Reconstruction of Severely Resorbed Alveolar Ridge Crests with Dental Implants Using a Bovine Bone Mineral for Augmentation

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This study reviews the outcome of implant placement in 61 patients after augmentation of severely atrophic alveolar bone with a bovine bone mineral, Bio-Oss. Bone augmentation was performed at 4 different sites: alveolar crest width, alveolar crest height, antral cavity, or nasal cavity. After a mean healing time of 11.9 months, 231 implants were placed in Bio-Oss bone. The time of loading of the implants varied between 12 and 113 months. Calculated from the time of implant placement and irrespective of loading time, a survival rate of 80.5% for the individual implants was estimated. In most patients (73%), Bio-Oss was mixed with autogenous bone from the chin. However, the results indicated that autogenous bone may be excluded from the Bio-Oss graft. (Int J Oral Maxillofac Implants 2001;16:90–97)

Key words: *alveolar bone loss, alveolar ridge augmentation, bovine bone, dental implants*

Rehabilitation of advanced resorbed alveolar bone following the extraction of teeth often causes difficulty if conventional removable dentures are used because of the lack of retention and instability. Atrophy of the edentulous arch may also be accompanied by other problems, such as pain, poor oral function, and loss of facial form. Many of these problems can be eliminated with the use of osseointegrated implants to support fixed prostheses or removable overdentures. Methods for increasing bone volume to facilitate implant placement have been reported.[1] The most frequently used material for augmentation has been autogenous iliac and intraoral bone, and maintenance of autogenous bone in the maxillary sinus for 5 to 10 years has been reported.[2] However, complications such as reduction in the size of the bone graft[3,4] and long-lasting symptoms at the donor site have been reported.[5]

Alternative bone graft materials have been developed. A frequently used bone substitute material, Bio-Oss (Geistlich Söhne AG, Wolhusen, Switzerland), which is an anorganic bovine porous bone material, has been evaluated in several animal[6,7] and clinical studies.[8–10] However, further studies are needed to evaluate the long-term clinical outcome of this xenograft bone material.

The purpose of the present study was to describe the surgical technique and evaluate long-term clinical results with the use of Bio-Oss as a bone graft material to enable reconstruction with implant-supported suprastructures in severely resorbed alveolar bone.

MATERIALS AND METHODS

Patients

Seventy-one consecutive patients (mean age 60 ± 11 years, range 24 to 84 years) treated between 1989 and 1997 for advanced atrophy of the maxilla and/or the mandible were included in the study (Table 1). The patients demonstrated alveolar crest resorption that rendered implant placement impossible without bone transplantation. Four different sites were augmented: *(1)* alveolar crest width (CW), *(2)* alveolar crest height (CH), *(3)* antral cavity (SH), and *(4)* nasal cavity (NH). A total of 92 sites were augmented (Table 2). The proposed inclusion criteria were: *(1)* for augmentation of the antral and nasal

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Table 1 Patient Data at the Time of Bone Augmentation

	Patient age					
Sex	**≤ 40**	**41–50**	**51–60**	**61–70**	**> 70**	**Total**
Female	2	9	12	16	11	50
Male	2	2	9	5	3	21
Total	4	11	21	21	14	71

Table 2 No. and Location of Bone Augmentations

Site	No. of augmentations
Crest width	43
Crest height	10
Nasal cavity	3
Antral cavity	36
Total	92

cavities, availability of less than 4 mm and 6 mm of crestal bone height, respectively; *(2)* for maxillary crestal width augmentation, a crestal height of less than 7 mm at a crestal width of 4 mm; and *(3)* augmentation of crestal height needed to treat local bone loss.

Bone Augmentation

The graft material consisted of the following:

1. Autogenous bone (1.5 to 3 cm^3), taken subapically from the chin and cut into pieces (2 × 2 × 2 mm).
2. Bio-Oss, an anorganic bovine hydroxyapatite, which is available as spongiosa granules (diameter 0.25 to 1.0 mm). About 2 to 6 g were used in each patient.
3. Autogenous blood collected from the alveolar crest incision.
4. Tisseel Duo Quick (Immuno AG, Vienna, Austria) syringe No. 1 (Tisseel solution), which was stored at –20ºC and thawed in a 37°C water bath before use. The contents of syringe No. 1 were mixed with Bio-Oss (0.5 mL/g Bio-Oss), autogenous blood, and the bone chips, giving the mixture a plastic, moldable consistency.
5. Tisseel Duo Quick syringe No. 2 (thrombin solution), which was stored at –20°C and thawed at 37°C before use. The addition of thrombin gave the graft an elastic, hard consistency.

The above graft material was used for bone augmentation in 52 of the 71 patients. The remainder of the patients (n = 19) received the graft without autogenous bone.

At the time of the augmentation procedure, patients were given 500 mg of floxacillin (Heracillin, Astra, Södertälje, Sweden) and 500 mg × 4 of tinidazol (Fasigyn, Pfizer, New York, NY). One hour prior to surgery, the patients were given diazepam (0.5 mg/kg body weight) (Valium, Roche, Basel, Switzerland) and 1 mL of atropine (0.5 mg/mL; NM Pharma, Stockholm, Sweden) subcutaneously. Postoperatively, tinidazol (500 mg × 2) and floxacillin (500 mg × 3) were given for 8 and 9 days, respectively. When indicated after surgery, the patients were also given 500 to 1,000 mg of paracetamol (Alvedon, Astra; or Distalgesic, Eli Lilly, Indianapolis, IN) 3 to 4 times a day.

Harvest of Autogenous Chin Bone. After administration of local anesthesia (xylocaine adrenalin 2%; Astra) an incision was made in the mandible from the site of the right canine to the left canine and a mucoperiosteal flap was reflected. The bone was exposed, and about 1 × 3 × 1 cm of bone was removed subapical to the incisors using a fissure bur and an osteotome, leaving the lingual compact layer intact. The mucoperiosteal flap was sutured back in place, and the harvested bone was cut into pieces (approximately 2 × 2 × 2 mm each) with a bone-cutting forceps and stored at room temperature in sterile, physiologic saline solution until used.

Augmentation of the Antral and Nasal Cavities. After local anesthesia, an incision was made on the maxillary alveolar crest from the site of the right third molar to the left third molar, in combination with a vertical incision in the midline. A mucoperiosteal flap was reflected and the maxillary crest was exposed. Blood from the incision sites was collected and mixed with the Bio-Oss granules. After the addition of autogenous bone chips and the Tisseel solution (syringe No. 1), the bone graft was ready for use.

For augmentation of the maxillary sinus, the lateral wall of the antrum was exposed. A demarcation line was marked with an osteotome, and the thin cortex (approximately 1.5 × 1.5 cm) covering the antrum was carefully removed. The antral mucosa was lifted and the space created was filled with graft material.[11] The graft material was added layer by layer (2 to 3 mm each layer), and between each layer, drops of Tisseel thrombin solution (syringe No. 2) were added to give the graft a firm, rubber-like consistency. The caudal part of the antrum was augmented to a height of at least 13 mm from the top of the crest to the superior part of the graft. For augmentation of the

Table 3 No. of Placed and Failed Implants with Respect to Healing Time of Bone Graft

Time (mo.) between bone augmentation and implant placement	No. of implants placed	No. of implants failed
0	7	0
8	3	0
9	43	12
10	45	13
11	49	14
12	41	6
13	11	0
14	8	0
16	4	0
18	6	0
22	1	0
23	4	0
26	2	0
29	3	0
44	4	0
Total	231	45

Table 4 Different Implant Systems Used

Implant system	No. placed
Astra* (Mölndal, Sweden)	3
Cresco† (Lausanne, Switzerland)	4
IMZ‡ (Interpore, Irvine, CA)	4
Nobel Biocare† (Göteborg, Sweden)	66
Sterngold-ImplaMed† (Attleboro, MA)	111
Straumann‡ (Waldenburg, Switzerland)	21
Swede-vent† (Paragon, Encino, CA)	22
Total	231

*Ti-blasted surface (TioBlast).
†Machined surface.
‡Titanium plasma-sprayed surface.

nasal cavity, the nasal mucosa was lifted and the space was filled with graft material (as above) to a height of 13 mm from the top of the crest if possible.

Crest Augmentation. After exposure of the crest, small cavities (1 mm in diameter) were prepared extending from the cortical bone into the bone marrow for bone cells to penetrate the graft material. The graft was placed layer by layer as an onlay graft on the alveolar crest, with drops of Tisseel thrombin solution placed between each layer. The wounds were sutured with Vicryl 4-0 (Ethicon/Johnson & Johnson, New Brunswick, NJ).

After bone augmentation, the patients did not wear a removable prosthesis for 2 weeks. Before use, the prosthesis was relined with a soft tissue conditioner. After another 2-week period, the prostheses were relined with Vertex Soft NF (Dentimex BV, Zeist, The Netherlands).

After a mean healing period of 11.9 months, the results of bone augmentation were examined both clinically and radiographically. The clinical examination included recording of any pain and/or swelling. Radiographically, bone healing was evaluated by panoramic radiography (Kodak T-MAT G, Rochester, NY). The authors examined apposition of the bone graft to alveolar bone and the radiopacity and radiolucency of the implanted bone. Augmentation of alveolar crest width could not be evaluated radiographically. In these cases, tomography was used for evaluation.

Implant Placement

Implants were placed in the augmented bone after a mean healing period of 11.9 months (range, 0 to 44 months) (Table 3). Three patients had 7 implants placed simultaneously with augmentation using Bio-Oss for repair of local bone destruction. In some situations, patients hesitated to have implants placed; hence, the time between bone augmentation and implant placement was prolonged compared to the original protocol, which was 11 months.

The implant systems used in the present study are shown in Table 4. In most patients (88%), implants with a machined surface were placed. The most frequently used implant lengths were 10, 13, and 15 mm.

One hour prior to implant placement, the patients were given 0.5 mg/kg body weight of diazepam (Valium) and 1 mL of atropine (NM Pharma) subcutaneously, as described previously, in combination with phenoximethylpenicillin (Calciopen, 2 g × 2; Astra), which was subsequently prescribed for 10 days. The implants were placed under local anesthesia (xylocaine adrenalin; Astra) using the standard 2-stage technique. When indicated, the patients were given paracetamol postoperatively, as previously described.

Prosthetic Treatment

Fourteen days after surgery, the prostheses were relined, as described previously. After a healing period of 6 months (maxilla) and 3 months (mandible), implant-supported dentures were fabricated using such techniques as considered appropriate for the conditions presented. The distribution of the different types of prostheses was as follows: 39 fixed prostheses, 6 single-tooth replacements, and 16 overdentures.

Follow-up

The patients were examined clinically every 6 months for the first 2 years after implant placement and annually thereafter. The clinical examinations included recording of complications according to Albrektsson et al.[12] Bone resorption and osseointegration of the implants were evaluated using postoperative radiographs.

Radigraphic Evaluation. The marginal bone levels were evaluated by intraoral radiographs exposed to a standardized parallel technique on 3 occasions: at the time of prosthesis connection, 1 year after loading, and 3 years after loading of the implants. The same reference level for measurement of the marginal bone level was used for all 3 occasions. Isometric projection was a prerequisite for registration of results. Measurement of bone levels was done using a millimeter ruler, and changes in the bone level over time were calculated. Each millimeter measured as a difference in the amount of attached marginal bone was registered as 1 unit of difference. A total of 83 implants in 27 patients were considered. A number of implants were excluded because of missing or non–ideally projected radiographs.

RESULTS

Of the 71 augmented patients, 61 had implants placed. Dropout was related to the following factors: 1 patient died before implant placement, 1 patient showed severe resorption of the augmented bone, 5 patients did not want to continue treatment, 2 patients showed resorption of the graft because of postoperative infection, and 1 patient was treated for a keratocyst.

Irrespective of follow-up time, treatment was regarded as successful for 54 of the 61 patients, as these patients were wearing implant-supported prostheses according to treatment plan at the last follow-up visit. Treatment was regarded as a failure in 7 patients; of these, 5 had received removable prostheses because of implant failure and 2 others needed a second operation to replace failed implants.

A total of 231 implants were placed in the 61 consecutive patients. Figure 1 indicates the time of implant loading, which varied between 12 and 113 months. The prosthesis in function for 113 months represents a patient who received simultaneous augmentation for local bone loss and implant placement. Calculated from the time of implant placement, a total of 45 implants were lost, which resulted in a survival rate of 80.5% for the individual implants. As shown in Fig 1, 34 implants were lost prior to or at the time of abutment connection. After prosthesis placement, 11 of the remaining 197 implants (5.6%) were lost. Of these, the majority (8 implants) were lost shortly after loading; only 3 implants were lost after more than 12 months of loading. As shown in Fig 1, 100 implants were loaded for 12 to 60 months, and the rest (86 implants) were loaded for more than 60 months.

Evaluation of the results for implants placed in the 4 different graft locations showed varying results (Table 5). All implants placed in the grafted nasal cavity and about 33.3% of the implants placed after augmentation of the alveolar crest height were lost. Alveolar crest width and the antral cavity were the most frequent sites for bone augmentation, and the survival rates for implants in these sites were 84.1% and 82.7%, respectively (Table 5).

It has previously been reported that Bio-Oss seems to be well incorporated into surrounding tissues, and radiographic evaluation showed that the material was not resorbed after 44 months.[13] Similarly, Figs 2a to 2c show a representative patient with a severely resorbed alveolar crest who met the inclusion criteria for the present study. Augmentation of the antral cavity with Bio-Oss made implant placement possible at this site, and the implants were maintained in the grafted bone after 4 years of loading (Figs 2a to 2c).

Data regarding the failed implants are shown in Table 6. Patients with implant failure often lost more than 1 implant. All but 1 of the patients shown in Table 6 received a graft that included autogenous bone. In the absence of autogenous bone, an implant survival rate of 92.2% was calculated, versus 77.2% for grafts that included autogenous bone. Irrespective of the augmentation site, the time of bone healing between bone augmentation and implant placement seemed important for the result. As shown in Table 3, no implants were lost when bone healing time was prolonged for more than 12 months; this was longer than the original study protocol called for (ie, 11 months). Evaluation of smoking habits showed that 7 of the 13 patients (54%) who lost implants were smokers, versus 13 of the 48 patients (27.1%) without implant failure.

Changes in marginal bone levels over time are shown in Table 7. From the time of prosthesis connection to 1 year after loading, the marginal bone level was reduced by less than 1 mm for 90% of implants and between 1 and 2 mm for 5% of the implants. Advanced reduction in the bone level was observed around 2 of the 39 implants. Measurements after 3 years of loading showed a bone level reduction of less than 1 mm for 82% of implants and of 1 to 2 mm for 11% of implants. The marginal bone level was reduced by 2 to 3 mm around 1 of the 38

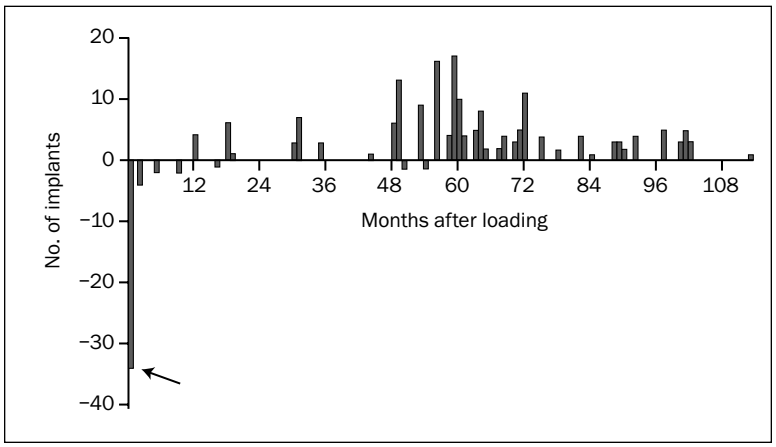

Fig 1 Graph showing time since loading of individual implants (time zero) in relation to implant failure. Values above the x-axis indicate the time of loading of the individual implants. Values below the x-axis indicate the number and time of implant failures. The implants lost prior to or at abutment connection are shown on the y-axis *(arrow)*.

Table 5 Distribution of Implant Survival and Failure with Respect to Graft Location

	Crest width		Crest height		Antral cavity		Nasal cavity	
Outcome	No. of patients	No. of implants	No. of patients	No. of implants	No. of patients	No. of implants	No. of patients	No. of implants
Survival	34	90	4	10	23	86	0	0
Failure	5	17	2	5	7	18	3	5
Total	39	107	6	15	30	104	3	5

implants. After 3 years of loading, 1 implant was lost, and around another implant, marginal bone level reduction of between 8 and 9 mm was observed.

DISCUSSION

The present study represents a preliminary evaluation of a bone augmentation technique that has been used in the Clinic of Oral and Maxillofacial Surgery, Saltsjöbaden, Sweden, for more than 9 years. Seventy-one consecutive patients demonstrating severe atrophy of the alveolar crest were included.

Bio-Oss is derived from bovine bone processed to yield natural bone material without the organic component. Bio-Oss has been reported to have good tissue acceptance and to provide a scaffold for new bone deposition with natural osteotrophic properties.[14] In a previous study, histologic examination of the present material showed long-term bone regeneration around the Bio-Oss particles.[13] A comparative histologic study of Bio-Oss and autogenous bone grafts in rabbits showed that implanted autogenous bone was actively resorbed and new bone was formed, whereas bone formation was observed adjacent to the anorganic bone particles without signs of bone resorption.[15] The collected information poses the question of whether Bio-Oss should be regarded as a resorbable material, which has previously been described.[16]

For most applications, Bio-Oss was mixed with autogenous bone harvested from the chin. The rationale behind the inclusion of autogenous bone was to add bone growth factors to improve osseointegration of the graft. However, when enough bone was not available from this site, autogenous bone was not used. A preliminary evaluation indicated that the absence of autogenous bone did not seem to negatively affect the treatment results. Consequently, autogenous bone has been excluded from the graft mixture for recent treatment in the clinic, thereby eliminating eventual problems with symptoms from this donor site. The importance of adding autogenous bone to the graft mixture is unclear and needs future evaluation. As indicated in the inclusion criteria, although the implants were placed in the Bio-Oss graft, autogenous crestal bone was involved in varying degrees with maintenance of the implants. Primary stabilization was obtained, even when the implants were placed mainly in the Bio-Oss bone.

When the present augmentation method was first introduced, problems with wound dehiscence arose during the first 2 weeks after augmentation. This problem was later avoided by using a more spacious

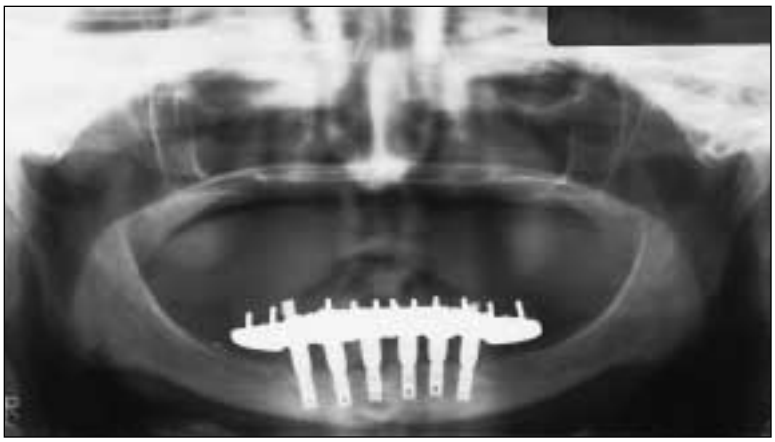

Fig 2a Panoramic radiograph of an atrophic alveolar crest.

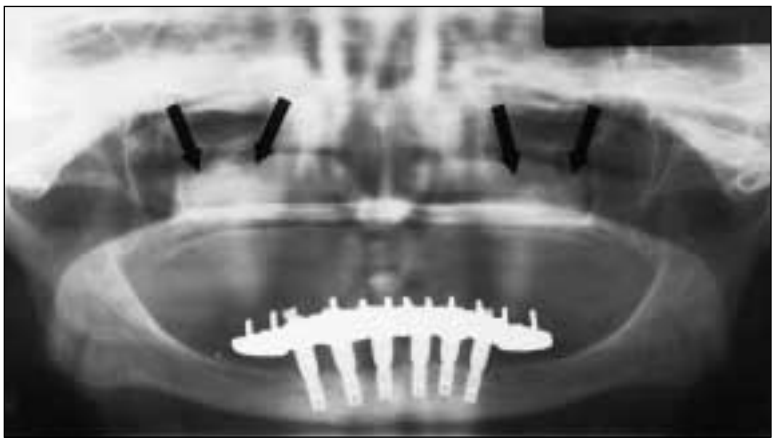

Fig 2b Same patient after augmentation of the antral cavity with Bio-Oss. The graft material seems to be well incorporated into the surrounding tissue *(arrows).*

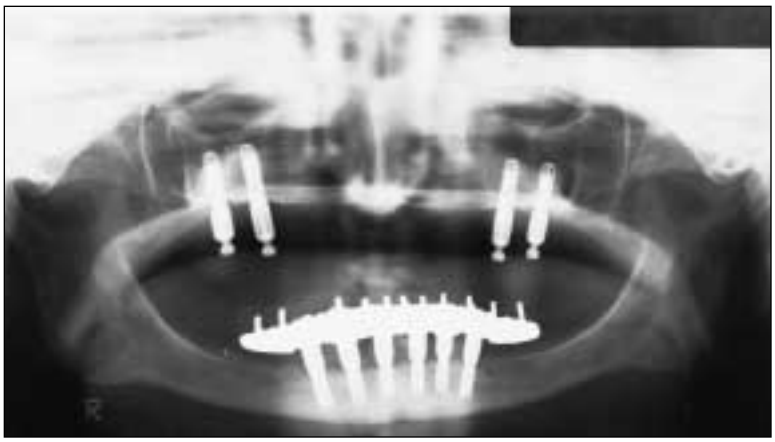

Fig 2c Same patient after 4 years of loading of implants placed in the grafted area.

Table 6 Evaluation of Implant Failures with Respect to Patient Sex, Age, Smoking Habits, Graft Type, and Augmentation Site

Sex	Age	No. of implants lost	Type of graft*	Augmentation site†	Smoker‡
F	58	3	ABT	SH	Yes
M	56	2	ABT	CH	Yes
F	62	5	ABT	CH+NH	Yes
M	38	1	ABT	SH	Yes
M	54	3	ABT	SH	Yes
F	72	6	ABT	CW+SH	No
F	70	1	ABT	SH	No
F	54	4	ABT	SH	Yes
M	63	6	ABT	NH+CW	No
M	51	3	ABT	CW+SH+NH	Yes
M	55	1	ABT	SH	No
M	51	6	ABT	CW	No
F	61	4	BT	CW	No

*ABT = graft containing autogenous bone; BT = graft without autogenous bone.
†CH = crest height; CW = crest width, NH = nasal cavity, SH = antral cavity.
‡More than 10 cigarettes per day.

Table 7 Marginal Bone Reduction (mm) Seen During the Observation Periods 0 to 1 Year and 0 to 3 Years After Loading

	Marginal bone reduction (mm)*							
Time	0 to < 1	1 to < 2	2 to < 3	6 to < 7	8 to < 9	> 10	Implants lost	Total
Year 0 to 1	35	2	0	1	0	1	0	39
Years 0 to 3	31	4	1	0	1	0	1	38

*Expressed as number of implants with amount of bone loss.

Rehmann plastic surgical procedure (ie, cutting the periosteum horizontally to make the mucoperiosteal flap cover the graft material). The dehiscence healed secondarily and had no effect on the final result. In 4 patients, postoperative infection was recorded. These were treated with antibiotics and healed uneventfully.

Initially, a healing period for the Bio-Oss graft of approximately 11 months before implant placement was prescribed. Earlier implant placement (6 months) after sinus elevation has been described in the literature.[8,9] Simultaneous grafting of the sinus and implant placement has been reported when 4 mm of crestal bone was present and when primary stabilization could be obtained.[10] Evaluation of the present results indicated that a healing period longer than 12 months could be advantageous under the present conditions. A comparative animal study also indicated that delayed implant placement in combination with sinus augmentation seemed to be preferable.[17]

Evaluation of the results of augmentation of the nasal cavity and alveolar crest height indicated a high probability of implant failure when these sites were involved. The survival rate of implants placed in augmented sinuses in the present study was in line with or somewhat lower than what has previously been reported in the literature.[10,18] One contributing factor to the difference in results could be the proposed inclusion criteria. These results, however, indicated the importance of long-term, systematic follow-up of the treatment. Less has been published concerning the long-term success of implant placement after augmentation of the alveolar crest width. However, the results of the present study showed good predictability for the use of Bio-Oss in this application.

The results showed an overrepresentation of smokers in the group of patients who lost 1 or more implants. This is in agreement with a previous study, which also pointed to smoking as a contributing factor to implant failure.[19] No correlation

between implant length and implant failure was observed in the present study.

Most implants (88%) used in the present study were screw-type implants with a machined surface. In contrast to a previous report indicating that an enlarged surface area is preferable in combination with bone grafts,[8] the present study showed good results with the machined-surface screw-type implants. Similarly, when autogenous bone was used as a graft, screw-type implants with a machined surface have proved effective.[20] The time of bone healing before implant placement may be important, as new bone formation with the Bio-Oss particles is essential for the osseointegration of implants.[9]

The patients included in the present study will be continuously followed over time and their treatment evaluated. After between 4 and 6.5 years of functional loading, fixed prostheses were removed and the stability of 32 individual implants in 15 patients was examined with the Periotest (Siemens, Bensheim, Germany). The results indicated that the implants are clinically stable. These results will be presented and evaluated in detail in a separate study.

CONCLUSION

The present study showed the efficacy of using Bio-Oss for the augmentation of severely resorbed alveolar crests in treating patients with implant-supported prostheses. The results indicated that a healing time of grafted bone of more than 12 months before implant placement may be advantageous under the present conditions. The results also indicated that autogenous bone may be excluded from the Bio-Oss mixture, thereby eliminating potential problems with the donor site. The present study has shown screw-type implants with a machined surface to be effective in combination with bone augmentation using a Bio-Oss/Tisseel mixture.

ACKNOWLEDGMENTS

This study was funded by support from Sterngold, Attleboro, MA, USA.

REFERENCES

1. Garg AK. Augmentation grafting of the maxillary sinus for placement of dental implants: Anatomy, physiology, and procedures. Implant Dent 1999;8:36–46.
2. Block MS, Kent JN, Kallukaran FU, Thunthy K, Weinberg R. Bone maintenance 5 to 10 years after sinus grafting. J Oral Maxillofac Surg 1998;56:706–714.
3. Breine U, Brånemark P-I. Reconstruction of alveolar jaw bone. An experimental and clinical study of immediate and preformed autologous bone graft in combination with osseointegrated implants. Scand J Plast Reconstr Surg 1980;14:23–48.
4. Burchardt H. The biology of bone graft repair. Clin Orthop 1983;174:28–42.
5. Van der Wal KG, de Visscher JG, Stoelinga PJ. The autogenous inner table iliac bone graft. A review of 100 patients. J Maxillofac Surg 1986;14:22–25.
6. Pinholt EM, Bang G, Haanaes HR. Alveolar ridge augmentation in rats by Bio-Oss. Scand J Dent Res 1991;99:154–161.
7. Jensen SS, Aaboe M, Pinholt EM, Hjørting-Hansen E, Melsen F, Ruyter IE, Nat R. Tissue reaction and material characteristics of four bone substitutes. Int J Oral Maxillofac Implants 1996;11:55–66.
8. Valentini P, Abensur D. Maxillary sinus floor elevation for implant placement with demineralized freeze-dried bone and bovine bone (Bio-Oss): A clinical study of 20 patients. Int J Periodontics Restorative Dent 1997;17:233–241.
9. 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. A human case report. Clin Oral Implants Res 1998;9:59–64.
10. Hürzeler MB, Kirsch A, Ackermann K-L, Quiñones 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.
11. Boyne PJ, James RA. Grafting of the maxillary sinus floor with autogenous marrow and bone. J Oral Surg 1980;38: 613–616.
12. Albrektsson T, Dahl E, Enbom L, Engevall S, Engquist B, Eriksson AR, et al. Osseointegrated oral implants. A Swedish multicenter study of 8139 consecutively inserted Nobelpharma implants. J Periodontol 1988;59:287–300.
13. Skoglund A, Hising P, Young C. A clinical and histologic examination in humans of the osseous response to implanted natural bone mineral. Int J Oral Maxillofac Implants 1997; 12:194–199.
14. Aichelmann-Reidy ME, Yukna RA. Bone replacement grafts. Dent Clin North Am 1998;42:491–503.
15. Young C, Sandstedt P, Skoglund A. A comparative study of anorganic xenogenic bone and autogenous bone implants for bone regeneration in rabbits. Int J Oral Maxillofac Implants 1999;14:72–76.
16. Klinge B, Alberius P, Isaksson S, Jönsson J. Osseous response to implanted natural bone mineral and synthetic hydroxylapatite ceramic in the repair of experimental skull bone defects. J Oral Maxillofac Surg 1992;50:241–249.
17. Hürzeler MB, Quiñones CR, Kirsch A, Gloker C, Schüpbach P, Strub JR, Caffesse RG. Maxillary sinus augmentation using different grafting materials and dental implants in monkeys. Part I. Evaluation of anorganic bovine-derived bone matrix. Clin Oral Implants Res 1997;8:476–486.
18. Fugazzotto PA, Vlassis J. Long-term success of sinus augmentation using various surgical approaches and grafting materials. Int J Oral Maxillofac Implants 1998;13:52–58.
19. Jones JD, Saigusa M, Van Sickels JE, Tiner BD, Gardner WA. Clinical evaluation of hydroxyapatite-coated titanium plasma-sprayed and titanium plasma-sprayed cylinder dental implants. A preliminary report. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1997;84:137–141.
20. Raghoebar GM. Augmentation of the maxillary sinus floor with autogenous bone for the placement of endosseous implants. J Oral Maxillofac Surg 1993;51:1198–1203.