purpose:** This prospective study followed 61 patients who were partially dentulous and considered to have insufficient bone volume for routine implant treatment and consequently underwent sinus inlay bone grafting.

**Patients and Methods:** The patients were treated with maxillary sinus floor augmentation with particulated autogenous bone from the mandibular ramus/corpus. After a healing period, dental implants (n = 180) were installed.

**Results:** Radiographic examination revealed average residual vertical bone heights of 6.5 mm in the first premolar region, 3.8 mm in the second premolar region, 3.5 mm in the first molar region, and 2.6 mm in the second molar region. The average implant lengths were 12 mm in the first premolar region and 11 mm in the second premolar, first, and second molar regions. All patients received a fixed partial prosthesis. All bone grafts were stable, and the implant survival rate was 98.9%. There were few cases of minor complications postoperatively and no record of any injured teeth, heavy bruising, bleeding, or swelling in either the donor site or the recipient site. The present clinical study demonstrated a low failure rate of surface-modified dental implants when placed into the maxillary sinus an average of 7 months after augmentation with particulate mandibular bone grafts and followed up to delivery of the final fixed prosthesis.

**Conclusion:** The findings indicate that treatment with endosseous implants may be as predictable in patients with inadequate bone who underwent sinus floor augmentation as in patients with adequate bone volume.

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Prosthetic rehabilitation of a severely atrophic maxilla poses a challenging therapeutic problem, because bone augmentation is required to enable placement and ensure stability of a sufficient number and length of implants. Augmentation of the maxillary sinus floor with autogenous bone is a commonly used technique

in this situation. Bone grafts have been harvested from different sites of the skeleton, including the iliac crest, tibia, fibula, calvarium, rib, maxillary tuberosity, mandibular lower border, mandibular coronoid process, mandibular symphysis, and mandibular ramus. Although it is possible to harvest large amounts of

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bone from extraoral sites, such as the iliac crest, postoperative morbidity with bruising, swelling, pain, and functional problems from the donor site occasionally occurs. An extraoral approach also may produce a permanent cutaneous scar, and the procedure usually involves general anesthesia with multiple days of hospitalization.<sup>1-3</sup>

Harvesting of bone from intraoral sites, such as the mandibular ramus or symphysis, is an attractive option when smaller bone grafts are needed.<sup>4-7</sup> Local anesthesia is often sufficient for such procedures. With the increasing demand for bone augmentation procedures, the need for development and testing of less complicated techniques that result in minimum of morbidity and predictable outcome is becoming ever more important.<sup>8,9</sup>

In a meta-analysis based on the available literature, Tong et al<sup>10</sup> reported a failure rate of about 10%. This is in line with a previous retrospective study from the present research group, where a failure rate of about 10% was shown.<sup>11</sup> Interestingly, all implants were lost during the period from abutment connection to delivery of the final fixed prosthesis, indicating poor integration of the implants. In our earlier study, blocks of bone from the iliac crest were placed before or in conjunction with the placement of turned titanium implants. Block grafts likely take longer to heal than particulate bone grafts, as indicated by the results of Johansson et al,<sup>12</sup> who reported a higher insertion torque when placing implants in particulate bone grafts than in block autogenous bone grafts. Furthermore, histological studies have demonstrated better integration of turned titanium implants when placed after an initial healing period of 6 months.<sup>13,14</sup> In addition, histology from clinical investigations has demonstrated a stronger bone response to implants with a moderately rough surface compared with turned implant surfaces.<sup>15,16</sup> Consequently, the placement of surface-modified implants after initial healing of a bone graft can be anticipated to improve the clinical outcome of maxillary sinus floor augmentation procedures.

Albreksson and Wennerberg<sup>17</sup> noted that moderately rough surfaces demonstrate stronger bone responses than smoother or rougher surfaces. Most currently marketed implants are moderately rough. Oral implants permit bone ingrowth into minor surface irregularities through biomechanical bonding or osseointegration. Increased biochemical bonding seems possible with certain surfaces. According to Albreksson and Wennerberg,<sup>18</sup> results for Nobel Biocare dental implants (TiUnite surface; Göteborg, Sweden) have been clinically documented in 1- to 2-year follow-up studies, with a failure rate of approximately 3%. Sandblasted and acid-etched Straumann ITI dental implants (SLA surface; Basel, Switzerland) have been documented with good clinical results up to 3 years. The

Astra Tech dental implant (TiOblast surface; Mölndal, Sweden) is the only design with documented survival over 10 years of follow-up and success over 7 years of follow-up.<sup>17,18</sup>

This prospective study was undertaken to describe the surgical technique for using particulate bone from the mandible for maxillary sinus floor augmentation before the placement of surface-modified implants, as well as to report the clinical outcome from bone grafting to delivery of the final prosthesis.

## Patients and Methods

### PATIENTS

The study group included 61 patients (23 males, 38 female) with a mean age of 55.7 years (Table 1). All of the patients were partially dentulous and considered to have insufficient bone volume for routine implant treatment because of advanced horizontal and vertical bone loss of the alveolar processes and/or extensive pneumatization of the maxillary sinuses. All patients were consecutive cases treated by 4 surgeons. The choice of treatment was based on the amount of bone available for implant placement as determined by pre-surgical clinical and radiographic examinations. In any case with severe atrophy, the patient underwent bone augmentation using an autogenous bone graft. Each patient received a particulate cortical bone graft harvested from the lateral part of the ramus/body of the mandible. The goal of treatment was to provide the patient with a fixed partial prosthesis with the operation performed under local anesthesia.

### SURGERY

#### *Bone Grafting*

In 8 patients, the bone augmentation was performed under general anesthesia through a nasal-endotracheal tube supplemented with infiltration of local anesthesia agents. The other 53 patients were treated under local anesthesia, using lidocaine/epinephrine 2% mostly in combination with bupivacaine/epinephrine 5% with or without perioral sedation with flunitrazepam (0.5 to 1.0 mg) given 1 hour preoperatively (Table 2).

Between the retromolar area and the area of the second or first molar, a 20- to 30-mm incision was

**Table 1. DISTRIBUTION OF PATIENTS IN TERMS OF AGE AND GENDER**

n	Males/Females	Mean Age	Age (yrs) Range
61	23/38	55.7 years	17 to 78

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**Table 2. TYPE OF ANESTHESIA USED FOR MAXILLARY SINUS FLOOR AUGMENTATION**

	n
Local anesthesia without oral sedation	31
Local anesthesia with oral sedation	22
General anesthesia	8
Total	61

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made in the facial vestibule on the external oblique ridge of the mandible. The lateral aspect of the mandible was exposed, and the location of the osteotomy was marked with a 1-mm fissure bur. The osteotomy was started anterior to the coronoid process, cutting along the anterior border of the ramus medially to the external oblique ridge, and completed in the molar region of the mandibular body. The lengths of the anterior and posterior vertical cuts were determined by the size of the graft required. The inferior osteotomy, which connects the vertical cuts, was made with a diamond disc creating a 2-mm depth in the cortical bone. With adequate osteotomy through the cortical layer, the splitting of the bone block was done with careful bending movements using a chisel. After the bone was removed, any sharp edges around the osteotomy were smoothed with a round bur. The wound was rinsed with saline solution, hemostatic dressing (collagen) was placed into the donor area, and the wound was carefully sutured in layers using resorbable sutures.

In all 61 patients, the harvested bone was kept in saline solution or blood until being particulated in a surgical bone mill for sinus inlays. In 8 of the 61 patients, part of the harvested bone was kept as a bone block and trimmed and used as onlay bone graft.

The approach to the posterior maxilla was made by a crestal incision along the alveolar process. The alveolar crest was subsequently exposed by raising a buccal mucoperiosteal flap, and a bony window was established on the lateral aspect of the maxillary sinus. The sinus membrane was carefully elevated, and the particulate bone was positioned in contact with the floor of maxillary sinus. In 8 cases, the alveolar crest had to be widened, with some of the harvested bone then used as a block. The bone block was trimmed and fixed with titanium osteosynthesis screws (7 to 15 mm long and 2 mm diameter) on the lateral aspect of the alveolar crest. Wound closure was done with absorbable 4-0 sutures (Vicryl; Ethicon, Somerville, NJ). Postoperatively, the patient was given phenoxymethylpenicillin (1 g twice daily for 7 days) routinely.

### *Implant and Abutment Surgery*

After a healing period of 5 to 21 months (mean, 7.2 months), implant placement was carried out. In total, 180 surface-modified dental implants were placed using 3 different implant systems: 119 Straumann ITI dental implants (SLA surface), 38 Nobel Biocare dental implants (TiUnite surface), and 23 Astra Tech dental implants (TiOblast surface). The implants ranged in length from 8 to 15 mm (mean, 11.5 mm) and in diameter from 3.3 to 4.8 mm (mean, 3.9 mm).

An effort was made to avoid perforating the maxillary sinus with the implant drill or the implant, also ensuring that the implant was covered with grafted bone at the apical part. A nonsubmerged technique was used for the Straumann implants, and a submerged technique was used for the other implant systems. The implants were allowed to heal for 3 to 6 months before abutment connection and prosthetic treatment.

### PROSTHODONTICS

No temporary partial dentures were used after bone grafting or implant surgery. Gold-acrylic resin or gold-ceramic fixed partial prostheses were fabricated.

### EXAMINATION AND FOLLOW-UP

Data were collected from the time of bone augmentation until the delivery of the definitive prosthesis, a time frame ranging from 9 to 28 months (mean, 12.8 months). Age and gender, jaw bone volume according to the classification system of Cawood and Howell,<sup>19</sup> type of bone graft and grafting technique, type and number of implants placed and lost, implant position, and prosthetic outcome were recorded.

### RADIOGRAPHIC EXAMINATION

The radiographic material for this study comprised a presurgical panoramic radiograph and a panoramic radiograph taken after implant installation. All radiographs were taken at optimal exposure, and anatomic landmarks were clearly visualized. All radiographs were hand-traced on acetate paper by a single examiner.

Reference lines were drawn through such structures as the top of the alveolar crest, the nasal bones, and the floor of the maxillary sinus directly on the presurgical radiograph with a sharp, soft pencil. The postsurgical radiograph was superimposed on anatomic structures, and the implant sites were evaluated before and after surgery with regard to the implant's position and its vertical bone volume, including grafted and residual bone.

The classification system of Cawood and Howell<sup>19</sup> was used in conjunction with the presurgical panoramic radiograph to classify the bone volume in the

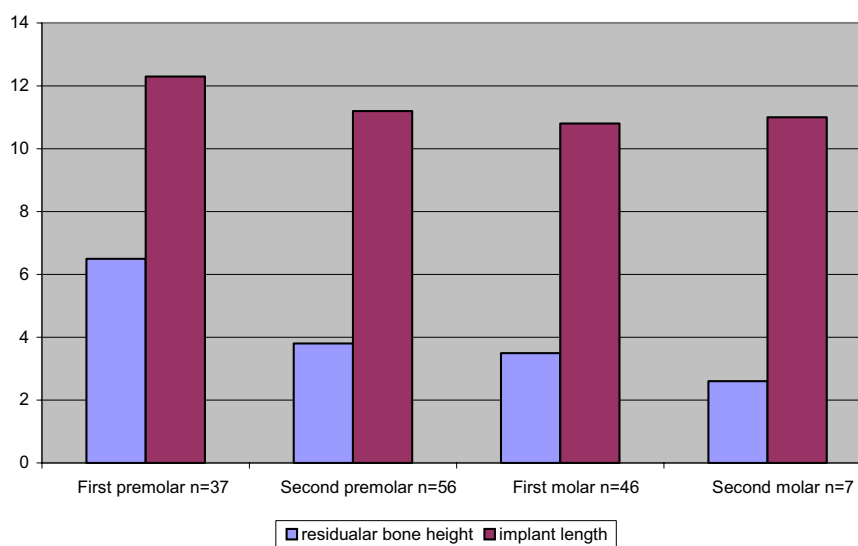
posterior maxilla, with a bone height of  $\leq 5$  mm corresponding to Class V-VI, 6 to 12 mm corresponding to Class III-IV, and  $\geq 12$  mm corresponding to Class I-II. In the posterior edentulous maxillary region, 55 of the 61 patients were considered Class V or VI, and 6 patients were considered Class III or IV. No patient was classified as Class I or II.

## Results

### IMPLANT AND BONE GRAFT STABILITY

The 61 patients received 52 unilateral and 9 bilateral sinus inlay bone grafts. Eight patients also received an onlay bone graft in addition to the bone augmentation of the maxillary sinus floor. All bone grafts were stable, and together they supported a total of 146 implants, of which only 2 failed (1.4%), giving an early survival rate of 98.6%. The implant failures occurred in the canine and premolar positions, both engaged in grafted bone. In the residual bone, 34 implants were installed, of which none failed. Only 2 of the 180 total implants placed (1 Straumann implant and 1 Nobel Biocare implant) were lost, for an implant survival rate of 98.9%.

The radiographic examinations showed an average residual vertical bone height of 6.5 mm in the first premolar region (37 implants), 3.8 mm in the second premolar region (56 implants), 3.5 mm in the first molar region (46 implants), and 2.6 mm in the second molar region (7 implants), as shown in Figure 1. The average implant length was 12 mm in the first premolar region and 11 mm in the second premolar, first, and second molar regions, as also shown in Figure 1.



**FIGURE 1.** Distribution of residual bone height before bone grafting and implant lengths after implant placement in different regions of the posterior maxilla.

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### PROSTHESIS STABILITY

All patients received a fixed prosthesis after an implant healing period of 2 to 17 months (mean, 5.7 months).

### COMPLICATIONS

The postoperative symptoms at the donor site were similar to those occurring after surgical removal of teeth. Paresthesia of the inferior alveolar nerve occurring in 1 patient but resolved completely in less than 2 months. There were no records of injured teeth, heavy bruising, or bleeding or swelling from either the donor site or the recipient site. Three patients exhibited local postoperative infection with a shallow fistula at the recipient site. This infection was managed with antibiotics; cure occurred within 2 to 3 weeks, and the infection had no negative effect on bone graft or implant survival. In 3 patients, implant installation revealed that the new bone was softer than the residual bone. This had no negative affect on primary implant stability, but 1 of the 10 implants installed in such soft bone failed.

## Discussion

Maxillary sinus bone inlay procedures, including implant installation, have been documented and reviewed in numerous reports.<sup>10,20-23</sup> Jensen et al<sup>21</sup> analyzed retrospective data from sinus floor augmentation procedures collected from 38 surgeons and including 2,997 implants and 1,007 maxillary sinus floor augmentations over a 10-year period. Analysis of this database demonstrates a 90% survival rate for



implants placed in sinus grafts with at least 3 years of function. Tong et al<sup>10</sup> reviewed the literature due to specified inclusion criteria in which 10 studies could be included for a meta-analysis, including various grafting materials. A failure rate of about 9% was found, with no differences based on the grafting material used or on the timing of implant placement.<sup>10</sup>

Becktor et al<sup>24</sup> investigated the implant survival rate in 182 patients with a total 1,120 implants in edentulous maxillas. This study included 2 patient groups: a graft group, comprising 64 patients with 437 implants; and a nongraft group, comprising 118 patients receiving 683 implants between 1990 and 1996. The implant survival rate was 75.1% in the graft group and 84.0% in the nongraft group after a mean follow-up of 68.9 months—a statistically significant difference. The implant survival rate in the premolar region was comparable in the 2 groups. The graft group had significantly more failures than the nongraft group in the incisor region but not in the canine, premolar, and molar areas.<sup>24</sup> Different outcomes may be expected when comparing edentulous and dentulous jaws, as discussed by Ragoobar et al,<sup>25</sup> who found a 97% survival rate in dentulous patients versus a 90.8% survival rate in edentulous patients. This is in line with our previous experience, where we found an overall implant survival rate of 91.3% in 17 partially dentulous patients,<sup>11</sup> indicating a better clinical outcome with bone grafting procedures done in partially dentulous patients compared with totally edentulous patients as reported previously.

Interestingly, in both of our previous studies,<sup>11,24</sup> implant failure resulted mainly between abutment connection and delivery of the final prosthesis. This indicates that the implants were not well integrated and were sensitive to repeated manipulation during the attachment and detachment of abutments and impression copings during the prosthetic phase. More implants failed when placed simultaneously with the bone graft compared to when a 2-stage procedure was used. Biologically, a 2-stage surgery is preferable, because it allows revascularization, maturation, and incorporation of the grafted bone before the implant is inserted.<sup>13</sup> If the residual bone height beneath the maxillary sinus is 4 to 5 mm and of good quality, then initial stability of the implants likely can be achieved using either approach; however, in cases with insufficient bone volume where primary implant stability cannot be achieved, delayed implant placement is preferred.<sup>13,26</sup> On the other hand, simultaneous placement is less invasive, more cost-effective, and more time-efficient.

The implants used in our previous studies had a turned surface, which also may have contributed to the high failure rate in grafted bone. Clinical histology of microimplants has demonstrated a stronger bone

response to surface-modified implants compared with turned implants,<sup>15,16</sup> confirming the findings of numerous animal investigations.<sup>27</sup> Brechter et al evaluated 200 surface-modified implants used in various bone reconstruction procedures and found a failure rate of 1.5% after a follow-up of at least 12 months. The same team had previously reported a failure rate of 8% when using turned implants, possibly indicating a better outcome with surface-modified implants.<sup>28</sup> In the present study we found a similar low failure rate, different than the high early failure rates reported in our previous work.<sup>11,24</sup> Comparative clinical trials are needed to statistically establish possible differences, however.

Becktor et al<sup>29</sup> reported that opposing dentition was found to correlate with implant failure in patients receiving grafts, because more failures occurred in patients with inadequate premolar and molar support. In contrast to edentulous patients, the partially dentulous patients in the present study did not wear dentures during the healing phase, which likely eliminated the risk of occlusal overload. Moreover, in partially dentulous patients, occlusal forces on the definitive prosthetic construction are reduced and merely transferred to the natural dentition.

Using the mandibular symphysis as a donor site for harvesting bone in reconstructive jaw surgery is a well-known technique. Some recent reports have focused on morbidity after bone harvesting from this region.<sup>7,30,31</sup> In a prospective study, Nkenke et al<sup>7</sup> investigated 20 outpatients who underwent harvesting of chin grafts and were followed up for 12 months. Within 1 week postoperatively, 8 of the patients demonstrated superficial sensory impairment; in these patients, 8 nerve territories showed hypoesthetic reactions and 5 showed hyperesthetic reactions. After 12 months, 2 patients still suffered from hypoesthesia of 1 side of the chin. After 12 postoperative months, 11.4% of the teeth examined (mostly canines) had lost their pulp sensitivity. Nkenke et al<sup>6</sup> also reported a prospective study using 20 retromolar bone grafts obtained using a trephine drill technique. No teeth were reportedly injured, no direct injury of the inferior alveolar or lingual nerve occurred, and no postoperative sensitivity impairment could be detected. These studies and others<sup>31,32</sup> demonstrated that higher morbidity is related to harvesting bone from the mandibular symphysis compared with harvesting from the retromolar region. Few complications due to intraoral bone harvesting were seen in the present study. Paresthesia of the inferior alveolar nerve occurred in 1 patient, who recovered completely in less than 2 months. There were no records of heavy bruising, bleeding, or swelling from either the donor site or the recipient site. Three patients developed local postoperative infection at the recipi-

ent site, which was managed with antibiotics and cured after 2 to 3 weeks. No sinusitis symptoms were observed. Other authors have reported transient sinusitis in 5% to 27% of patients undergoing maxillary sinus floor augmentation procedures.<sup>25,26,33,34</sup> In a prospective study, Timmenga et al<sup>35</sup> concluded that maxillary sinus floor elevation surgery with autogenous bone grafting appeared to have no clinical consequences in patients without signs of pre-existing maxillary sinusitis. Hallman et al<sup>30</sup> investigated a patient group similar to our present group that underwent maxillary floor augmentation with a mixture of autogenous bone and deproteinized bovine bone as grafting material. Computed tomography was used to evaluate sinus status presurgically and postsurgically. Some 67% of the sinuses were judged to be healthy presurgically, and 71% were healthy with no signs of swollen mucosa 3 years postsurgically. This finding indicates that grafting the floor of the maxillary sinus should not increase the risk for sinusitis.

The use of alternative implant sites and tilted implants has been advocated in an effort to reduce the need for bone grafting procedures. Dental implants placed in the zygomatic bone have been used in conjunction with regular implants in patients with severe resorption of the maxilla.<sup>36-40</sup> But few studies have included long-term evaluation of soft tissue and bone reactions to zygomatic implants. Recently, Becktor et al<sup>41</sup> reported on 31 zygomatic implants with a mean follow-up of 46.4 months and a survival rate of 90.3%. Six patients had been treated for recurrent sinusitis, 3 of whom had 1 zygomatic implant removed because of infection in the maxillary sinus.

Another alternative technique for bone grafting is the pterygomaxillary implant.<sup>42-44</sup> Sorni et al,<sup>45</sup> in a review of the literature, reported a 86.3% to 97.2% survival rate for the pterygomaxillary implant and no major complications during implant surgery.

As discussed earlier, Becktor et al<sup>11</sup> reported an overall implant survival rate of 91.3% in 17 partially dentulous patients treated with bone block graft procedures with the iliac crest as the donor, with a mean follow-up of 53.1 months. In that study, about 10% (5/48) of the implants placed in augmented bone failed, compared with about 5% (1/21) of the implants placed in residual bone. It also was found that more implants failed when placed simultaneously with the bone graft than when a 2-stage procedure was used. These findings indicated more favorable integration in residual bone and in well-incorporated bone grafts. From the same clinic, Johansson and Ekfeldt<sup>46</sup> reported an implant survival rate of 96% in 76 partially dentulous patients treated during the same time period but without bone augmentation procedures, with a mean follow-up of 53.9 months.

The present study demonstrates the possibility of achieving improved results through a combination of particulate mandibular bone for augmentation and delayed placement of surface-modified implants. The survival rate was 98.9% (2/180) for all implants and 98.6% (2/148) for implants placed in grafted areas after a mean follow-up of 12.8 months, up to the day of definitive delivery of fixed prostheses. The present patient group will be re-evaluated after a longer follow-up period.

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