

# Maxillary Sinus Floor Augmentation and Simultaneous Implant Placement Using Locally Harvested Autogenous Bone Chips and Bone Debris: A Prospective Clinical Study

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**Purpose:** The aim of this study was to prospectively evaluate the status of implants, marginal bone loss, and outcome of maxillary sinus floor augmentation in patients undergoing maxillary sinus lift and simultaneous implant placement with the use of bone grafts harvested adjacent to the actual surgical site.

**Materials and Methods:** Patients in need of maxillary sinus floor augmentation to enable implant placement were enrolled in 2 different groups. In group A, a “bone trap” was used to harvest bone debris during implant preparation with additional bone collected by further drilling adjacent to the implant sites. In group B, a “bone scraper” was used to harvest cortical bone chips from the zygomatic buttress and from the lateral sinus wall before opening of a bony window. All patients were provided a fixed partial denture after a healing period of 3 to 6 months. A total of 61 patients with 81 Straumann implants (Institut Straumann AG, Basel, Switzerland) were assessed, with 17 patients (20 implants) in group A and 44 patients (61 implants) in group B.

**Results:** One implant was lost (in group B) before loading. The survival rate after a follow-up of 12 to 60 months was 98.8%. There was no significant difference in marginal bone loss on the mesial and distal sides of the implant when baseline to 1-year registration was compared with baseline to final registration. During the same time, graft height decreased significantly on the distal apical side of the implants.

**Conclusions:** Bone grafts can be locally harvested at the site of the maxillary sinus augmentation procedure to enable placement, successful healing, and loading of 1 to 3 implants.

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The posterior region of the edentulous maxilla often presents insufficient bone quantity and quality for prosthetic rehabilitation with endosseous implants. The inadequate bone volume is a result of ongoing maxillary sinus pneumatization and remodeling of the alveolar crest.<sup>1-3</sup> The technique of maxillary sinus floor elevation was initially described by Boyne and

James in 1980.<sup>4</sup> Since then, numerous articles have been published regarding different grafting materials and modifications of this first-described technique.<sup>5,6</sup> Augmentation of the maxillary sinus floor with autogenous bone is a frequently used method where the bone grafts have been harvested from both extraoral and intraoral donor sites. Common intraoral donor

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sites include the maxillary tuberosity, the zygomaticomaxillary buttress, the zygoma, the mandibular symphysis, and the body and ramus of the mandible. When a smaller amount of autogenous bone graft is needed, an intraoral donor site is suitable and local anesthesia is sufficient for such a procedure. In a recent study, Becktor et al<sup>7</sup> used particulate autogenous bone from the mandibular body for sinus floor augmentation in a 2-stage procedure, where the residual vertical bone height varied between 2.6 and 6.5 mm. They reported an implant survival rate of 98.9% after a follow-up of 12 months with minimal postoperative complications.

The aim of this prospective study was to describe the surgical technique using autogenous bone chips and bone debris, harvested adjacent to the actual surgical site, with simultaneous implant placement to further decrease morbidity and reduce time to prosthetic loading. The purpose was also to report on the treatment outcome by assessing bone graft survival, marginal bone levels, and survival of implants and prosthetic constructions.

## Materials and Methods

### PATIENTS

Sixty-six consecutive patients were enrolled in the study. Of these, 4 patients were lost to follow-up and 1 patient lost the implant before loading, leaving 61 patients for long-term assessment. All patients had insufficient bone volume for conventional implant treatment because of vertical bone loss of the alveolar processes and/or extensive pneumatization of the maxillary sinuses (Table 1). The inclusion criteria were 1) severe atrophy of the posterior maxilla but with sufficient bone height remaining for primary implant stability at the time of surgery, 2) absence of maxillary sinus disease, and 3) absence of pathology affecting neighboring teeth. Radiographic examination was performed to confirm the healthy condition of the maxillary sinuses and adjacent teeth before implant treatment. All patients were carefully informed about the intended procedures and could at any time terminate their participation in the study.

**Table 1. DISTRIBUTION OF RESIDUAL BONE HEIGHT**

Residual Bone (mm)	No. of Patients	No. of Implants
3	8	8
4 to 5	22	38
6 to 7	26	26
8 to 10	9	9

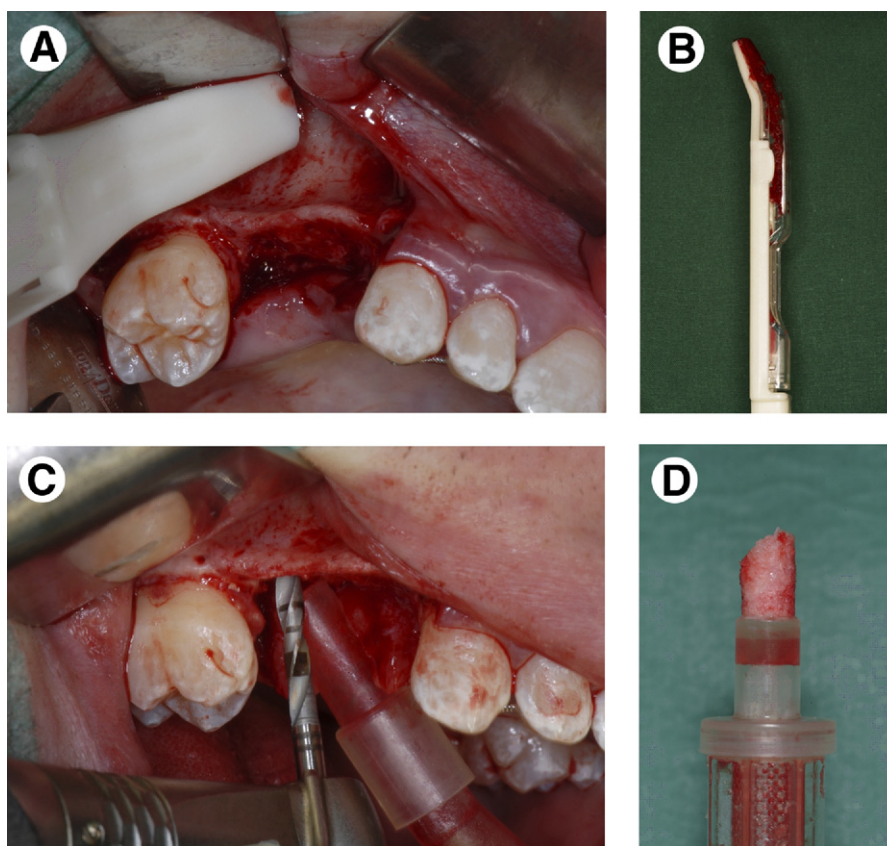
Jobansson et al. Maxillary Sinus Floor Augmentation. *J Oral Maxillofac Surg* 2010.

### SURGICAL PROCEDURE

All patients were treated by use of local anesthesia (20-mg/mL lidocaine and 12.5- $\mu$ g/mL epinephrine). In addition, 4 patients received sedation with oral flunitrazepam (0.5 to 1.0 mg) 1 hour preoperatively.

The approach to the posterior maxilla was made via a crestal incision along the posterior alveolar process. The alveolar crest and lateral aspect of the maxilla were 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 implant sites prepared in accordance with the conventional Straumann implant protocol (Standard Plus with sandblasted, large grit, acid-etched surface; Institut Straumann AG, Basel, Switzerland). Implants were placed with lengths of 8 to 12 mm and diameters of 3.3 to 4.8 mm, as indicated by the clinical situation. During implant site preparation, the height of the residual alveolar bone was measured to the nearest millimeter with a depth gauge. In cases with very thin residual bone, osteotomes (Institut Straumann AG) for bone condensation were used after the initial drilling to expand the implant site to secure implant stability. The bone graft, harvested as described later, was placed in contact with the floor of the maxillary sinus and around the apical part of the implants. Half of the graft material was placed before the implant was inserted and the rest after. The graft was used alone without any synthetic bone substitute or membrane. Efforts were made to avoid perforation of the sinus membrane during the procedure, thus ensuring that the implant was covered with grafted bone at the apical aspect. Two different harvesting methods to collect bone were used (Fig 1). In group A (17 patients [20 implants]) the Astra Tech BoneTrap (Astra Tech, Mölndal, Sweden), a single-use collector with a plastic housing and an inner perforated cylinder (pore size, 0.3 mm), was used during implant preparation, with additional bone volume collected by further drilling adjacent to the implant sites. This technique was changed for patients in group B (44 patients [61 implants]). The use of a disposable manual cortical bone-harvesting device (Curved Safescraper; Meta, Reggio Emilia, Italy) allowed the harvesting of particulate cortical bone chips from the zygomatic buttress and the lateral sinus wall before opening of the bony window.

Wound closure was made with absorbable No. 4-0 sutures (Vicryl; Ethicon, Somerville, NJ). Postoperatively, patients were given phenoxymethyl penicillin (1 g 3 times daily for 7 days) and rinsed with a 0.1% chlorhexidine solution for 1 minute twice a day for 14 days, starting 1 day before surgery. Thereafter patients were instructed to use a soft brush with 0.1%



**FIGURE 1.** A, Bone chips harvested from zygomatic buttress with bone scraper. B, Bone scraper with bone chips. C, Bone harvested with bone collector. D, Bone collector with collected bone debris.

*Jobansson et al. Maxillary Sinus Floor Augmentation. J Oral Maxillofac Surg 2010.*

chlorhexidine gel every night until prosthetic treatment was completed. The implants were allowed to heal for 3 to 6 months before prosthetic treatment depending on the residual bone height.

**PROSTHODONTICS**

The patients were allowed to use temporary partial dentures 10 days after grafting and implant surgery once the sutures had been removed. The dentures were carefully adjusted and the fitting surface covered with a soft denture liner to prevent overloading during further healing of the installed implants. Gold-ceramic fixed partial prostheses were fabricated as permanent constructions.

**EXAMINATION AND FOLLOW-UP**

Data were collected at the time of bone augmentation and implant placement, at 6 months after these procedures, on the day of delivery of the permanent prosthesis, and then yearly (Table 2).

**RADIOGRAPHIC EXAMINATION**

The radiographic records consisted of intraoral radiographs taken before surgery, after insertion of the

permanent prosthesis (baseline measurements), and then at the yearly reviews. All linear measurements were performed on intraoral radiographs. The radiographs were obtained with a long-cone paralleling technique with a film holder (Eggen, Lillehammer, Norway). Kodak Ektaspeed films (Eastman Kodak, Rochester, NY) were used, and the radiographs were

**Table 2. IMPLANT FOLLOW-UP PERIOD FOR GROUP A (BONE COLLECTOR) AND GROUP B (BONE SCRAPER) AND FOR ALL IMPLANTS**

Time	No. of Implants		
	Group A	Group B	Total
Before loading	20	62*	82
6 mo	20	61	81
12 mo	20	61	81
24 mo	20	38	58
36 mo	20	14	34
48 mo	15	5	20
60 mo	10	0	10

\*One implant was lost before loading.

*Jobansson et al. Maxillary Sinus Floor Augmentation. J Oral Maxillofac Surg 2010.*

**FIGURE 2.** Measurements of apical and marginal bone levels with reference points.

*Jobansson et al. Maxillary Sinus Floor Augmentation. J Oral Maxillofac Surg 2010.*

processed in a Periomat Plus developing processor (Dürr Dental AG, Bietigheim-Bissingen, Germany). Care was taken to ensure a clear image of the threads on both sides of the implant in the marginal and apical regions if at all possible. All intraoral radiographs were photographed to yield a digital image by use of a Planistar light board (Planistar Lichttechnik, Himmelstadt, Germany), a copying stand (Hama GmbH & Co KG, Monheim, Germany), and a camera with a microlens (AF Micro NIKKOR 60 mm; Nikon, Tokyo, Japan) to make distortion-free copies for more accurate measurements in a graphics-editing program on a computer screen (Adobe Photoshop CS3 Extended; Adobe Systems, San Jose, CA). The distance between 4 implant threads was used for calibration. The marginal bone level was assessed from a reference point (junction of prosthesis and implant) to where the bone tissue met the implant surface on the mesial and distal aspects. The apical bone level was assessed mesially and distally from a reference line tangential to the most apical point of the implant and perpendicular to the axis (Fig 2). If bone was at or above the apical point, the level was scored as 0 mm. If implant threads were not clearly imaged on one and/or both sides of the implant, no measurement was performed (classified as a "missing" value in Tables 3 and 4). For 20 randomly chosen implants, the measurements of the marginal bone height and the apical bone level on the mesial and distal surfaces were repeated. The precision of a single measurement (s) was expressed by use of the formula suggested by Dahlberg<sup>8</sup>:  $s = \sqrt{\sum d^2/2n}$ , where  $d$  is the difference between 2 measurements and  $n$  is the number of double measurements. The measurement precision was estimated to be 0.29 mm. All radiographs were evaluated by the same specialist in oral radiology.

## STATISTICS

The statistical analyses included descriptive statistics and the Wilcoxon signed rank tests to compare marginal and apical bone levels between baseline and 1-year follow-up and between baseline and final follow-up. The same method was used to compare apical bone levels on the mesial and distal sides at 1-year follow-up.  $P$  less than .01 was chosen as the threshold for statistical significance.

## SURVIVAL CRITERIA

Implant survival was based on quantitative measurements of the individual implant as suggested by Roos et al.<sup>9</sup> An implant was classified as surviving if it fulfilled its purported function, if no persistent pain or discomfort was reported, and if no implant mobility was observed.

Prosthetic survival was defined as a prosthesis fulfilling its purported function.

## Results

A total of 61 patients (42 women and 19 men; range, 18 to 85 years) were included in the study and provided with a total of 81 implants. Of these, 17 patients with 20 implants were included in group A and 44 patients with 61 implants in group B. The height of the residual alveolar process was measured during surgery and varied between 3 and 10 mm. Of the implants, 8 were inserted in 3 mm of residual bone and 38 were inserted in bone with a residual height of 4 to 5 mm. The remaining implants ( $n = 35$ ) were placed in sites with 6 to 10

**Table 3. APICAL BONE LEVEL AFTER 1 YEAR**

	Apical Bone Level	
	Mesial	Distal
No. of evaluated surfaces	65	62
Missing (No. of unevaluated surfaces)	16	19
Mean (mm)	0.81	0.86
Median (mm)	0.00	0.00
Maximum (mm)	5.80	5.73
Minimum (mm)	0.00	0.00
SD	1.20	1.22
$P$ value*	.555	.555
0 (mm)	36	32
>0 to <1 (mm)	6	7
1 to <2 (mm)	11	13
2 to <3 (mm)	9	8
3 to <4 (mm)	2	0
4 to <5 (mm)	0	0
5 to <6 (mm)	1	2

\*Comparison of mesial and distal at 1 year.

*Jobansson et al. Maxillary Sinus Floor Augmentation. J Oral Maxillofac Surg 2010.*



**Table 4. MARGINAL AND APICAL BONE LOSS BETWEEN BASELINE (PROSTHETIC LOADING) AND 1-YEAR REGISTRATION AND BETWEEN BASELINE AND FINAL REGISTRATION**

	Marginal Bone Loss: Baseline to 1-yr Registration		Apical Bone Loss: Baseline to 1-yr Registration		Marginal Bone Loss: Baseline to Final Registration		Apical Bone Loss: Baseline to Final Registration	
	Mesial	Distal	Mesial	Distal	Mesial	Distal	Mesial	Distal
No. of evaluated surfaces	68	63	64	60	68	63	64	60
Missing (No. of unevaluated surfaces)	13	18	17	21	13	18	17	21
Mean (mm)	-0.19	-0.01	-0.17	-0.33	-0.13	-0.12	-0.27	-0.73
Median (mm)	-0.09	0	0	0	-0.07	-0.39	0	-0.16
Maximum (mm)	1.11	2.12	1.81	1.57	2.77	2.54	1.81	1.57
Minimum (mm)	-1.95	-1.92	-2.8	-5.73	-2.66	-2.11	-5.46	-6.52
SD	0.59	0.72	0.80	1.06	0.92	1.01	1.10	1.47
<i>P</i> value*					.680	.114	.501	.001
≥0 mm	25	31	41	39	28	21	40	28
-1 to <0 mm	34	27	14	13	29	36	14	17
-2 to <-1 mm	8	4	6	5	9	5	6	8
-3 to <-2 mm	0	0	2	2	2	1	3	2
-4 to <-3 mm	0	0	0	0	0	0	0	2
-5 to <-4 mm	0	0	0	0	0	0	0	1
-6 to <-5 mm	0	0	0	1	0	0	1	1
-7 to <-6 mm	0	0	0	0	0	0	0	1

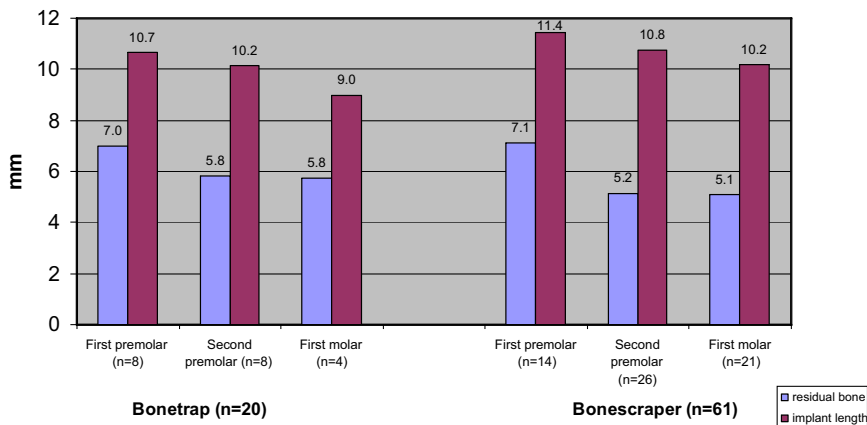
\*Comparison of marginal and apical bone loss between baseline and 1 year and between baseline and final registration.

*Jobansson et al. Maxillary Sinus Floor Augmentation. J Oral Maxillofac Surg 2010.*

mm of bone, and most of these implants were adjacent to an implant with less residual bone height (Table 1).

Figure 3 shows the residual bone height as measured at the position of the first premolar, second premolar, and first molar. The mean residual bone height for group A at these sites was 7.0 mm, 5.8 mm, and 5.8 mm, respectively, with a mean implant length, if placed in these sites, of 10.7 mm, 10.2 mm, and 9.0 mm, respectively. The mean residual bone height for group B at these sites was 7.1 mm, 5.2 mm, and 5.1 mm, respectively, with a mean implant length of 11.4 mm, 10.8 mm, and 10.2 mm, respectively.

All patients were provided with a fixed partial denture after a mean healing period of 5.2 months. The follow-up period ranged from 12 to 60 months. One implant (in group B), noted to be unstable at the time of insertion, was lost before loading, giving an overall survival rate of 98.8%. This failed implant was successfully replaced in a second-stage procedure and not included in the study. In 3 patients a minor membrane perforation occurred. These perforations were repaired by a gelatin-based hemostatic compound (Spongostan film; Ferrosan A/S, Soeborg, Denmark). No implant failures were noted during the loading period (Table 2).



**FIGURE 3.** Distribution of mean residual bone height and implant lengths in different regions.

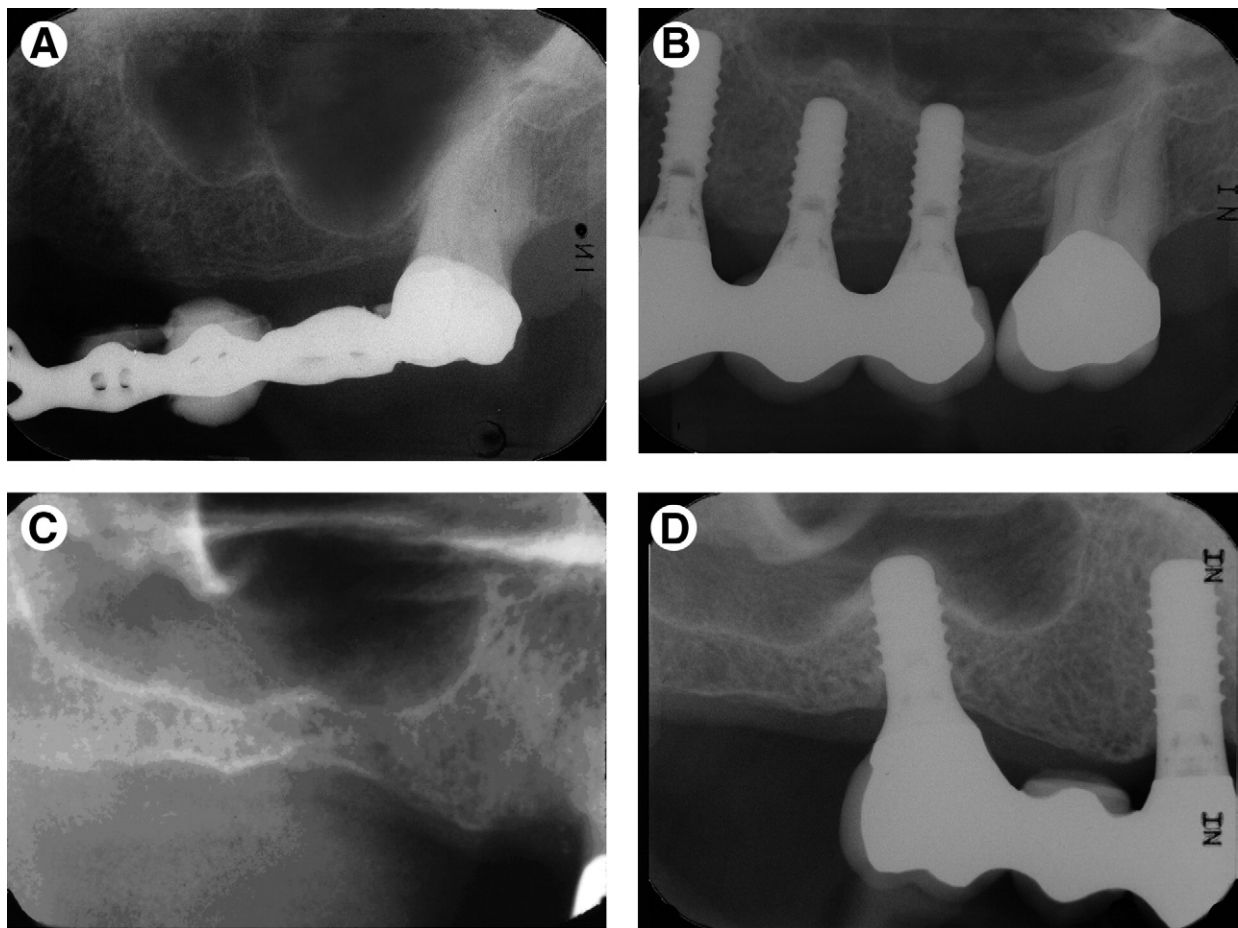
*Jobansson et al. Maxillary Sinus Floor Augmentation. J Oral Maxillofac Surg 2010.*

At 1-year registration, the mean apical bone level on the mesial aspect was 0.81 mm, as calculated from a reference line tangential to the most apical point of the implant and perpendicular to the axis (range, 0 to 5.80 mm; SD, 1.20); the corresponding value for the apical distal aspect was 0.86 mm (range, 0 to 5.73 mm; SD, 1.22) (Fig 2). The difference between the mesial and distal aspects of the apical bone level was not significant (Table 3).

There was no significant difference in marginal bone loss on the mesial and distal sides of the implant when baseline to 1-year registration was compared with baseline to final registration. However, the mean apical bone loss on the distal aspect was 0.33 mm between baseline and 1-year registration (range, -5.73 to 1.57 mm; SD, 1.06) and 0.73 mm between baseline and final registration (range, -6.52 to 1.57 mm; SD, 1.47). This difference was statistically significant ( $P = .001$ ). On the mesial aspect of the implant apex, there was no significant change in graft height over time (Figs 2, 4B; Table 4).

## Discussion

Autogenous bone has long been considered the “gold standard” for bone grafting applications in implant treatment. In this study 2 methods of harvesting autogenous bone were used. Initially, a bone collector was used to collect bone debris during drilling of the implant sites (group A).<sup>10,11</sup> Some studies have reported a risk of contamination of the collected bone particles even if attempts are made to reduce this by using a stringent aspiration protocol.<sup>12-15</sup> The clinical relevance of this bacterial contamination is debatable. More recently, efficient bone scrapers for the collection of larger graft volumes have been introduced.<sup>16,17</sup> Such a bone scraper was used in group B, and consequently, because of the ability to harvest a greater volume of bone by use of this instrument, longer implants could usually be placed (Fig 3). Peleg et al<sup>18</sup> described the zygomatic buttress as a convenient harvesting area when using a bone scraper, being close to the recipient site when augmenting the sinus floor.



**FIGURE 4.** Representative clinical cases: sinus region before treatment (A) and at 24 months' follow-up (B) in group A and sinus region before treatment (C) and at 24 months' follow-up (D) in group B.

Berengo et al<sup>19</sup> concluded that bone harvested with a round bur in a low-speed handpiece, a bur in a high-speed handpiece, a spiral implant bur, or a bone scraper is not ideal for grafting, because their study showed an absence of osteocytes and a predominance of nonvital bone. This is not in agreement with Zaffe and D'Avenia,<sup>17</sup> who did find osteocytes in bone chips harvested with a bone scraper. A study by Pallesen et al<sup>20</sup> concluded that the early stages of bone regeneration were positively influenced by autogenous bone grafts with smaller particle sizes.<sup>21</sup> However, as a result of our clinical experience, we prefer to use a bone scraper, even though larger particle sizes are created when compared with a bone collector, because it is easier to collect a greater bone volume to support the sinus lift.

The techniques we describe in this report are clinically reliable and associated with minimal morbidity. Minimal loss of the bone graft occurred, and the long-term implant survival was excellent (Figs 2, 4).

It is possible, however, to avoid a bone graft altogether. An alternative sinus augmentation can be performed by a less invasive osteotome technique, where elevation of the sinus floor is performed by inward collapse of the residual crestal floor by use of specially designed osteotomes.<sup>22</sup> According to Summers,<sup>22</sup> a membrane lift of 4 to 5 mm can be performed with this technique. Nkenke et al<sup>23</sup> concluded that a mean elevation of  $3.0 \pm 0.8$  mm could be attained by an endoscopically controlled osteotome technique alone before concomitant spontaneous perforation of the sinus membrane in the periphery of the elevated area occurred. In our study 79% of patients had a residual bone height of 4 to 7 mm. Using an osteotome and shorter implants (<10 mm) could be one method to further reduce the complexity of the surgical procedure.<sup>6,24-28</sup>

Recent interesting studies by Lundgren et al,<sup>29</sup> Palma et al,<sup>30</sup> Hatano et al,<sup>31</sup> and Sohn et al<sup>32</sup> have also shown that the use of a grafting material is not a prerequisite for predictable bone formation, which can occur simply after elevation of the sinus membrane. It has also been suggested that because any grafting material has to be resorbed and replaced, this could possibly decrease the speed of new bone formation. However, techniques that rely on absolute preservation of the integrity of the membrane for success can be demanding. We found that harvesting of particulate cortical bone chips from the zygomatic buttress and the lateral sinus wall before opening the bony window is a reliable technique and somewhat easier than removing and replacing the bony window. With this technique, we have found no need to use any membranes. However, Chen et al<sup>33</sup> reported a 100% survival rate for implants in a 2-year retrospective study using sinus membrane elevation alone,

even without replacement of the bony window. Further studies are needed to investigate the critical size of defect suitable for these types of "graftless" techniques.

A completely flapless approach using a mucosal punch and osteotomes guided by computed tomography scan to prepare the implant site and elevate the membrane could be an even less invasive technique by preserving vascularization and could minimize the risk of alveolar resorption.<sup>34,35</sup>

Our findings indicate that both graft-harvesting methods described can successfully be used for sinus floor augmentation in patients with otherwise inadequate alveolar bone height and provides adequate graft volume for 1 to 3 implants. Morbidity is minimal, and survival of the grafts, implants, and prosthetic constructions is satisfactory.

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