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# Histologic Analysis of Clinically Retrieved Titanium Microimplants Placed in Conjunction with Maxillary Sinus Floor Augmentation

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In this study, a new approach involving placement and subsequent retrieval of titanium microimplants was employed for the histologic investigation of the implant-tissue interface in conjunction with maxillary sinus floor augmentation. Nine patients scheduled for sinus floor augmentation and simultaneous placement of Brånemark implants were included in the study. After a sinus graft procedure and placement of implants, an additional microimplant was placed into the graft through the lateral wall of the sinus. At abutment connection, the microimplants were retrieved using a 3- or 5-mm-wide trephine drill. Six specimens were retrieved after 6 to 14 months from sites augmented with particulate radiated mineralized cancellous allograft. Another six implants were retrieved after 6 to 12 months from maxillary sinuses augmented with particulate autogenous bone grafts. The histologic analysis showed distinct differences between the two types of grafts. The sites with autogenous bone grafts displayed a normal morphology of bone and bone marrow, including formation of bone on the surfaces of the grafted particles and remodeling of newly formed as well as grafted bone. The bone was more mature after 11 to 14 months than at 6 months. The allografted sites had a mixed morphologic appearance of newly formed bone and nonviable allograft particles (about 75% of the total bone area) in loose connective tissue. Significantly more bone was found at the autografted than at the allografted implants. The use of autogenous bone for augmentation of the maxillary sinus floor resulted in a greater amount of viable bone surrounding the implant; however, simultaneous placement of implants apparently resulted in a low proportion of bone-implant contact after 6 to 14 months irrespective of graft type.

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**Key words:** allograft, autograft, histology, osseointegration, sinus floor augmentation, titanium oral implants

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Maxillary sinus bone graft augmentation is commonly used to increase the load-bearing bone volume available for posteriorly placed oral implants. Of the numerous grafting regimens that have been described, the use of simultaneous placement of graft material and implants has been advocated.<sup>1-8</sup> In spite of the generally favorable clinical results reported, it is not known to what extent the achieved implant sta-

bility is the result of integration of the implants in the graft material. In fact, the clinical results may be determined primarily by the amount of residual alveolar bone that supports the implants.<sup>5,9</sup> Although clinical and radiographic parameters such as implant stability and absence of peri-implant radiolucency can be used to study the treatment outcome, it is only in histologic sections of the bone-implant interface that tissue response and the degree of osseointegration can be analyzed. A number of studies present histology of human biopsies from the maxillary sinus after augmentation with various materials.<sup>5,10-13</sup> However, except for some case reports,<sup>14,15</sup> no clinical studies have been presented that include histology of the tissue-implant interface from consecutive patients to verify that osseointegration of the implant occurs in the grafted material.

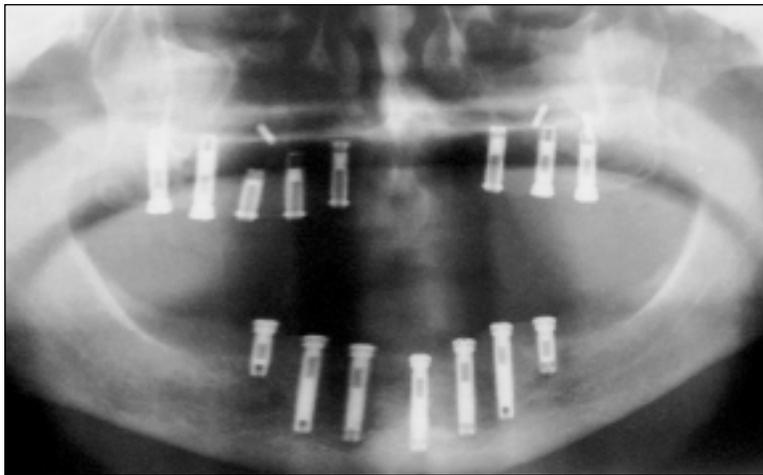
The present study used a new approach involving the placement and subsequent retrieval of 2-mm-

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**Fig 1** Radiograph showing one microimplant in each maxillary sinus as well as conventional implants.

wide and 6-mm-long commercially pure titanium implants to histologically study the titanium-graft interface in maxillary sinus floor augmentation using allograft or autogenous bone grafts.

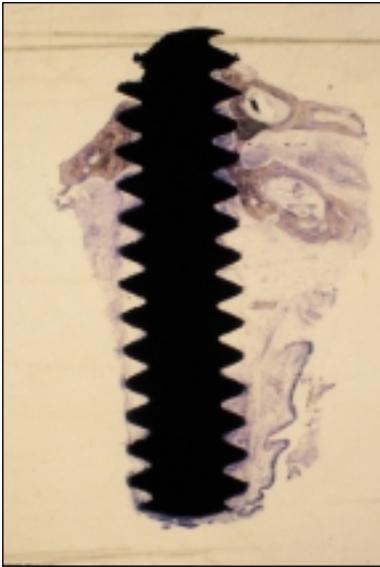
### Materials and Methods

**Patients and Surgery.** Nine patients, 6 females and 3 males ranging in age from 36 to 57 years, all of whom were referred to one clinic (Denver, Colorado) for implant treatment in the posterior maxilla, participated in the study. The patients were candidates for unilateral (six patients) and bilateral (three patients) maxillary sinus augmentation because of lack of bone for the placement of Brånemark system implants (Nobel Biocare, Gothenburg, Sweden) as determined by computerized tomography. According to the site classification by Jensen,<sup>16</sup> all patients belonged to Class C, ie, 4 to 6 mm of bone was available for implant stabilization. None of the patients showed any signs of sinus or intraoral disease at the time of maxillary sinus augmentation. The patients had been edentulous in the regions under consideration for at least 1 year. After being informed about the study, all patients signed a consent form.

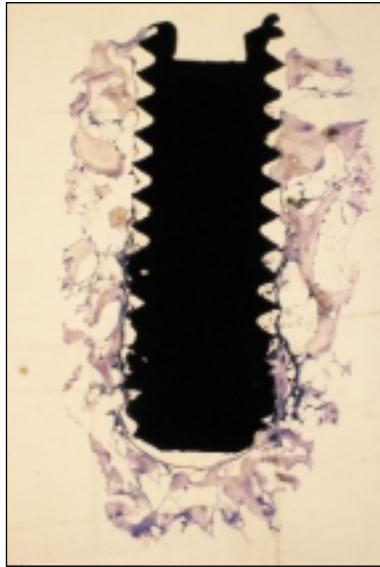
All patients underwent surgical procedures under general anesthesia as described elsewhere in detail.<sup>5</sup> In brief, a lateral maxillary sinus osteotomy with infraction was performed, combined with freeing of the sinus membrane to create a subsinus cavity in which graft material and implants could be placed. The implant sites were prepared according to the treatment guidelines for the Brånemark system, and 13- to 15-mm-long implants were placed so that they protruded into the sinuses. Two types of graft material were used: (1) radiated mineralized cancellous allograft (RMCA) (Rocky Mountain Tissue Bank,

Denver, CO) (six sites), and (2) iliac cancellous auto-graft (six sites). Both types of graft material were morselized by hand into small particles using a bone-cutting scissor and then tamped into place in the floor of the antrum around the implants. In each sinus subjected to grafting, a titanium microimplant (2 mm wide and 6 mm long;  $n = 12$ ) was placed into the graft material via the lateral bone wall (Fig 1). Preparation for placement of the test implant was made with a 1.8-mm-round bur under saline irrigation. The test implant was then self-tapped into place with a small screwdriver. The lateral bone walls were typically 1 to 2 mm thick, while the test implants intruded 4 to 5 mm into the sinuses. An expanded polytetrafluoroethylene (e-PTFE) membrane (GTAM, W.L. Gore & Associates, Flagstaff, AZ) was then placed over the osteotomy site. The wound was closed primarily using 4-0 chromic suture. Amoxicillin was administered 1 hour preoperatively and 10 days postoperatively at a dose of 500 mg. The patients were also placed on chlorhexidine rinses twice a day, and were instructed to eat liquid or soft diet and not to blow their nose for 10 days after surgery.

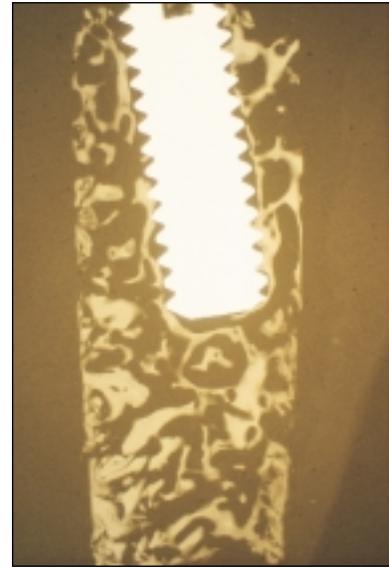
Six to 14 months after placement of bone graft and implants, the treatment area was exposed and the membranes were removed. All implants were clinically stable and healing abutments were connected to the implants. At the time of this report, the implants have served as anchorage to seven fixed prostheses for at least 24 months with no implant failures. All 12 microimplants were found to be clinically firm. The microimplants were removed with the surrounding bone using a 3- or 5-mm trephine drill. The retrieved test implants and surrounding tissues were immediately fixed by immersion in 4% buffered formalin solution.



**Fig 2a** Light micrograph showing an allograft specimen after 6 months. Some bone-implant contact is evident in the cortical wall of the maxillary sinus. However, most of the implant is encapsulated by a fibrous connective tissue that originates from the sinus mucosa (magnification  $\times 16$ ).



**Fig 2b** Light micrograph showing an allograft specimen after 6 months. The implant is surrounded by bone that seems to originate from the sinus wall as well as some atypical bone formation at the apical part. Loose connective tissue and fat cells are also visible. Most of the implant is not in contact with bone ( $\times 16$ ).



**Fig 2c** Microradiograph showing an allograft specimen after 6 months. Extensive amounts of trabecular bone are seen in the specimen; however, only a few sites are in contact with the bone ( $\times 16$ ).

**Specimen Processing and Analysis.** The fixed specimens were dehydrated in a graded series of ethanol and embedded in plastic resin (Technovit 7200 VCL, Kulzer, Wehrlein, Germany). Sections were cut and ground to a thickness of approximately  $150\ \mu\text{m}$  by means of Exakt cutting and grinding equipment (Exakt Apparatebau, Norderstedt, Germany). The sections were microradiographed using Kodak High Resolution Plates, type 1A, and a Machlett OEG-50 x-ray tube (Machlett Laboratories, Stamford, CT). The plates were exposed to radiation of 17.5 kV, 20 mA and 20 minutes, and processed in Kodak D-19 developer for 5 minutes at  $20^\circ\text{C}$ . The ground sections were then further ground to a thickness of about  $10\ \mu\text{m}$  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 (Ernst Leitz Wetzlar, Wetzlar, Germany) connected to an IBM PC. The morphometric measurements comprised: (1) the amount of bone occupying the area of all implant threads (percentage bone area); (2) the amount of bone occupying the area of the threads in the augmented sinus (percentage bone area); (3) the degree of bone-implant contact in all implant threads (per-

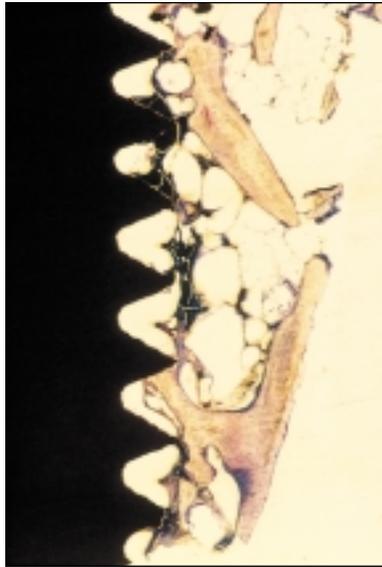
centage bone contact); and (4) the degree of bone-implant contact in the implant threads in the augmented sinus (percentage bone contact).

**Statistical Analysis.** Wilcoxon's signed rank test was used for statistical analyses, and a statistically significant difference was considered if  $P < .05$ .

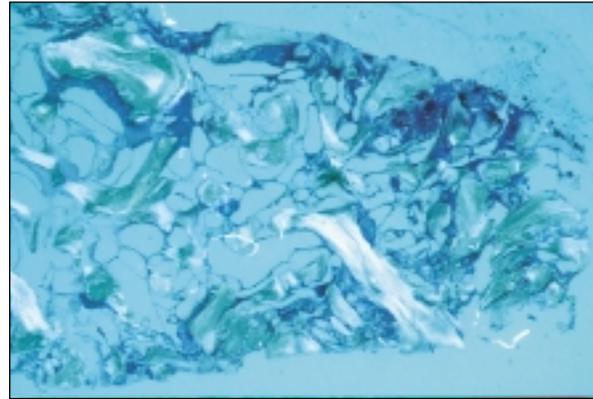
## Results

The histologic analysis showed the presence of varying degrees of bone in all specimens. In general, normal bone formation and remodeling had occurred in the autograft specimens, while a mixed morphologic picture of nonviable bone particles and connective tissue and minor bone formation was evident in the allograft specimens.

**Implants in Irradiated Mineralized Cancellous Allograft.** In the five allografted patients followed for 6 months, varying amounts of bone/allograft were present in connective tissue containing large vessels and fat cells, ranging from none (one patient, Fig 2a), to sparse (two patients, Fig 2b), to considerable (two patients, Fig 2c). In most areas along the implant surface, loose connective tissue was observed (Fig 3). About 50 to 75% of the bone in the grafted area represented nonviable allograft par-

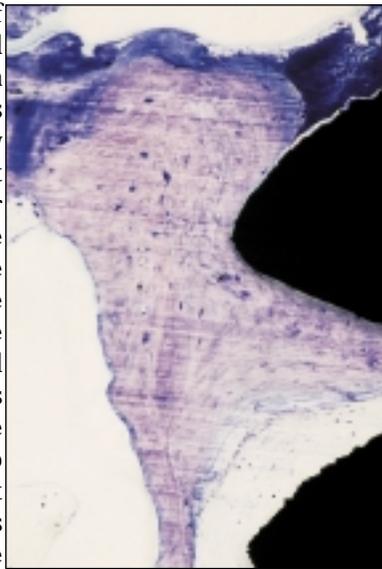


**Fig 3** Light micrograph showing the interface region of an allograft specimen after 6 months. An admixture of vital and nonvital bone embedded in loose connective tissue is seen. Except for part of one thread, no direct bone-implant contact can be observed ( $\times 40$ ).



**Fig 4** Polarized light micrograph of a detail of the allograft specimen shown in Fig 2c. A mixture of mostly nonvital allograft particles is embedded in loose connective tissue ( $\times 100$ ).

ticles, some of which showed bone formation on their surfaces but the majority of which did not (Fig 4). No or only negligible amounts of bone were found in the threads of three implants, and some bone was found in the remaining two specimens. Most of the bone was found where the implant penetrated the sinus



**Fig 5** Light micrograph of an allograft specimen after 6 months demonstrating direct bone-implant contact in the wall of the maxillary sinus ( $\times 100$ ).

Some bone-implant contact was observed in the cortical wall of the maxillary sinus in these specimens (Fig 5), but almost no contact was seen in the part with the graft (Figs 2 to 5). Newly formed viable bone found in some specimens in the grafted area seemed to have

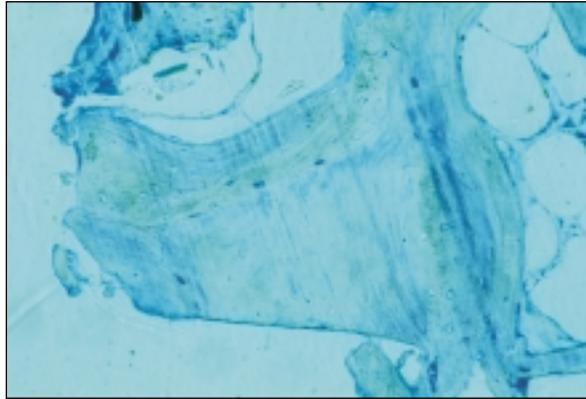
originated from the lateral sinus wall and to have migrated along the implant surface (Fig 2b).

In the allograft patient followed for 14 months, formation of lamellar bone at the surface of the nonviable allograft particles was evident (Figs 6 and 7). Nonviable allograft particles showed some signs of resorption, but were still present and constituted about 50% of the total bone area. An apparently normal bone marrow consisting of loose cell-rich connective tissue with vessels was present in the intr trabecular space. Although a large amount of bone was present outside the implant, a low proportion of bone-implant contact was observed within the threads of the implant in the grafted area, and most contacts were seen in the original bone of the lateral sinus wall (Fig 6).

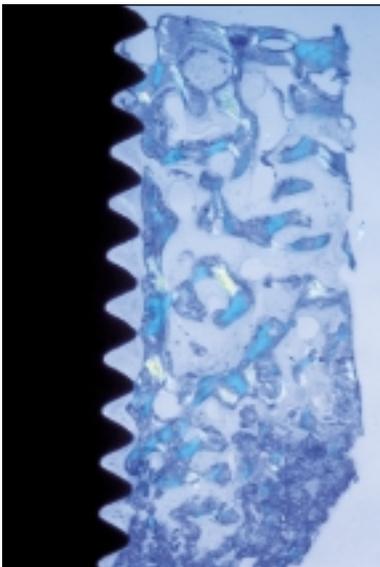
**Implants in Autogenous Bone Graft.** In the autograft patients followed for 6 to 7 months, viable trabecular lamellar bone with interspersed normal marrow tissue was observed (Fig 8). The grafted bone particles showed signs of resorption and active bone formation on their surfaces. The grafted particles constituted about 25% of the total bone area. The implant threads had a greater proportion of newly formed bone than the allografted sinuses. However, except for in the cortical wall, bone was only occasionally found to be in direct contact with the implant surface (Fig 9).



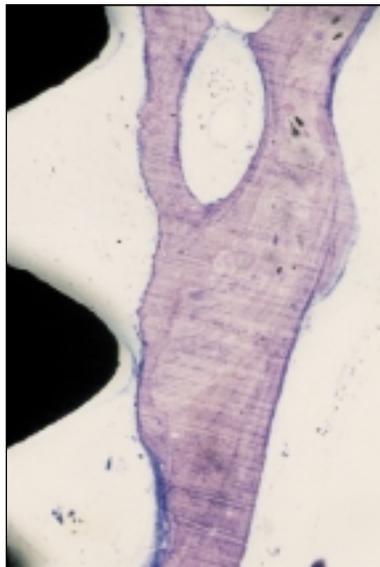
**Fig 6** Microradiograph of an allograft specimen after 14 months. The bone surrounding the implant is more dense than the specimens that have spent a shorter time healing. However, except in the cortical wall, the proportion of bone-implant contact is low ( $\times 16$ ).



**Fig 7** Light micrograph of an allograft specimen after 14 months showing bone formation and encapsulation of an allograft particle ( $\times 250$ ).



**Fig 8 (Left)** Polarized light micrograph of an autograft specimen after 6 months. The implant is surrounded by bone and bone marrow with a normal morphology. Few contacts between the bone and the implant surface can be seen ( $\times 40$ ).

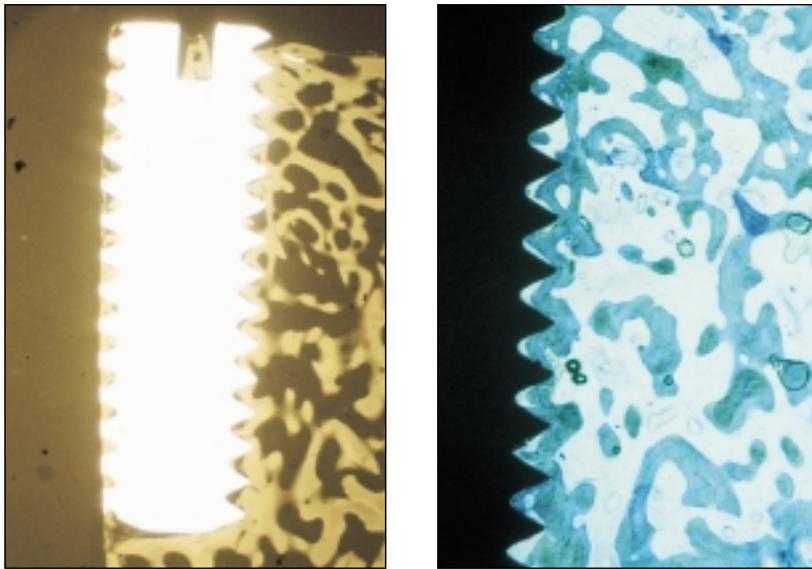


**Fig 9 (Right)** Light micrograph of an autograft specimen after 6 months. A grafted bone particle has been incorporated with newly formed bone ( $\times 100$ ).

The two autograft specimens followed for 11 and 12 months, respectively, showed a more mature bone morphology than the 6- to 7-month specimens (Fig 10). The bone was denser but still trabeculated. It was not possible to distinguish between the newly formed and remodeled bone and the grafted bone particles, which seemed to have been fully incorpo-

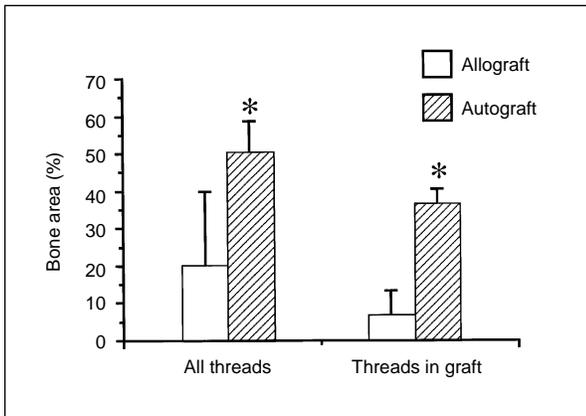
rated and replaced by newly formed bone (Fig 11). The proportion of bone-implant contact and the amount of bone found in the implant threads was high in the 12-month specimens and lower in the 11-month specimens.

**Morphometric Measurements.** Considerably more bone, in amounts that were statistically signifi-

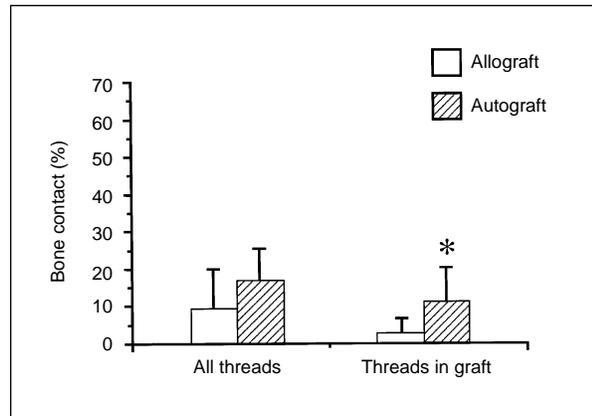


**Fig 10** (Left) Microradiograph of an autograft specimen after 12 months. A large portion of the implant seems to be in contact with mature trabecular bone ( $\times 16$ ).

**Fig 11** (Right) Light micrograph of the specimen shown in Fig 10. The bone is more mature as compared to the 6-month specimens ( $\times 16$ ).



**Fig 12** Results of the morphometric measurements of bone area in implant threads (mean  $\pm$  SD; asterisk = statistically significant difference;  $P < .05$ ).



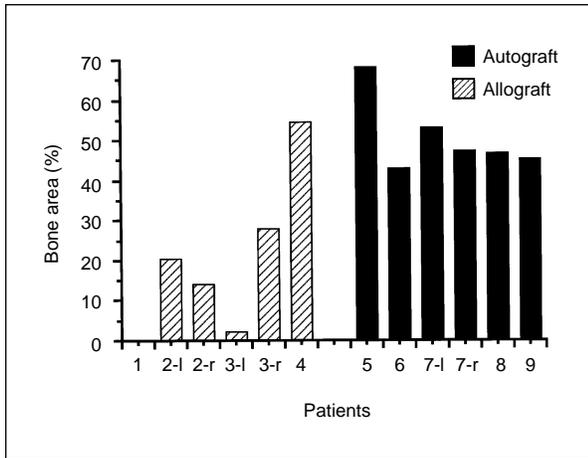
**Fig 13** Results of the morphometric measurements of bone-implant contact (mean  $\pm$  SD; asterisk = statistically significant difference;  $P < .05$ ).

cant, was found in the implant threads of the implants placed with autogenous bone (Fig 12). Regarding the extent of bone-implant contact, there was a significantly greater amount for the implants placed with autogenous bone, but only for the threads in the graft (Fig 13). Figures 14 to 17 show the amount of bone and proportion of bone-implant contact for the different specimens.

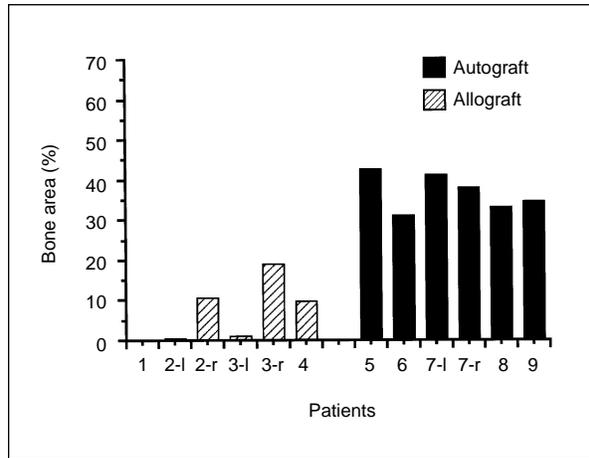
**Discussion**

In this study it was shown that the use of titanium microimplants, placed into the human maxillary sinus at the time of bone grafting and retrieved 6 to 14

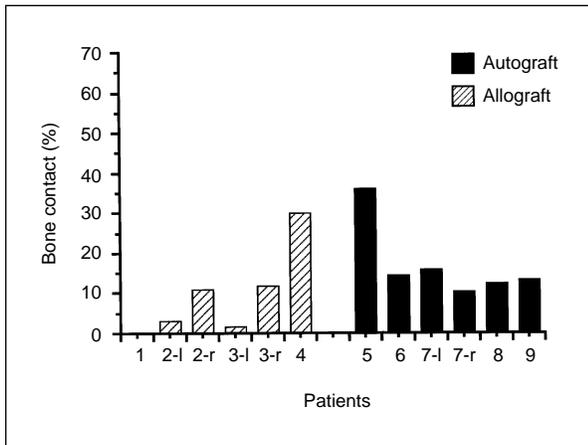
months later, constituted a useful model for the histologic evaluation of the sinus graft-implant interface. The procedure did not interfere with the ordinary implant treatment and sinus floor augmentation procedure. No complications related to the microimplants were experienced. This suggests that microimplants may be used in other situations to obtain well-controlled specimens for histologic evaluation of the human tissue-implant interface. The microimplants were not placed in exactly the same orientation as those placed for masticatory function, which may have influenced the results in the present study. It is possible that if the bottom of the sinus floor had been involved and present in the biopsies, more



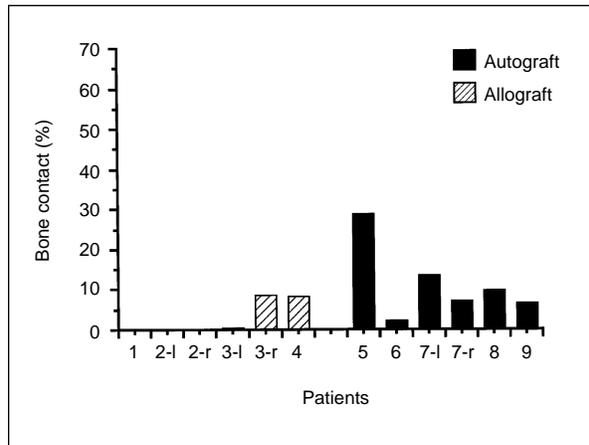
**Fig 14** Results of the morphometric measurements of bone area in all implant threads for the different specimens. The specimens in patients 4, 5, and 6 were observed for a period of 11 to 14 months, while all other specimens were observed for 6 to 7 months.



**Fig 15** Results of the morphometric measurements of bone area in implant threads in the grafted sinus for the different specimens.



**Fig 16** Results of the morphometric measurements of bone-implant contact in all threads for the different specimens.



**Fig 17** Results of the morphometric measurements of bone-implant contact in threads in the grafted sinus for the different specimens.

bone could have been found because of compaction of the graft in the axial direction. However, care was taken to make sure that the microimplants were well within the graft.

The present study revealed a very low, or no, degree of osseointegration of the microimplants in the allografted sinuses. Nonetheless, all root-form implants placed in the present study were clinically stable at the time of abutment connection and remained so after more than 2 years of functional loading. This lasting stability can be attributed to the support of the residual crestal bone, which in most cases was about 5 mm. As has been shown by Jensen and Greer,<sup>5</sup> there appears to be a correlation between the

amount of supporting residual bone and loss of implants, irrespective of the particulated graft used for sinus grafting. In that study, the implant survival rate was only 29% when the residual bone was less than 3 mm (class D sites), while all implants were stable when the residual bone was 7 mm or more. The results from Jensen and Greer<sup>5</sup> as well as from the present study indicate that sufficient osseointegration in the graft does not occur during a 6- to 14-month healing period, at least when radiated mineralized cancellous allograft material is used. Therefore, the efficacy of immediately placing implants and particulate bone grafts in the maxillary sinus can be questioned. Does the graft biomechanically support the

implants, or is the stability related to the anchorage of the implants in the residual alveolar bone only?

Sennerby et al<sup>17</sup> showed that the stability of titanium implants depended on the amount of compact bone in the interface, and that a small amount of compact bone may be sufficient to achieve and maintain osseointegration during functional loading. This is supported by the findings of several authors. For instance, Lekholm<sup>18</sup> reported an 88% survival rate for 7-mm implants over a 5-year period. Jemt and Lekholm<sup>19</sup> reported that the failure rate for short implants placed in severely resorbed maxillae (20 to 28.7%) was similar to that for implants simultaneously placed with autogenous onlay grafts in the maxilla (19.3%) after 5 years, which indicates that the bone graft minimally improved the clinical results. In a recent study by Ellegaard et al,<sup>9</sup> it was demonstrated that implants placed in a few millimeters of alveolar bone and protruding into the maxillary sinus without placement of a graft were as successful as endosseous root-form implants placed in adjacent sites with sufficient bone volume during a 3-year period. The poor results of simultaneous placement of implants in class D sites reported by Jensen and Greer<sup>5</sup> may also be related to the fact that radiated mineralized cancellous allograft was mainly used in that study. As has been shown in the present study, a negligible degree of osseointegration was obtained in this type of graft. In contrast to these specimens, the morphologic picture was quite different when autogenous graft had been used, indicating that autogenous bone is preferable. However, although the degree of bone contact was significantly greater for the autograft specimens, it was probably still insufficient to allow loading of the implants.

In the present study it was observed that formation of mature lamellar bone was also evident in the allografted situation after 14 months, although a minimal amount of bone was present in the implant interface. Therefore, one possible way to solve the problem of having "low contents" of osseointegration in the graft is to perform a two-stage procedure. In this way, the graft is placed in the sinus prior to implant placement. Sufficient time can be given for the initial healing phase with bone formation and condensation and for the subsequent remodeling phase prior to implant placement. Another potential procedure is to follow a cautious provisional loading protocol and permit the residual bone crest to support the implant while awaiting osseointegration, including the part of the implant placed in the graft. However, controlled clinical studies with histology are required to test these hypotheses.

## Conclusion

The use of titanium microimplants placed into the maxillary sinus at the time of grafting and retrieved 6 to 14 months later constituted a useful model for histologic evaluation of the sinus graft-implant interface. The use of particulate autogenous bone grafts resulted in the formation of more viable bone when compared to the use of an allograft. Simultaneous grafting and placement of oral implants in the maxillary sinus resulted in negligible degrees of bone-implant contact, irrespective of type of graft.

## References

1. Kent J, Block M. Simultaneous maxillary sinus floor bone grafting and placement of hydroxyapatite-coated implants. *J Oral Maxillofac Surg* 1989;47:238-242.
2. 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.
3. Loukota RA, Isaksson SG, Linnér ELJ, Blomquist 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.
4. Streckbein R. Standardisiertes und einzeitiges Vorgehen beim "Sinuslifting." *Z Zahnärztl Implantol* 1992;8:254-257.
5. Jensen OT, Greer R. Immediate placement 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 & Maxillofacial Reconstruction*. Chicago: Quintessence, 1992:321-333.
6. Small SA, Zinner ID, Panno FV, Shapiro HJ, Stein JJ. Augmenting the maxillary sinus for implants: Report of 27 patients. *Int J Oral Maxillofac Implants* 1993;8:523-528.
7. Isaksson S. Evaluation of three bone grafting techniques for severely resorbed maxillae in conjunction with immediate endosseous implants. *Int J Oral Maxillofac Implants* 1994;9:679-688.
8. 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.
9. Ellegaard B, Petersen JK, Stoltze K. Implant therapy involving maxillary sinus lift in periodontally compromised patients. *Clin Oral Implants Res* 1997;8:305-315.
10. Moy PK, Lundgren S, Holme R. Maxillary sinus augmentation: Histomorphometric analysis of graft materials for maxillary sinus floor augmentation. *J Oral Maxillofac Surg* 1992;51:857-862.
11. Lundgren S, Moy P, Johansson C, Nilsson H. Augmentation of the maxillary sinus floor with particulated mandible: A histologic and histomorphometric study. *Int J Oral Maxillofac Implants* 1996;11:760-766.
12. Wallace SS, Froum SJ, Tarnow DP. Histologic evaluation of sinus elevation procedure: A clinical report. *Int J Periodont Rest Dent* 1996;16:47-51.
13. Boyne PJ, Marx RE, Nevins M, Triplett G, Lazaro E, Lilly LC, et al. A feasibility study evaluating rhBMP-2/absorbable collagen sponge for maxillary sinus floor augmentation. *Int J Periodont Rest Dent* 1997;17:11-25.

14. Whittaker JM, James RA, Lozada J, Cordova C, GaRey DJ. Histological response and clinical evaluation of heterograft and allograft materials in the elevation of the maxillary sinus for the preparation of endosteal dental implant sites. Simultaneous sinus elevation and root form implantation: An eight-month autopsy report. *J Oral Implantol* 1989;15:141-144.
15. GaRey DJ, Whittaker JM, James RA, Lozada JL. The histologic evaluation of the implant interface with heterograft and allograft materials: An eight-month autopsy report, part II. *J Oral Implantol* 1991;17:404-408.
16. Jensen OT. Site classification for the osseointegrated implant. *J Prosthet Dent* 1989;61:228.
17. Sennerby L, Thomsen P, Ericson LE. A biomechanical and morphometrical comparison of titanium implants inserted in cortical and cancellous bone in rabbits. *Int J Oral Maxillofac Implants* 1992;7:62-71.
18. Lekholm U. The Brånemark implant technique. A standardized procedure under continuous development. In: Laney WR, Tolman DE (eds). *Tissue Integration in Oral, Orthopedic & Maxillofacial Reconstruction*. Chicago: Quintessence, 1992:194-199.
19. Jemt T, Lekholm U. Implant treatment in edentulous maxillae: A 5-year follow-up report on patients with different degrees of jaw resorption. *Int J Oral Maxillofac Implants* 1995;10:303-311.