A Clinical and Histologic Evaluation of Implant Integration in the Posterior Maxilla After Sinus Floor Augmentation with Autogenous Bone, Bovine Hydroxyapatite, or a 20:80 Mixture

Mats Hallman, DDS[1]/Lars Sennerby, DDS, PhD[2]/Stefan Lundgren, DDS, PhD[3]

Purpose: *This study was designed to clinically and histologically evaluate the integration of titanium implants in different grafting materials used for maxillary sinus augmentation procedures.* ***Materials and Methods:*** *A total of 21 patients and 36 maxillary sinuses were augmented with (1) autogenous particulated bone from the mandibular ramus, (2) bovine hydroxyapatite (BH) with membrane coverage, or (3) an 80/20 mixture of BH and autogenous bone. The grafts were allowed to heal for 6 to 9 months prior to placement of microimplants for histology and standard implants for prosthetic rehabilitation. After another 6 months of healing, when abutments were connected, the microimplants were retrieved for histologic and morphometric analyses. The outcome of the standard implants was clinically evaluated after 1 year of loading.* ***Results:*** *The mean bone-implant contact was 34.6 ± 9.5%, 54.3 ± 33.1%, and 31.6 ± 19.1% for autogenous bone, mixture of 20% autogenous bone/80% BH, and 100% BH, respectively. The corresponding values for the bone area parameter were 37.7 ± 31.3%, 39.9 ± 8%, and 41.7 ± 26.6%. The BH area was found to be 12.3 ± 8.5% and 11.8 ± 3.6% for 20% autogenous bone/80% BH and 100% BH, respectively. There were no statistically significant differences for any parameter between any of the groups. After 1 year of loading, 6 of the 33 implants placed in autogenous bone grafts, 2 of the 35 implants placed in the BH/autogenous bone mixture, and 2 of 43 implants placed in BH were lost. There were no statistically significant differences between any of the groups.* ***Discussion:*** *The histomorphometric analysis showed no differences between the 3 groups, indicating that autogenous bone graft can be substituted with bovine hydroxyapatite to 80% or 100% when used for maxillary sinus floor augmentation. The effect of adding autogenous bone remains unclear but may allow for a reduction of the healing time.* ***Conclusion:*** *The results from this clinical and histologic study indicate that similar short-term results can be expected when using autogenous bone, BH, or a mixture of them for maxillary sinus floor augmentation and delayed placement of dental implants.* (INT J ORAL MAXILLOFAC IMPLANTS 2002;17:635–643)

Key words: *autogenous bone graft, bovine hydroxyapatite, clinical study, dental implants, fibrin glue, maxillary sinus floor augmentation*

Augmentation of the maxillary sinus floor with autogenous bone or bone substitutes is a commonly used method to increase bone volume prior to placement of implants in the posterior maxilla.[1] One purpose of the augmentation procedure is to provide a sufficient volume of bone tissue for mechanical support and integration of the implants. Even though several clinical and radiographic investigations have generally demonstrated good results irrespective of techniques and grafting materials,[2–13] little is known about the healing pattern and integration processes of implants placed in different grafting materials in humans.

Bovine hydroxyapatite (BH) (Bio-Oss, Geistlich Pharmaceutical, Wolhusen, Switzerland) is a bone substitute that has been used and evaluated for bone augmentation purposes.[10–12,14,15] Histologic studies of specimens from animals and humans have shown

[1]Consultant, Clinic for Oral & Maxillofacial Surgery, Public Health Service, Gävle City, Sweden; and Research Fellow, Department of Oral & Maxillofacial Surgery, Umeå University, Umeå, Sweden.
[2]Professor, Department of Oral & Maxillofacial Surgery, Umeå University, Umeå, Sweden.
[3]Professor, Department of Biomaterials/Handicap Research, Institute for Surgical Sciences, Göteborg University, Göteborg, Sweden.

Reprint requests: Dr Mats Hallman, Clinic for Oral Maxillofacial Surgery, Public Health Service, Gävle Hospital, SE 80187 Gävle, Sweden. Fax: +46-26155347. E-mail: mats.hallman@lg.se

BH to have bone-conductive properties[10–12,16–19] but have also indicated that BH will not be resorbed with time.[11,20] In clinical follow-up studies of maxillary sinus floor augmentation procedures, the authors have used BH alone or in combination with autogenous bone, demineralized freeze-dried bone, or fibrin glue.[10–12,15] It has been anticipated that the addition of autogenous bone will induce and facilitate bone formation with incorporation of the bone substitute.[8–12] The advantage of using bone substitutes alone prior to implant surgery is obvious, since no donor site for harvesting of autogenous bone is necessary. However, the question remains as to what role autogenous bone plays in the healing process and whether it can be completely replaced with a substitute. The clinical studies referred to above have reported similar implant survival rates, irrespective of the technique used, but with varying follow-up time.[9,12,21,22] However, conclusions should be drawn with caution, since only a few implants were followed during a short period of time.

Several animal models have been utilized for histologic and biomechanical analyses of the bone graft/implant interface.[23,24] Placement and retrieval of titanium microimplants from grafted areas have earlier been performed to study the integration of titanium implants in maxillary sinus floor augmentation situations comparing allogenic and autogenous bone grafts[25] and in the grafted maxilla using iliac crest bone.[26]

The aim of this clinical and histologic investigation was to study the graft/titanium implant interface in maxillary sinuses augmented with autogenous bone, BH, or an 80:20 mixture of BH and autogenous bone. The clinical performance of standard implants placed in the different grafts during the first year of loading was also evaluated.

MATERIALS AND METHODS

Patients

Twenty-one patients (14 women, 7 men) with a mean age of 54 years (range 19 to 80 years) participated in the study. The patients were referred to the Department of Oral and Maxillofacial Surgery, Gävle Hospital, Gävle, Sweden, for maxillary sinus augmentation because of lack of bone for the placement of endosseous implants. The inclusion criterion was that less than 5 mm of alveolar bone in the floor of the sinus remained, as determined by conventional tomography. The patients were classified as Class V or VI in the posterior regions of the maxilla and the edentulous patients were Class III or IV in the anterior maxilla, all according to Cawood and Howell.[27] After being informed about the study, the patients signed a consent form. The study was approved by the regional ethical committee.

Maxillary Sinus Floor Augmentation Surgery

All patients underwent surgical procedures under local anesthesia with lidocaine (2%) with epinephrine (1:80,000) (Xylocaine/Adrenalin, Astra, Södertälje, Sweden) and perioral sedation (Midazolam/Dormicum, Roche, Stockholm, Sweden). The surgical procedure for the maxillary sinus augmentation procedure has been described elsewhere.[2,9] In brief, a lateral maxillary sinus osteotomy with infracture was performed, combined with stripping off the sinus membrane, to create a subsinus cavity into which the graft material could be placed.

Bone Augmentation Materials

Two different grafting materials were used: *(1)* autogenous particulated bone from the mandibular ramus, and *(2)* BH (Bio-Oss; particle size = 0.25 to 1.00 mm). Harvesting of the corticocancellous mandibular ramus grafts was performed under local anesthesia (lidocaine 2% with epinephrine [1:80,000], Xylocaine/Adrenalin, Astra). As a prophylactic measure, all patients received 300 mg of Clindamycine (Pharmacia/Upjohn, Stockholm, Sweden) 1 hour before surgery and 3 times daily for 10 days. The mandibular ramus was exposed through a mucoperiosteal incision from the second premolar to the lateral side of the ramus. A unicortical osteotomy was performed using a fissure bur, and the buccal cortical plate was fractured laterally with osteotomes. The bone graft was milled and kept in autogenous blood. The periosteum and mucosa were carefully readapted and sutured using resorbable sutures. A fibrin glue (Tisseel Duo Quick, Immuno, Vienna, Austria) was added to the different mixtures of grafts after thrombin (Thrombin, Immuno) was added to catalyze the setting.

Treatment Protocol

Bilateral maxillary sinus floor augmentation was performed in 11 patients (groups 1a and 1b). In a randomized manner, one side was grafted with 100% particulated bone from the mandibular ramus (group 1a) and the contralateral side with a mixture of 80% BH and 20% bone from the mandibular ramus (group 1b). After a mean healing time of 6.5 months (range, 6 to 7 months), 67 Brånemark System implants were placed (self-tapping Mark II, 3.75 mm diameter; Nobel Biocare, Göteborg, Sweden) (Table 1a). Thirty-three implants were placed in the side augmented with autogenous bone only

Table 1a No. of Implants Placed, Failed, and Retrieved After 1 Year in Function in Maxillary Sinuses Augmented with Autogenous Bone Alone or Mixed with BH

	Group 1a		Group 1b		
Patient no.	Implant lengths (mm)	Implant failures	Implant lengths (mm)	Implant failures	Retrieved microimplants
1	15,13,13	1	13,13,13	0	1 + 1
2	13,13,13	1	13,13,13	0	0
3	13,13,13	0	13,13,10	0	1 + 1
4	13,15,13,10	2	10,15,15	0	0
5	7,7,7	0	7,7,7,7	0	0
6	15,13,13	0	15,13,13	0	1 + 1
7	10,10,10	1	10,10,10,10	1	1 + 1
8	11.5	0	11.5	0	1 + 1
9	10,10,10,13	1	13,13,10,10	1	1 + 1
10	10,10,10	0	10,10,10,10	0	1 + 1
11	15,13,13	0	15,13,13	0	1 + 1
Total (failure rate)	33	6 (18%)	35	2 (5.7%)	8 + 8

Group 1a = sinus augmented with autogenous bone only; Group 1b = sinus augmented with 80:20 mixture of BH and autogenous bone.

Table 1b No. of Implants Placed, Failed, and Retrieved After 1 Year in Function in Maxillary Sinuses Augmented with BH

	Group 2		
Patient no.	Implant lengths (mm)	Implant failures	Retrieved microimplants
12	10,13,13	0	1
13	13,15,10	0	1
14	13,13	0	1
15	13,13,13	0	1
16	13,13	0	1
17	13,13,13,13	0	1
18	10,10,10,10,13,13,13	0	1
19	13,13,13,13,13,13	1	1
20	10,10,10,10,10,10,10,10	1	1
21	15,15,13,13,13	0	0
Total (failure rate)	43	2 (4.6%)	9

and 35 implants were placed in the side augmented with a mixture of BH and autogenous bone.

A second group of 10 patients underwent unilateral (6 patients) or bilateral (4 patients) maxillary sinus floor augmentation using 100% BH (group 2). A resorbable membrane (BioGide, Geistlich Pharmaceutical) was used to cover the defect in the lateral wall of the maxillary sinus on the lateral wall of the graft to inhibit the ingrowth of fibrous connective tissue (in group 2 only). According to the authors' earlier experience of grafting with 100% BH, the healing period was prolonged because the newly formed bone was too immature after 6 months of healing to provide enough stability for the placement of dental implants. The mean healing time for this group was 8.5 months (range, 8 to 9.5 months). After the healing period, 43 implants were placed (self-tapping Mark III, 3.75 mm diameter, Nobel Biocare) (Table 1b).

After a healing period of 6 months, abutment connection was performed in all patients. Prosthetic treatment with screw-retained metal-ceramic fixed prostheses was provided, and all patients were followed during 1 year of functional loading. All patients had their own teeth with or without crowns as an opposing occlusion.

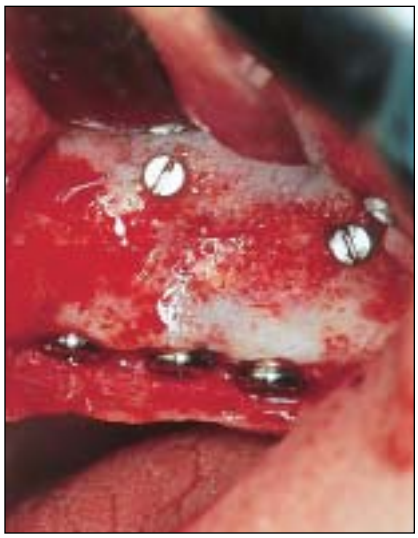


Fig 1a Two test implants in the lateral wall of the maxillary sinus 6 months after an augmentation procedure.

Fig 1b Retrieved test implant with surrounding bone.

Placement and Retrieval of Microimplants

Thirty screw-shaped microimplants were produced from turned (machined) commercially pure titanium. The implants were 5 mm in length and 2 mm in diameter and had a slotted head. Prior to surgery, the implants were cleaned in ultrasonic baths with trichloroethylene and absolute alcohol, 10 minutes in each solution, and sterilized by autoclaving.

At the time of standard implant placement, 1 microimplant was placed laterally in each augmented sinus in all patients (Fig 1a). Preparation for placement of the test implant was made with a 1.6-mm twist drill under saline irrigation. The test implant was then self-tapped into place with a small screwdriver.

At abutment connection surgery, 25 of the placed microimplants were retrieved along with the surrounding bone (Fig 1b) using a 3- or 5-mm trephine, depending on available space between the standard dental implants. The retrieved microimplants were fixed by immersion in 4% buffered formaldehyde solution.

Specimen Processing and Analysis

The fixed specimens were dehydrated in a graded series of ethanols and embedded in plastic resin (Technovit 7200 VCL, Kulzer, Wehrheim, Germany). Sections were cut and ground to a thickness of approximately 150 µm by means of Exact cutting and grinding equipment (Exact Apparatebau, Norderstedt, Germany). The ground sections were further ground to a thickness of about 10 µm and stained with 1% toluidine blue and 1% pyronin-G.

Examination, photography, and morphometric measurements were made in a Leitz Orthoplan microscope equipped with a Microvid morphometric system (Leitz, Wetzlar, Germany) connected to a personal computer. The morphometric measurement comprised: *(1)* the amount of bone occupying the area of the implant threads (percentage bone area); *(2)* the amount of graft material occupying the area of the threads (percentage graft [BH] area); and *(3)* the degree of bone-implant contact with all implant threads (percentage bone-implant contact).

Statistical Analysis

The Wilcoxon signed rank test was used for paired statistical analysis and the Wilcoxon sum rank test was used for unpaired analysis of the morphometric parameters. The Fisher exact test was used to compare implant failure rates. A difference was considered statistically significant if $P < .05$.

RESULTS

Implant Survival

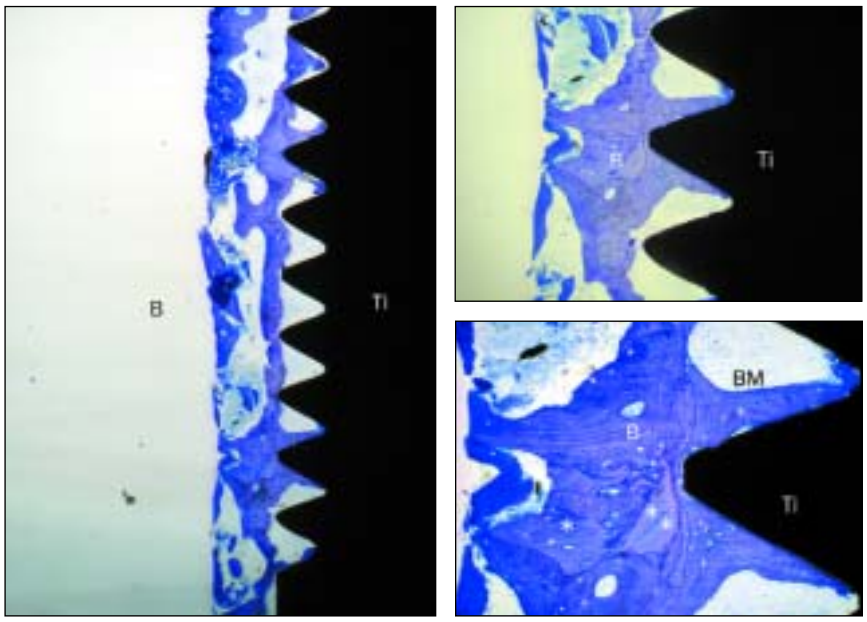
Six of the 33 dental implants placed in 100% autogenous bone grafts were lost. The survival rate for this group was 82.4% after 1 year of loading (group 1a). Two of the 35 dental implants placed in an 80:20 mixture of BH and autogenous bone were lost, resulting in a survival rate of 94.4% after 1 year of loading (group 1b) (Table 1a). Two of 43 dental implants placed in 100% BH (group 2) were lost, resulting in a survival rate of 96% after 1 year of loading (Table 1b). There were no statistically significant differences (NS) between loss of implants in any of the groups.

Figs 2a to 2c Light micrographs of a microimplant placed in 100% autogenous bone (1% toluidine blue and 1% pyronin-G).

Fig 2a *(Left)* Overview. The interface area is occupied by bone (B) and soft tissue. In some areas the bone is seen in direct contact with the titanium implant (Ti) (×4).

Fig 2b *(Top right)* Detail of area shown in 2a, showing bone (B) in direct contact with the implant surface (Ti) (×10).

Fig 2c *(Bottom right)* A few autogenous bone particles *(asterisks)* can be distinguished in an area with lamellar and woven bone. Bone (B) and bone marrow (BM) tissue are seen in close apposition with the implant surface (Ti) (×20).

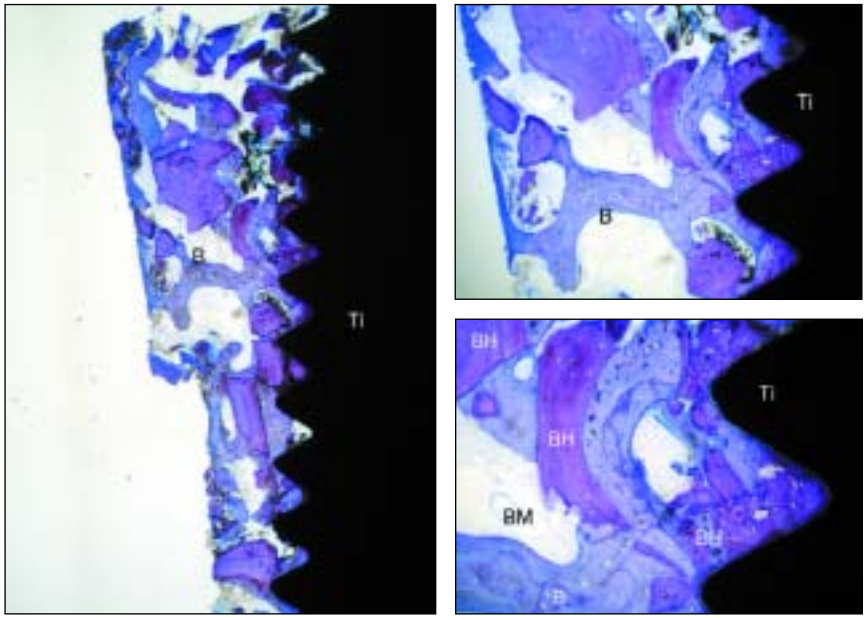


Figs 3a to 3c Light micrographs of a microimplant placed in an 80/20 mixture of BH and autogenous bone (1% toluidine blue and 1% pyronin-G).

Fig 3a *(Left)* Overview showing mineralized tissue (B) and soft tissue in the interface area (×4).

Fig 3b *(Top right)* Detail of area shown in Fig 3a. The implant (Ti) is seen in direct contact with the mineralized tissue (B) (×10).

Fig 3c *(Bottom right)* BH, newly formed bone (B), and bone marrow (BM) can be distinguished at a higher magnification. However, it is difficult to identify any grafted autogenous bone particles in this section (×20). Ti = implant.



Histology and Morphometry

Because of limited space between the standard dental implants in 3 of the patients in group 1 and 1 patient in group 2, it was not possible to retrieve all microimplants. Histologic examination could be made of a total of 25 microimplants (8 from group 1a, 8 from group 1b, and 9 from group 2).

Analysis showed the presence of bone tissue in varying degrees in all specimens (Figs 2 to 4). In general, the gross anatomy of the tissues surrounding the microimplants was similar for the 3 types of grafting materials. The specimens consisted of newly formed bone tissue, bone graft material, loose connective tissue, and occasional areas of fat cells. Bone formation and remodeling adjacent to the implant surface were evident in the specimens (Figs 2b, 3b, and 4b). BH particles were embedded in an admixture of woven and lamellar bone and were

Figs 4a to 4c Light micrographs of a microimplant placed in 100% BH (1% toluidine blue and 1% pyronin-G).

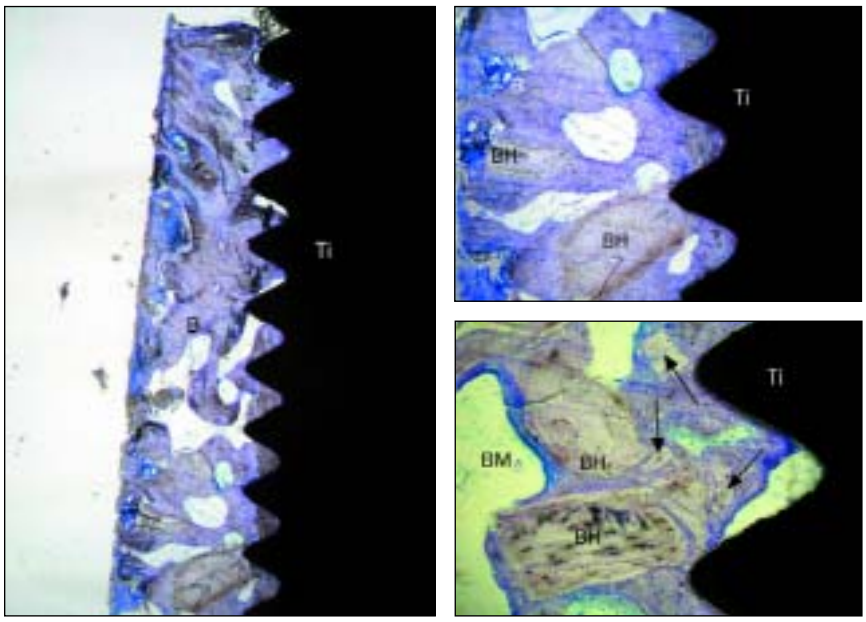


Fig 4a *(Left)* Overview showing mineralized tissue (B) in close relation with the implant (Ti) (×4).

Fig 4b *(Top right)* Detail of area shown in Fig 4a, showing BH particles to be well incorporated with newly formed bone (B). The implant (Ti) is in direct contact with the bone (×10).

Fig 4c *(Bottom right)* An area with numerous BH particles (BH, *arrows*) well embedded in newly formed bone. Bone is seen in direct contact with the implant (Ti) (×20). BM = bone marrow.

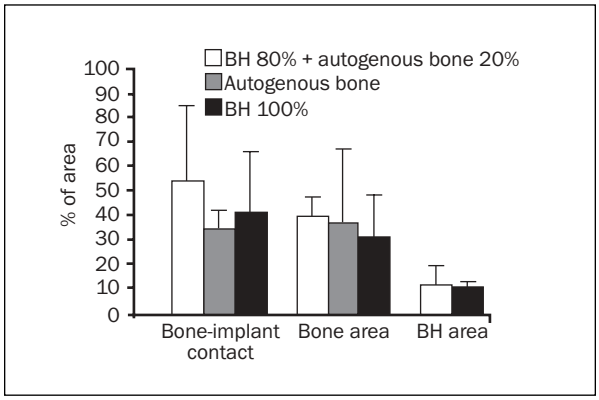


Fig 5 Results of the morphometric analyses. There were no statistically significant differences ($P > .05$) between the groups for any of the parameters.

easily identified because of their staining and morphologic appearance, ie, sharp edges and lack of resorption (Figs 3c and 4c). Smaller particles of BH could be seen in the interface, probably as a result of the drilling when placing the microimplants (Figs 3c and 4c). Bone formation was seen directly on the surface of the BH particles. The particles were seldom seen in direct contact with the surface of the microimplant, but were usually separated from it by newly formed bone or loose connective tissue. The BH particles did not seem to be affected by resorption and remodeling. The autogenous particles could be distinguished only diffusely, since they were partly resorbed and incorporated with the newly formed and remodeled bone (Fig 2b). Because of this, no attempts were made to quantify their area in the specimens. The soft tissue components consisted of a loose connective tissue rich in vessels and cells, and, in some areas, of fat cells. The soft tissue resembled the morphology of bone marrow tissue (Figs 2c, 3c, and 4c). Although inflammatory cells were present, there were no signs of pathologic inflammation.

The mean bone-implant contact in the specimens retrieved from patients in group 1a (autogenous bone) was 34.6 ± 9.5%, in group 1b (80:20 mixture of BH and autogenous bone) 54.3 ± 33.1%, and in group 2 (BH) 31.6 ± 19.1%. The corresponding values for the bone area parameter were 37.7 ± 31.3% (group 1a), 39.9 ± 8% (group 1b), and 41.7 ± 26.6% (group 2). The BH area was found to be 12.3 ± 8.5% and 11.8 ± 3.6% for groups 1b and 2, respectively (Fig 5). There were no statistically significant differences for any parameter between any of the groups.

DISCUSSION

In this study it was confirmed that the microimplant technique can be used to evaluate the bone-implant interface in augmented maxillary sinuses without interfering with the healing of standard implants if the inter-implant space is sufficient.[25,26] One obvious advantage with the technique is that the bone tissue response to an augmentation material, as well as the integration of an implant into the material, can be studied in patients. The experimental situation also

makes it possible to correlate the histologic findings with the clinical outcome of the standard implants placed in the same area.

As frequently described previously,[8–12] bone formation was seen at the surface of the BH particles, which seemed to become well incorporated with the new bone. The BH particles showed a distinct staining and were easily identified. However, there were no signs of resorption, in contrast to the autogenous bone particles. Because of this and of the staining properties of the autogenous graft (similar to native bone), these were more difficult to identify in the specimens. The autogenous bone particles showed bone resorption and bone formation on their surfaces, in contrast to the BH particles. The BH particles were seen in contact with the implant surface only occasionally. Instead, newly formed and sometimes lamellar bone was found in direct contact with the implants. This seemed to indicate that the BH particles did not prevent bone formation and integration of the implant. Morphometric analysis revealed no statistically significant differences when comparing microimplants retrieved from maxillary sinuses augmented with autogenous bone alone, BH particles alone, or a mixture of the two. However, a prolonged healing time for the latter group was needed. During clinical follow-up of the standard implants, 6 of 33 implants placed in autogenous bone graft were lost. Two of 35 implants placed in the mixed grafts (80:20 BH and autogenous bone) and 2 of the 43 implants in 100% BH were lost. The differences were not statistically significant. The results indicated that a similar bone tissue response and integration of titanium implants could be expected in the 3 situations, at least in the short-term perspective.

The inclusion criteria used for maxillary sinus floor augmentation and endosseous dental implants are of major importance for the clinical outcome. It is likely that the role of the augmented tissue for mechanical support of an implant becomes more important with decreasing thickness of the residual bone below the maxillary sinus. Jensen and Greer[28] demonstrated a 100% survival rate when the residual bone in the floor of the maxillary sinus was 7 mm and a 29% survival rate when 3 mm of residual bone remained. The reason for the differences is probably related to the possibility of achieving primary stability, which has been shown to be one determinant factor for implant failure, since implant failure seems to occur more often in bone with a low density.[29,30]

Lack of primary stability will result in micromotion at the tissue-implant interface, which may lead to fibrous encapsulation rather than bone formation. Therefore, if good primary stability can be obtained in small amounts of dense bone, for instance, by using an adapted surgical technique with narrower drills and self-tapping implants, it is possible that the implant can remain stable during functional loading. For example, implants used for craniofacial reconstruction are only 3 or 4 mm long, and high long-term survival rates have been obtained, even when a 1-stage approach is used.[31] However, craniofacial implants are generally not subjected to the same type and magnitude of loading as are intraoral implants. Ellegaard and coworkers[32] found that implants placed in a few millimeters of bone and protruding into the maxillary sinus without a graft were as successful as implants placed in an adjacent site with sufficient bone volume during a 3-year period. They used implants with an increased surface roughness, which may have contributed to the favorable results. A recent microimplant study in patients by Ivanoff and associates[33] showed a higher degree of bone contact and more bone around the threads of microimplants with an enhanced surface roughness compared to machined, threaded implants. In the present study machined implants were used, and it is possible that the degree of bone-implant contact may have been higher if textured implants had been used.

Previous histologic studies using the microimplant technique for machined implants have shown that complete integration of an implant placed simultaneously with a bone graft takes an extended time, probably longer than 12 months.[25,26] It was also shown that placement of implants after initial healing of the graft resulted in a more rapid integration process, where lamellar bone was seen at the implant interface after 6 months of healing. In the present study, a healing period of 6 months was utilized before implant placement, except in the patient group treated with 100% BH, where a 9-month healing period was used. It was anticipated that the addition of autogenous bone particles and marrow to the BH might facilitate proliferation of vessels and tissues, initiation of new bone formation, and incorporation of the grafts. For this reason it was speculated that a longer healing period was needed for the 100% BH group, since new bone proliferation must occur from the peripheral bone walls only. However, this may have influenced the morphometric results, since it is possible that if the 2 groups with autogenous bone had had a similarly long healing period before retrieval, more bone and perhaps statistical differences when compared with the BH group would have been found.

BH was first used as a bioresorbable material and anticipated to be replaced by autogenous bone with

time. However, histologic documentation of the performance of this material in humans points to the fact that the material is not resorbed over time. For instance, the authors' results[10] have shown no decrease in the amount of BH from 6 months to 3 years after a maxillary sinus floor was augmented with BH and autogenous bone. Moreover, Schlegel and Donath[20] reported no signs of resorption when they analyzed 126 clinical specimens from 71 patients with up to 6 years of follow-up. Instead, it seems that BH particles will remain in the bone tissue and slowly be embedded in lamellar bone, which may result in a more dense bone than if the BH had been resorbed. Schlegel and Donath described this phenomenon as an increased radiopacity around the BH material with time. It can be speculated that this may have a positive influence on implant stability, which is determined in great part by the density of the surrounding bone. In fact, Haas and coworkers[34,35] demonstrated a higher push-out force for implants placed simultaneously with BH as compared with non-augmented controls in the sheep maxillary sinus. The short-term clinical results of the standard implants in this study indicated fewer implant failures in the maxillary sinuses augmented with BH; however, this could not be statistically verified.

The resistance of BH to resorption and degradation may be advantageous for maintaining the initial dimensions of the augmented area with time. Recent results from radiographic analyses of 20 patients with 30 maxillary sinuses augmented with an 80/20 mixture of BH and autogenous bone showed less than 10% change over 24 months of follow-up, which supports this hypothesis.[12] Other authors have reported similar results. Froum and associates[22] followed 13 patients with radiographic measurements and measured a 1.4% mean change in the graft height 2 to 3 years after grafting. Moreover, McAllister and colleagues[36] concluded that the density and height of the augmented monkey maxillary sinus remained stable up to 1.5 years after the procedure.

In the group of patients augmented with 100% BH, a resorbable membrane was used on the lateral wall of the graft to inhibit ingrowth of fibrous connective tissue. This was a decision made according to earlier experiences that used only BH as a grafting material. The healing time was also extended from 6 to 9 months. This is in accordance with other studies[22,37] that used grafting materials that were only osteoconductive. In a study by Tawil and Mawla[37] the use of a membrane was beneficial (lower implant failure rates) if the healing time after immediate implant placement was between 6 and 9 months compared to longer healing times. In this study, machined implants were used, and it was concluded that these implants could be used with predicable results if the healing time was over 9 months. Perhaps membranes should be used if shorter healing times are preferred.

CONCLUSION

The short-term clinical outcome and histologic evaluation of osseointegration were found to be similar for titanium implants placed in maxillary sinuses 6 to 9 months after augmentation with autogenous bone, BH, or a combination of these materials.

ACKNOWLEDGMENTS

This work has been supported by grants from the Hjalmar Svensson Foundation, the Wilhelm and Martina Lundgren Foundation, and Geistlich Pharmaceutical. Mrs Petra Johansson and Hayde Bolouri are gratefully acknowledged for their skillful technical assistance.

REFERENCES

1. Jensen OT. Treatment planning for sinus grafts. In: Jensen OT (ed). The Sinus Bone Graft. Chicago: Quintessence, 1999:49–68.
2. Boyne PJ, James RA. Grafting of the maxillary sinus floor with autogenous bone marrow. J Oral Surg 1980;38: 613–616.
3. Jenssen J, Krantz-Simonsen E, Sindet-Pederssen S. Reconstruction of the severely resorbed maxilla with bone grafting and ossseointegrated implants. A preliminary report. J Oral Maxillofac Surg 1990;48:27–32.
4. Hirsch JM, Ericsson I. Maxillary sinus augmentation using mandibular bone grafts and simultaneous installation of implants. A surgical technique. Clin Oral Implants Res 1991; 2:91–96.
5. Loukota RA, Isaksson S, Linner ELJ, Blomqvist JE. A technique for inserting endosseous implants in the atrophic maxilla in a single-stage procedure. Br J Oral Maxillofac Surg 1992;30:46–49.
6. Small SA, Zinner ID, Panno FV, Shapiro HJ, Stein JI. Augmenting the maxillary sinus for implants: Report of 27 patients. Int J Oral Maxillofac Implants 1993;8:523–528.
7. Hürzeler MB, Kirsch A, Ackermann KL, Quinones CR. Reconstruction of the severely resorbed maxilla with dental implants in the augmented maxillary sinus: A 5-year clinical investigation. Int J Oral Maxillofac Implants 1996;11: 466–475.
8. Skoglund A, Hising P, Young C. Clinical and histologic examination in humans of the osseous response to implanted natural bone mineral. Int J Oral Maxillofac Implants 1997; 12:194–199.

9. Yildirim M, Spiekermann H, Biesterfeld S, Edelhoff D. Maxillary sinus augmentation using xenogenic bone substitute material Bio-Oss in combination with venous blood. A histologic and histomorphometric study in humans. Clin Oral Implants Res 2000;11:217–229.
10. Hallman M, Cederlund A, Lindskog S, Lundgren S, Sennerby L. A clinical histologic study of bovine hydroxyapatite in combination with autogenous bone and fibrin glue for maxillary sinus floor augmentation. Results after 6-8 months of healing. Clin Oral Implants Res 2001;12:135–143.
11. Hallman M, Lundgren S, Sennerby S. Histological analysis of clinical biopsies taken 6 months and 3 years after maxillary sinus floor augmentation with 80% bovine hydroxyapatite and 20% autogenous bone mixed with fibrin glue. Clin Implant Dent Relat Res 2001;2:87–96.
12. Hallman M, Hedin M, Sennerby L, Lundgren S. A prospective 1-year clinical and radiographic study of implants placed after maxillary sinus floor augmentation with bovine hydroxyapatite and autogenous bone. J Oral Maxillofac Surg 2002; 60:277–284.
13. Hising P, Bolin A, Branting C. Reconstruction of severely resorbed alveolar ridge crests with dental implants using a bovine bone mineral for augmentation. Int J Oral Maxillofac Implants 2001;16:90–97.
14. Wallace SS, Froum SJ, Tarnow DP. Histologic evaluation of sinus elevation procedure: A clinical report. Int J Periodontics Restorative Dent 1996;16:47–51.
15. Hürzeler MB, Quinones CR, Kirsch A, Schupbach P, Strub JR, Caffesse RG. Maxillary sinus augmentation using different grafting materials and dental implants in monkeys. Part 1. Evaluation of anorganic bovine- derived bone matrix. Clin Oral Implants Res 1997;8:476–486.
16. Mandelkow HK, Hallfeldt KKJ, Kessler SB, Gayk M, Siebeck M, Schweiberer L. Knochenbildung nach Implantation verschiedener Hydroxylapatitkeramiken. Unfallchirurg 1990;93:376–379.
17. Fukuta K, Har-Shai Y, Collares MV, Lichten JB, Jackson IT. Comparison of inorganic bovine bone mineral particles with porous hydroxyapatite granules and cranial bone dust in the reconstruction of full-thickness defect. J Craniofac Surg 1992;3:25–29.
18. Klinge B, Alberius P, Isaksson S, Jönsson J. Osseous response to implanted natural bone mineral and synthetic hydroxyapatite ceramics in the repair of experimental skull bone defects. J Oral Maxillofac Surg 1992;50:241–249.
19. Piattelli M, Favero GA, Scarano A, Orsini G, Piattelli A. Bone reactions to anorganic bovine bone (Bio-Oss) used in sinus augmentation procedures: A histologic long-term report of 20 cases in humans. Int J Oral Maxillofac Implants 1999;14:835–840.
20. Schlegel AK, Donath K. Bio-Oss: A resorbable bone substitute? J Long Term Eff Med Implants 1998;8:201–209.
21. Valentini P, Abensur D, Densari D, Graziani JN, Hämmerle CHF. Histological evaluation of Bio-Oss in a 2-stage sinus floor elevation and implantation procedure. Clin Oral Implants Res 1988;9:59–64.
22. Froum SJ, Tarnow DP, Wallace SS, Rohrer MD, Cho SC. Sinus floor elevation using anorganic bovine bone matrix (OsteoGraf/N) with and without autogenous bone: A clinical, histologic, radiographic, and histomorphometric analysis—Part 2 of an ongoing prospective study. Int J Periodontics Restorative Dent 1998;16:528–543.
23. Rasmusson L, Sennerby L, Lundgren D, Nyman S. Morphological and dimensional changes after barrier removal in bone formed beyond the skeletal borders at titanium implants. A kinetic study in the rabbit tibia. Clin Oral Implants Res 1997:8:103–116.
24. Rasmusson L, Meridith N, Cho I-H, Sennerby L. The influence of simultaneous vs delayed placement on the stability of titanium implants in onlay bone grafts. A histologic and bimechanic study in the rabbit. Int J Oral Maxillofac Surg 1999;28:224–231.
25. Jensen OT, Sennerby L. Histologic analysis of clinically retrieved titanium microimplants placed in conjunction with maxillary sinus floor augmenation. Int J Oral Maxillofac Implants 1998;13:513–521.
26. Lundgren S, Rasmusson L, Sjöström M, Sennerby L. Simultaneous or delayed placement of titanium implants in free autogenous iliac bone grafts. Histological analysis of the bone graft–titanium interface in 10 consecutive patients. Int J Oral Maxillofac Surg 1999;27:31–37.
27. Cawood JL, Howell RA. A classification of the edentulous jaw. Int J Oral Maxillofac Surg 1988;17:232–236.
28. Jensen OT, Greer R. Immediate placing of osseointegrating implants into the maxillary sinus augmented with mineralized cancellous allograft and Gore-Tex: Second-stage surgical and histological findings. In: Laney WR, Tolman DE (eds). Tissue Integration in Oral Orthopedic and Maxillofacial Reconstruction. Chicago: Quintessence, 1992:321–333.
29. Friberg B, Jemt T, Lekholm U. Early failures in 4641 consecutively placed Brånemark dental implants. Int J Oral Maxillofac Implants 1991;6:142–146.
30. Jaffin RA, Berman CL. The excessive loss of Brånemark fixtures in type IV bone. J Periodontol 1991;62:2–4.
31. Tjellström A, Granström G. One-stage procedure to establish osseointegration: A zero to five years follow-up report. J Laryngol Otol 1995;109:593–598.
32. Ellegaard B, Petersen JK, Stoltze K. Implant therapy involving maxillary sinus lift in periodontally compromised patients. Clin Oral Implants Res 1997;8:305–315.
33. Ivanoff CJ, Widmark G, Hallgren C, Sennerby L, Wennerberg A. Histologic evaluation of the bone integration of TiO_2-blasted and turned titanium microimplants in humans. Clin Oral Implants Res 2001;12:128–134.
34. Haas R, Donath K, Födinger M, Watzek G. Bovine hydroxyapatite for maxillary sinus grafting: Comparative histomorphometric findings in sheep. Clin Oral Implants Res 1998;9: 107–116.
35. Haas R, Mailath G, Dörtbudak O, Watzek G. Bovine hydroxyapatite for maxillary sinus augmentation: Analysis of interfacial bond strength of dental implants using pull-out tests. Clin Oral Implants Res 1998;9:117–122.
36. McAllister BS, Margolin MD, Cogan AG, Buck D, Hollinger JO, Lynch SE. Eighteen-month radiographic and histologic evaluation of sinus grafting with anorganic bovine bone in the chimpanzee. Int J Oral Maxillofac Implants 1999;14:361–368.
37. Tawil G, Mawla M. Sinus floor elevation using bovine bone mineral (Bio-Oss) with and without the concomitant use of a bilayered collagen barrier (Bio-Gide): A clinical report of immediate and delayed implant placement. Int J Oral Maxillofac Implants 2001;16:713–721.