Maxillary Sinus Augmentation: Histologic and Histomorphometric Analysis

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Purpose: *Implant placement in the posterior maxilla may often be contraindicated because of insufficient bone volume and the presence of the maxillary sinus. In these situations, sinus floor lifting and grafting frequently have been proposed as the best treatment. The aim of this study was to compare histologically the use of 100% autogenous bone versus a combination of autogenous bone and corticocancellous pig bone for maxillary sinus augmentation.* ***Materials and Methods:*** *Eighteen patients requiring bilateral maxillary sinus augmentation were selected for this study. Bone for grafting was harvested from the iliac crest. Each patient received 100% autogenous bone in 1 randomly selected sinus (control side) and a 1:1 mixture of autogenous bone and corticocancellous pig bone particles in the contralateral sinus (test side). Five months after the augmentation procedure, bone biopsy specimens were taken at the time of implant placement.* ***Results:*** *No complications were observed during the surgical procedures; all patients healed uneventfully. No signs or symptoms of maxillary sinus disease were observed during the 5 months after surgery. No significant differences in bone percentages were observed in the bone biopsies from test and control sides.* ***Discussion and Conclusion:*** *It could be concluded from this study that corticocancellous pig bone particles can be successfully used in a 1:1 mixture with autogenous bone from the iliac crest for maxillary sinus augmentation in cases of severely atrophic maxilla.* Int J Oral Maxillofac Implants 2005;20:519–525

Key words: *autogenous bone, bone regeneration, corticocancellous bone, maxillary sinus augmentation*

The placement of dental implants requires a sufficient amount of bone to stabilize the implants. Implant placement in the posterior maxilla may often be complicated by insufficient bone volume and the presence of the maxillary sinus. Generally, this limited quantity of bone volume is related to the excessive resorption of alveolar bone following tooth removal and enlargement of the maxillary sinus. Patients who have a normal maxillomandibular relationship in terms of interarch distance and buccal-palatal relationships cannot be treated with onlay grafts to provide a satisfactory prosthetic rehabilitation. Therefore, in these situations, sinus floor lifting and grafting followed by the placement of implants in the reconstructed bone have frequently been proposed as the best treatment option.[1–3]

Various materials are available for sinus grafting. Autogenous bone is considered the gold standard because of its high biocompatibility, osteoinductive potential, and good clinical outcomes.[4,5] The collection of autogenous bone tissue requires an extra surgical site for bone harvesting, which increases the risks for morbidity and discomfort, particularly when bone is harvested from an extraoral site.[6,7] On the

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Table 1 Data Regarding 18 Patients Treated with a Bilateral Sinus Augmentation

Age/gender	Smoker*	Complications	Residual bone height (mm)†
37/F	Yes		1–2
50/M	No		1–3
46/F	Yes		2–2.5
46/F	No	BMP	1–2
50/F	Yes		1.5–2
45/M	No		1–2
43/M	Yes		1–3
55/F	No	RMP	1.5–2
53/F	Yes		1–2
54/F	Yes		1.5–2
57/M	No		1–3
60/F	Yes		1.5–2
54/M	Yes		2–2.5
45/M	No		1–2
48/F	Yes	RMP	1–2
47/F	No		1–1
52/F	Yes		2–2.5
46/F	No		1–3

BMP = bilateral membrane perforation; RMP = right membrane perforation.
*Patients smoking more than 10 cigarettes/day were excluded from the study.
†Residual sinus floor height measured on CT scan.

other hand, bone harvesting from intraoral sites cannot always provide enough grafting material for bone reconstruction in patients with severely atrophic maxillae.[8] To avoid or reduce the problems associated with bone graft harvesting, many authors have advocated the use of other materials, such as corticocancellous bovine bone, calcium sulfate, coral hydroxyapatite, and bioactive glasses.[9–11] However, all of these materials have shown bone-conductive properties and often foreign body reactions.[12]

To minimize donor site morbidity without losing the osteoinductive potential of autogenous bone, the use of bone substitutes in combination with autogenous bone has been recommended.[5,13]

Therefore, the purpose of this study was to histologically compare the use of autogenous bone (100%) versus autogenous bone with corticocancellous pig bone used in a 1:1 ratio in a within-patient control study for maxillary sinus augmentation.

MATERIALS AND METHODS

Patient Selection

Eighteen systemically healthy patients (12 women and 6 men) were included in this study. The mean age was 46.7 years (range 37 to 60 years). Four patients were completely edentulous; the remaining 14 patients were partially edentulous in the posterior maxilla.

The following criteria were used to select the patient population: need for bilateral sinus lifting and grafting, presence of severe maxillary bone atrophy (class V according to the Cawood & Howell classification),[14] presence of a residual maxillary sinus floor of less than 3 mm, and presence of healthy systemic conditions, without any disease that would contraindicate the surgical treatment or the general anesthesia. Patients smoking more than 10 cigarettes per day were excluded from the study; patients smoking less than 10 cigarettes per day were requested to stop smoking before and after surgery. However, there was no control of their compliance. Ten of 18 patients reported being smokers at the beginning of the study (Table 1).

All patients underwent a medical examination to identify factors that could induce sinus pathology before surgery. Patients with maxillary sinus pathology were excluded from the study.

All patients received and signed a written informed consent form. Radiographic examinations such as orthopantomography and computed tomography, if needed, were prescribed before and after the sinus augmentation surgery prior to implant placement.

Surgical Procedures

Maxillary sinus floor lifting and grafting were performed under general anesthesia, as described by other authors.[15,16] Briefly, the mucoperiosteal flap was raised and an osteotomy was performed on the lateral wall of the maxillary sinus to prepare a bony window using a round steel bur cooled with sterile saline solution. The sinus mucosa was carefully dissected and elevated using mucosal sinus elevators, and the bony wall was gently pushed inside the sinus cavity and formed the roof for the bone transplant. The antero-superior iliac crest was the extraoral site used for bone harvesting.

A within-patient control study was performed; thus 1 side of the maxilla, randomly selected, received autogenous bone particles alone (the control side), and the other (the experimental side) received a mixture composed of 50% autogenous bone and 50% corticocancellous pig bone particles (Osteobiol; Tecnoss, Coazze, Italy). The particles were about 0.25 to 1 mm in size. The bony sinus windows were covered with a resorbable collagen membrane (Tecnoss). The mucoperiosteal flap was sutured using vertical interrupted mattress sutures. During the 36 maxillary sinus augmentations (18 patients treated bilaterally), 4 sinus membrane perforations were observed in 3 patients. The perforations were carefully closed with a collagen membrane. The sinus was subsequently grafted, and the study protocol was not modified.

In all surgical procedures, intravenous antibiotic treatment (2 g cephalosporin) was initiated preoperatively, followed by intramuscular administration of an antibiotic (2 g cephalosporin) once a day for 5 days after surgery. Chlorhexidine mouthwash was prescribed twice daily for the next 21 days. Sutures were removed after 10 days. The use of dentures was not permitted until the dentures had been adjusted and refitted at least 2 weeks after surgery.

Five months after surgery, all patients received at least 2 implants on each side of the maxilla. A full-thickness flap was raised, the bone was inspected, and samples for biopsy were taken using a trephine drill under copious irrigation with sterile saline solution. At least 4 cylindric biopsy specimens (2 from each side) were taken from each patient. All the biopsy specimens were approximately 2 mm in diameter and 10 mm in length and were marked on the occlusal sides for the orientation during the histologic process. Titanium implants of 3.7 to 5 mm diameter and 10 to 15 mm in length (Premium; Sweden Martina, Padova, Italy) were placed at the same sites where the biopsy specimens were taken. A total of 90 implants were placed in the posterior area of the maxilla.

Histologic Analyses and Histomorphometry

The samples were fixed in 4% buffered formaldehyde, then dehydrated in graded series of alcohols from 50% to 100% and embedded in Epon resin (Fluka, Geneva, Switzerland) according to a previously described procedure.[17]

Longitudinal sections 50 ± 10 μm thick were obtained with an Isomet Buehler microtome (Buehler, Lake Bluff, IL). They were stained with toluidine blue, acid fuchsin, and fast green and observed with a Zeiss Axioscop microscope (Carl Zeiss, Oberkochen, Germany). Histomorphometry was performed with Kontron KS 300 software (Kontron Electronics, Munchen, Germany). Bone percentages were calculated using 2 sections for each sample.

The comparison between the test and control groups was performed with the independent Student *t* test (statistically significant at a level of α = .05). A *P* value was set at < .05 with the Bonferroni corrections for multiple comparisons.

RESULTS

No complications were observed during the surgical procedures. All patients healed uneventfully, and no signs or symptoms of maxillary sinus disease were observed during the 5 months after surgery. Four of 18 patients reported paresthesia or pain around the donor site (the iliac crest) 1 week following bone harvesting. These symptoms completely disappeared after the first postoperative month.

Radiographic examinations 5 months after surgery showed radiopacity, suggesting the presence of new trabecular bone in the control as well as the experimental sites in all patients (Figs 1a and 1b). A total of 90 Premium implants were placed in the grafted bone; all implants showed good primary stability after placement.

Histology and Histomorphometry

Control Sites. Histologic evaluation of the control sites (100% autogenous bone) at 5 months revealed the presence of vital lamellar bone and some areas of woven bone surrounding the grafted trabecular bone (Figs 2 and 3). The presence of incremental basophilic lines mixed with interposed reversion lines was observed. The bone grafts, which were incompletely resorbed, were well integrated in the biopsy samples and were in complete continuity with the new bone tissue that resulted from the remodeling. The medullary spaces were almost always filled with well-vascularized connective tissue with no signs of inflammation. Osteoblasts signified the ongoing bone formation process. Moreover, the maturity of the bone was confirmed by the presence of well-developed haversian systems. The mean bone volume at control sites was 70% ± 19.9%.

Experimental Sites. At the experimental sites (50% autogenous bone/50% corticocancellous pig bone particles), the histologic analysis showed the presence of some corticocancellous bone particles; the grafted bone material was easily distinguished from the natural bone by staining (Fig 4). The incompletely resorbed bone graft was well integrated in the biopsy samples and was in complete continuity with the new bone tissue formation. (Fig 5). In the medullary area, increased density of vascular connective tissue was observed. No evidence of inflammatory infiltrate, necrosis, or foreign body reaction was observed in any of the specimens. Mean bone volume at the experimental sites was 67% ± 14.9%.

No statistically significant differences were observed between control and test sites.

DISCUSSION

Implant placement in the maxillary premolar and molar areas can be difficult in many cases because of the presence of the large maxillary sinus. Sinus floor augmentation has proven to be a clinically predictable treatment,[18–20] making the posterior edentulous maxilla suitable for dental implant placement.

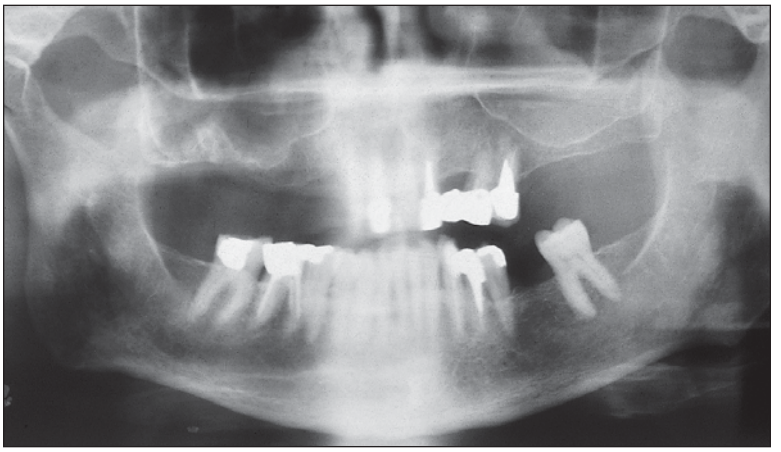

Fig 1a Preoperative radiograph illustrating a maxilla with severe bilateral atrophy.

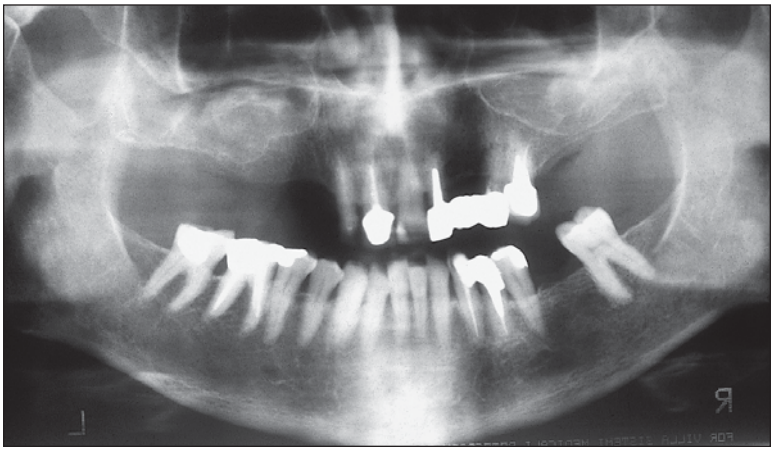

Fig 1b Postoperative radiograph 5 months after bilateral maxillary sinus grafting.

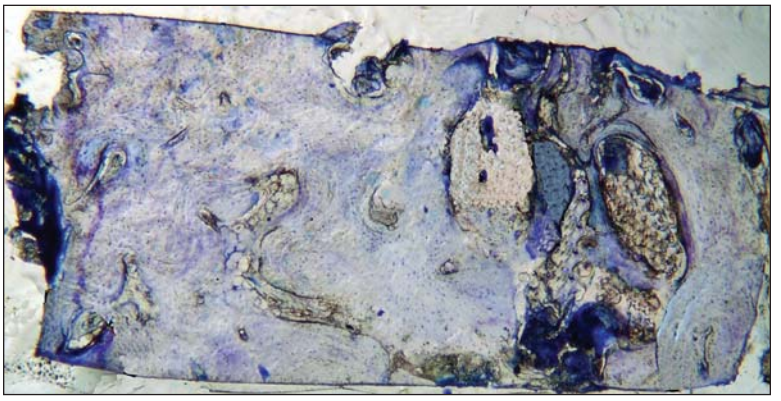

Fig 2 Histologic section from a control site. Trabecular deposition of vital lamellar bone represents high density. Small medullary spaces are present; inflammatory cells are not (toluidine blue; original magnification ×10).

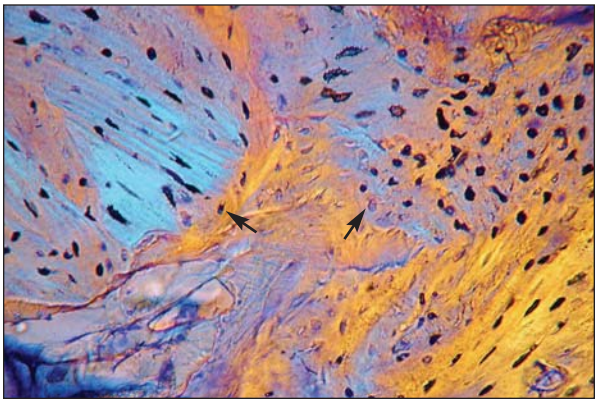

Fig 3 Histologic section from a control site. Note the lines of osteoblasts with interposed incremental and reversion lines *(arrows)* around grafted bone particles (differential interference contrast; original magnification ×160).

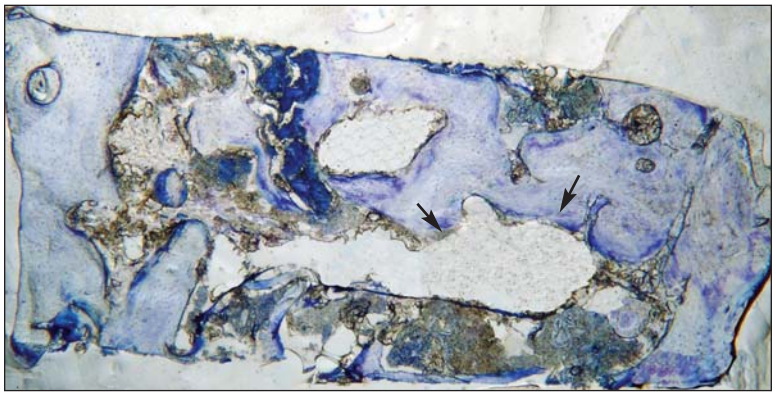

Fig 4 Histologic section from an experimental site. The presence of numerous lamellar bone growth lines surrounding particles of corticocancellous bone allograft can be observed. In the medullary areas *(arrows),* there was no evidence of inflammatory cells (toluidine blue; original magnification ×10).

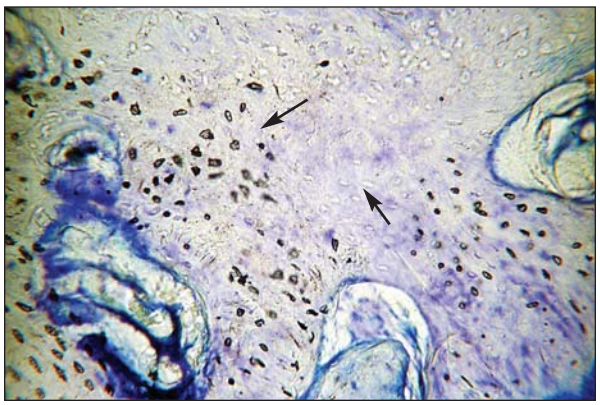

Fig 5 Histologic section from an experimental site. A detail of Fig 4 is seen here at a higher magnification. Newly formed bone *(long arrow)* with interposed incremental and reversion lines is present around grafted material *(short arrow)* (toluidine blue; original magnification ×160).

Autogenous bone is considered the preferred material for bone regeneration. The advantages of autogenous graft for bone augmentation are the angiogenic proliferation, presence of vital osteogenic cells, and release of growth factors.[21] The donor sites from which autogenous bone is obtained are generally the iliac crest for a bilateral maxillary sinus approach and intraoral sites for unilateral augmentation. These procedures increase the morbidity and complaints of discomfort from patients. Therefore, there is a need for a regenerative material that is biocompatible and replaceable by new bone to reduce the amount of the autogenous bone harvested. The aim of this study was to analyze the efficacy of a mixture of autogenous bone and corticocancellous pig bone to augment bone tissue in the human maxillary sinus.

The patients selected for this study had severe maxillary atrophy, with a residual bone crest height below the maxillary sinus between 1 and 3 mm. The insufficient bone volume contraindicated simultaneous implant placement during maxillary sinus augmentation. These clinical conditions showed high risks for bone grafting and implant micromobility and, consequently, an increased implant failure rate.[22] On the basis of these considerations, a delayed approach was planned in the present study, with a 5-month period between bone grafting and implant placement to allow remodeling and healing of the grafted bone.

The donor site for bone harvesting was the iliac crest. Invasive surgery was required to harvest a large volume of bone. The autogenous bone graft was used as particulate, since faster revascularization has been shown with particulate graft than with block grafts.[23] All of the grafted sites healed without complications. Four sinus membranes were damaged in 3 patients during surgical treatment and were subsequently closed using a collagen barrier. There were no healing complications in these 5 patients. None of the patients treated in this study exhibited sinus pathology after surgery. This was probably the result of careful examination before surgical treatment to identify clinical factors such as pre-existing sinus pathology and occluded osteum that could negatively influence the outcome of sinus augmentation. Patients who presented with unfavorable clinical conditions were excluded from the study.

Corticocancellous bone of bovine origin has been used for many years as a biomaterial for bone augmentation and sinus lifting, and it has shown good osteoconductive properties.[20,24] In the present study, corticocancellous pig bone particles at 5 months became partially resorbed and surrounded by new woven bone.

Histologic observations showed very similar bone

volume tissue percentages for the control and experimental sites. Findings from this study support the hypothesis that corticocancellous pig bone particles ranging in size from 0.25 to 1 mm have the capacity to augment bone when used as a graft material in association with autogenous bone. More studies in which the ratio of pig bone to autogenous bone is increased and the healing period is varied are needed before routine clinical use can be recommended. Moreover, histologic data from this study showed that almost the same quality and quantity of bone was obtained at control sites and experimental sites where corticocancellous pig bone particles were used as grafting material in a 1:1 mixture with autogenous bone. These findings demonstrated that corticocancellous pig bone particles represent a valid clinical alternative to autogenous bone and could partly replace it for maxillary sinus grafting and lifting. The absence of inflammatory signs around the heterologous particles suggested that deproteinized pig bone is a safe and biocompatible material. Similar histologic findings have been reported by other authors for bovine hydroxyapatite and β-tricalcium phosphate.[10,11]

Another aspect that must be taken into consideration is the resorption rate of the biomaterial. Many grafting materials such as corticocancellous bovine bone or hydroxyapatite require more time before resorption through multinuclear giant cell activity.[25,26] As a result of this slower remodeling phase, some particles of biomaterial could be still present in the grafted area when implants are placed. In the present study, evidence of resorption of the corticocancellous pig bone particles was observed at 5 months in association with the presence of colonies of osteogenic cells, which initiate the deposition of new bone. The progressive resorption of heterologous bone particles and their replacement by new bone could probably persist until the complete disappearance of heterologous biomaterial.

CONCLUSION

It might be concluded from this study that corticocancellous pig bone particles can be successfully used in a mixture with autogenous bone for maxillary sinus augmentation in cases of severely atrophic maxilla (Cawood class V). On the basis of these observations, more studies are needed to determine whether corticocancellous pig bone mixed with a small amount of autogenous bone (10% to 20% of the mixture's composition) from intraoral donor sites could be successfully used for bone grafting. The rationale for this approach would be reduction of amount of autogenous bone to be harvested and thus the elimination of the extraoral donor site and the associated morbidity and discomfort.

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