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Maxillary sinus floor grafting with β -tricalcium phosphate in humans: density and microarchitecture of the newly formed bone

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Abstract

Objectives: Graft insertion can effectively enhance the regeneration of debilitated bone. The effects of an alloplastic bone-replacing material, β -tricalcium phosphate (Cerasorb), and of autogenous bone graft were compared.

Materials and methods: In 17 edentulous patients, the maxillary sinus floor was extremely atrophied to such an extent that implant placement was impossible. The Schneiderian membrane was surgically elevated bilaterally by insertion of Cerasorb (experimental side) and autogenous bone graft (control side). After surgery, the recovery was followed clinically and radiologically. After 6 months, 68 bone cylinders were excised from the grafted areas and implants were inserted into their places. The bone samples were embedded into resin, and the osteointegration of the grafts was studied histologically. Trabecular bone volume (TBV) and trabecular bone pattern factor (TBPf) were quantified by histomorphometry.

Results: Cerasorb proved to be an effective bone-replacing material with osteoconductivity; it was capable of gradual disintegration, thereby providing space for the regenerating bone. The new bone density was not significantly different on the experimental and control sides ($32.4 \pm 10.9\%$ and $34.7 \pm 11.9\%$, respectively). However, the graft biodegradation was significantly slower on the experimental side than the control side. The TBPf value was lower on the control side than on the experimental side (-0.53 ± 1.7 and $-0.11 \pm 1.4 \text{ mm}^{-1}$, respectively), but this difference was not significant.

Conclusions: Six months after insertion of the grafts, the bone of the augmented sinus floor was strong and suitable for anchorage of dental implants, irrespective of whether autogenous bone or Cerasorb particles had been applied.

Bone regeneration can be facilitated both by systemic factors and by local insertion of bone-substitute materials. In maxillofacial surgery, various types of bone defects (atrophied alveolar ridge, periodontal bone destruction, cystic and tumorous jaw lesions and traumatic bone deformities) give rise to a need for local bone replacement (Moy et al. 1993; Aytig et al. 1999; Groeneveld et al. 1999). Maxillary and mandibular

bone alterations require excellent cosmetic reconstruction and also a good load-bearing capacity because of the masticatory forces. The strength of the newly formed bone is especially important when a bony bed is to be prepared for anchorage of dental implants.

Reduction of the chewing forces as a consequence of advanced age and the loss of teeth results in a gradual thinning of the

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bony floor of the maxillary sinus (Ariji et al. 1994). The alveolar recesses gradually extend even into the edentulous alveolar process (pneumatization). At the same time, vertical and horizontal bone loss of the alveolar ridge caused by outer resorption makes denture fixation impossible (Cawood & Howell 1988).

Augmentation of the bony sinus floor by insertion of graft materials is an excellent method to construct a suitable bony bed for implant placement (Tatum 1986; Misch 1987). Clinical and pathological evidence from many studies indicates that the use of an autogenous bone graft is favored as a gold standard (Boyne & James 1980; Wood & Moore 1988). However, there are many problems associated with harvesting of an adequate quantity of autogenous bone. It requires a second surgery, causing increases in the time demands and costs of the therapy, and giving rise to considerable complications at the donor site (Kalk et al. 1996).

The availability of suitable biomaterials to be used as a bone replacement that facilitates the bone regeneration would eliminate the need for an extra surgical site. Various grafts have been used for this purpose, including allogenic bone, alloplastic bone substitutes and their combinations (Moy et al. 1993; Aygit et al. 1999; Hanish et al. 1999; Tadjodin et al. 2000; Yildirim et al. 2000). The effects of these bone-replacing materials have been extensively studied in animal models (McAllister et al. 1999; Liu et al. 2000; Haas et al. 2002; Suba et al. 2004) and *in vitro* experiments (Laurencin et al. 1996; Anselme et al. 1999), but a direct comparison of the results with the clinical data on the patients is impossible.

Clinical observations in humans require non-invasive techniques, such as radiology and macromorphometry. However, the most effective way of evaluation of the density and stability of newly formed bone is histology and histomorphometry. An advantageous approach is the application of a two-stage technique: when the first step is the graft insertion and the second, after several months, is the implant placement in the grafted site (Lundgren et al. 1997). This second step provides an excellent possibility for taking biopsy specimens from the regenerating bone.

In a preliminary study, the two-stage technique was applied in four edentulous patients (Szabó et al. 2001). Bilateral sinus elevations revealed a similar bone-forming capacity of β -tricalcium phosphate (Cerasorb) and of an autogenous bone graft. The present study continues the previous one, with a prospective-controlled histologic and histomorphometric analysis of 17 cases, subjected to statistical analysis.

Materials and methods

Patient selection

The patient population comprised 17 completely edentulous individuals (10 women and 7 men) with an average age of 52 years (range, 39–66 years). The patients had no disease that might influence the treatment outcome. They were fully informed about the procedures, including the surgery, the bone substitute material and the implants. All gave their written informed consent. The Ethics Committee of the Semmelweis University approved the research protocol.

Preoperative examinations with panoramic images and in some cases, computed tomographic scans were performed. All patients had an insufficient bone height in the subantral maxillary floor (average 1.9 mm), being unsuitable for immediate implant placement. Improving the vertical bone height through surgical sinus floor augmentation created suitable implant sites. In the 17 cases, bilateral sinus floor elevations were completed.

Surgical procedures

In all 17 cases, surgery was performed under general anesthesia. The autotransplant was harvested before the time of sinus grafting; 4–5 cm³ spongiosa were taken from the left iliac crest. The bilateral sinus grafting was completed according to the classic method of Tatum (1986). The cavity thus created under the Schneiderian membrane was filled with 1.5–2 g β -tricalcium phosphate granules 500–1000 μ m in diameter (Cerasorb, Curasan AG, Kleiostheim, Germany) on the experimental side, and with 3–4 cm³ of autogenous spongiosa on the control side. After an average of 6.5 months of healing (range, 6–7.5 months), 68 cylindrical bone biopsies were taken from the grafted posterior maxilla (two each from the experimental

and control sides of all patients) using a trephine bur of 2 mm inner diameter and 3 mm outer diameter. Ankylos implants (Degussa, Friadent, Germany) were placed in osteotomy sites thus prepared.

Histology

For histologic and histomorphometric analyses, undecalcified bone biopsies were fixed in 4% buffered formalin for 24 h and then rinsed thoroughly in running water. Samples were dehydrated in ascending alcohol series and then embedded in methylmethacrylate resin at 4°C. Histological sections of 5 μ m thickness were cut parallel to the longitudinal axis of the biopsy specimen, using a diamond knife and a Jung-K microtome. Sections were stained with toluidine blue, hematoxylin and eosin and Goldner's trichrome stain for light microscopy. Graft particles often broke off the sections during handling, but their characteristic shapes were easily recognizable. Under polarized light, Cerasorb graft remnants and new collagenous bone trabeculae could be clearly distinguished by virtue of their different birefringence.

Tissue reactions, bone regeneration around the graft particles, microscopic structure of the bone/graft interface, graft bioresorption and new bone quantity and quality were histologically assessed.

Photomicrographs were taken by an Olympus BH2 microscope equipped with an Olympus DP50 digital camera (Olympus Optical Company Ltd., Melville, NY, USA).

Histomorphometric analysis

Measurements on the histological sections were performed by a computerized technique; the operating system applied was the Windows XP service pack 1 (©:Microsoft Corporation, Redmond, OR, USA). Image processing was performed with AnalySIS[®] of Soft Imaging System (Münster, Germany). Measurement fields were selected by visual monitoring of the microscopic image on screen. RGB images were converted to gray scale, and a manually refined luminescence threshold was then created to define the structures to be measured. Automatic calculation of the perimeter and area was achieved via pixel counting. Arithmetic dilatation of the chosen areas was performed by adding one pixel to each

surface. After calibration, the area was given in mm^2 and the length in mm.

Histomorphometric measurements were performed according to the principles of Parfitt et al. (1987). The density of the newly formed bone was characterized by the trabecular bone volume (TBV), which was defined as the area of the bone trabeculae as a percentage of the total area analyzed. The percentage of the graft area was also determined. The trabecular bone pattern factor (TBPf), which is an indicator of the microarchitecture of the newly formed bone, was also quantified (Hahn et al. 1992). Measurements of the trabecular bone area and perimeter, before and after arithmetic dilatation of the binary image, were performed to determine the relation of the convex and concave trabecular structures in the two-dimensional section. The higher the degree of trabecular connectivity, the lower the value of TBPf.

Statistical analysis

The mean and SD values were calculated. The data obtained were analyzed by a Student's *t*-test, with a significance level set at $P < 0.05$.

Results

Clinical observations

The healing period following maxillary sinus augmentation was completed for nearly all patients without complications. Minor nosebleeds occurred in two cases. No clinical symptoms indicating maxillary sinusitis occurred in any of the 17 patients. Postoperative complications at the donor site were not observed. On average, the radiographic vertical height of the grafted sinus floor was 15 mm (range: 12–16 mm) on the experimental side and 14.5 mm (range: 12–15 mm) on the control side.

Histology

Experimental side

In sections stained with hematoxylin & eosin and Goldner's trichrome method, many graft particles had been dissolved. However, their previous location could easily be recognized by their characteristic round or scalloped form and size (Fig. 1). The partly resorbed graft particles were not only invaginated by apposition of the newly formed bone, but the individual

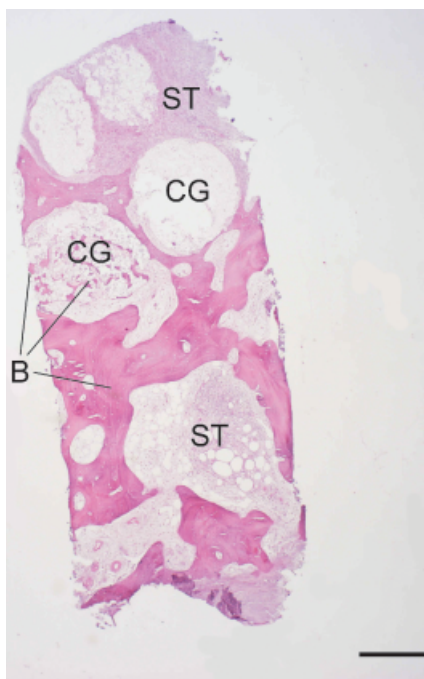


Fig. 1. Biopsy taken from the experimental side after 6 months of grafting. CG, cerasorb granule; B, bone; ST, soft tissue. H&E staining (scale bar = 500 μm).

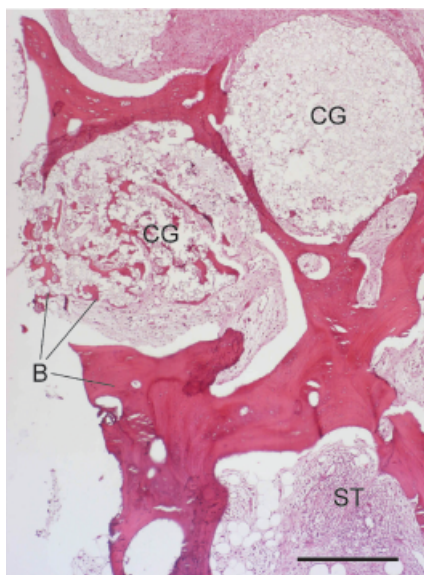


Fig. 2. Biopsy taken from the experimental side after 6 months of grafting. Porosity of the cerasorb granule (CG) is filled by branching bone strands (B). ST, soft tissue. H&E staining (scale bar = 600 μm).

granules had an osteoid or woven bone network in their pore system (Fig. 2). Intragranular invasion of the newly formed bone was conspicuous without any sign of osteoclastic activity. However, cytoplasmic accumulation of small achromatic graft remnants in the macrophages was a

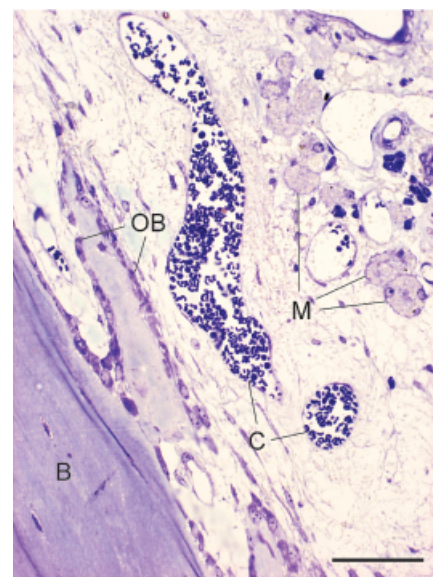


Fig. 3. Biopsy taken from the experimental side after 7 months. New bone formation (B) osteoblast activity (O) and achromatic particle-laden macrophages (M) can be seen. C, capillaries. Toluidine blue staining (scale bar = 80 μm).

notable finding (Fig. 3). After 6 months, the newly formed, predominantly lamellar bone was tightly intermingled with the graft particles at the tissue/graft interface. Bony sheathing of the Cerasorb granules was extensive, and where the graft particles had become completely sheathed, the osteoblastic activity disappeared. The graft remnants exhibited achromatic birefringence under polarized light (Fig. 4).

In one sample, there was a lack of bone formation in a demarcated area, in association with an intense inflammatory reaction.

Control side

The cancellous bone grafts had undergone considerable resorption by the sixth month (Fig. 5). Graft foci were entrapped in the newly formed, predominantly mature lamellar bone (Fig. 6). They were homogeneous acellular particles that stained almost like living bone. There was a continuous transition at the interface of the cancellous graft and the new bone. Some trabeculae demonstrated active bone remodelling with a chain of plump osteoblasts on one side, and resorption lacunae with multinucleate osteoclasts on the opposite side. Under polarized light, new bone formation was clearly recognized by the bright red birefringence of its collagenous fibers. Several

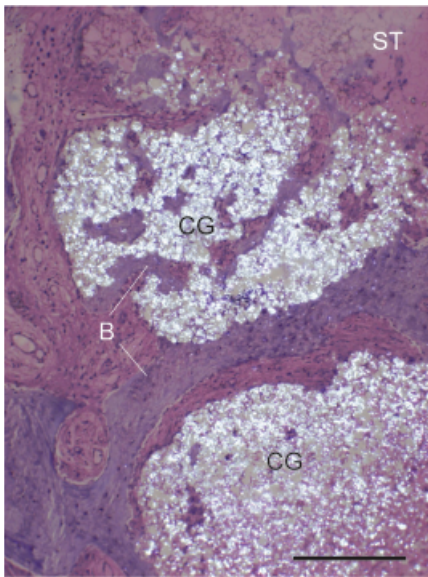


Fig. 4. Biopsy taken from the experimental side after 6.5 months of grafting. Scalloped surface of the cerasorb granule (CG), and peri- and intragranular bone strands (B) can be seen. ST, soft tissue. Toluidine blue staining. Polarized light (scale bar = 400 μ m).

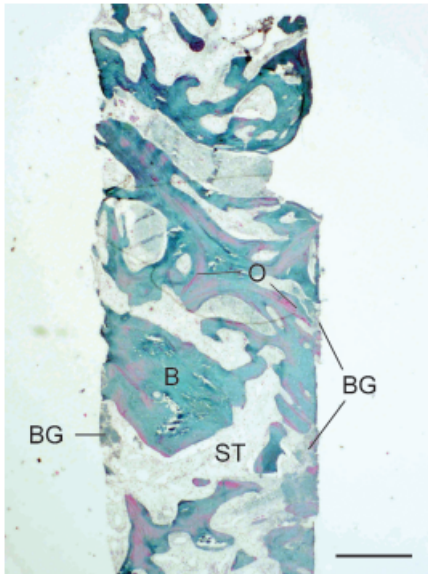


Fig. 5. Biopsy taken from the control side after 6 months of grafting. B, bone; O, osteoid; BG, bone graft; ST, soft tissue. Goldner staining (scale bar = 500 μ m).

samples showed minor bone formation, a predominantly fibrous marrow and a diffuse, thin network of newly formed trabeculae.

Histomorphometry

Bone density, graft density, TBPf and bone area were measured in 68 bone biopsy samples (Table 1).

Bone density

The mean bone density for the 17 cases was $32.4 \pm 10.8\%$ on the experimental side and $34.7 \pm 11.9\%$ on the control side; the difference was not significant ($P > 0.05$).

In an overwhelming majority of the patients (14 of 17 cases), the intensity of new

bone formation was similar on the two sides.

The new bone was markedly less dense on the experimental side in two of the 17 cases (nos. 4 and 9). In one of these patients, the minimal bone formation was associated with a local inflammatory reaction. In the other case, the Cerasorb graft density was quite high (21.2%).

The bone-forming capacity on the control side was smaller than on the experimental side in one case (no. 8).

In two cases (nos. 10 and 17), the ossification process was similarly weak on the two sides; the respective densities of the newly formed bone were 19.2% and 18.5% on the experimental side, and 18.4% and 17.6% on the control side. In these two cases, the new bone trabeculae were uniformly thin, with no focal inflammatory lesion.

Graft density

The graft density was markedly higher on the experimental side than on the control side. The mean density of the graft area was $13.1 \pm 4.5\%$ and $8.2 \pm 1.7\%$, respectively, this difference being highly significant ($P < 0.001$).

Connective tissue and bone marrow density

The mean densities of the connective tissue areas were similar on the experimental

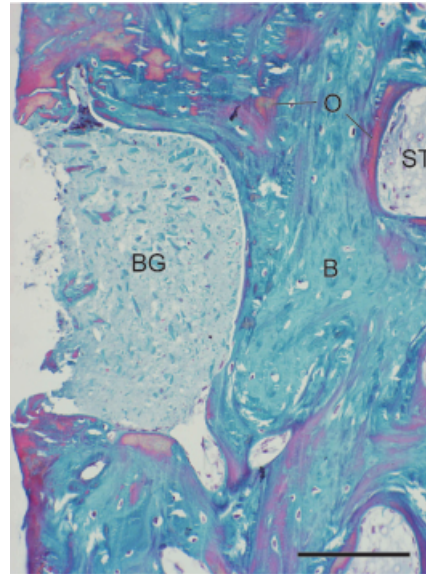


Fig. 6. Biopsy taken from the control side after 6 months of grafting. Bone (B) and osteoid (O) production and a focus of the resorbing bone graft (BG) can be seen. ST, soft tissue. Goldner staining (scale bar = 200 μ m).

Table 1. Histomorphometric values* on the experimental and control sides

No.	Experimental side			Control side		
	Bone density (%)	Graft density (%)	TBPf (1/mm)	Bone density (%)	Graft density (%)	TBPf (1/mm)
1	41.8	13.1	-0.16	51.5	7.6	-0.12
2	32.6	11.3	1.56	36.3	8.9	-0.88
3	24.8	17.5	0.31	27.6	6.7	-1.01
4	16.7	21.2	0.22	33.6	10.5	-1.87
5	23.8	10.4	0.55	24.25	8.6	1.22
6	36.5	8.7	-0.11	34.6	11.3	-0.57
7	29.9	11	-0.17	31.4	7.9	-0.29
8	27.6	9.8	-1.86	16.4	6.8	0.94
9	25	19.4	-1.96	44.2	7.8	-1.86
10	19.2	12.2	1.63	18.4	10.6	2.14
11	47.2	10.8	0.27	50.8	5.4	-3.23
12	50.7	8.1	-2.19	46.6	6.9	-2.08
13	40.4	10.3	-1.25	42.8	7.1	-1.99
14	26.7	12.2	1.85	24.5	8.7	1.11
15	45.7	11.8	-1.86	49.2	5.8	-2.25
16	43.4	11.2	-1.03	40.2	8.1	-1.43
17	18.5	23.5	2.41	17.6	9.9	3.13
Mean	32.38	13.09	-0.11	34.7	8.15	-0.53
SD	10.85	4.49	1.43	11.86	1.69	1.74
	Bone density	Graft density	TBPf			
P	0.10693659	0.00012541	0.1156			

*Each value is an average of two measured data on parallel biopsy samples. TBPf, trabecular bone pattern factor.

and control sides ($49.4 \pm 16\%$ and $50.4 \pm 19\%$, respectively). The mean bone marrow density was higher on the control side ($6.8 \pm 2.9\%$) than on the experimental side ($5.1 \pm 2.2\%$) ($P > 0.05$).

TBPf

These values generally displayed an inverse correlation with the bone density (Table 1). The higher the bone density, the lower the TBPf. In 11 of the 17 cases, the TBPf values on the control side were lower than that on the experimental side. The mean values were -0.53 ± 1.74 and $-0.11 \pm 1.43 \text{ mm}^{-1}$, respectively, but the difference was not significant ($P > 0.05$).

Area and length of biopsy samples

The mean areas of the biopsy samples taken from the two sides were quite similar: $8.85 \pm 1.7 \text{ mm}^2$ on the experimental side and $9.12 \pm 2.28 \text{ mm}^2$ on the control side. The mean length of the biopsy samples was $7.83 \pm 1.9 \text{ mm}$ on the experimental side and $8.08 \pm 2.2 \text{ mm}$ on the control side.

Discussion

The quantity and quality of the cancellous host bone are crucial for the stability of endosseous implants placed in the alveolar ridge. Bone graft insertion is commonly used in an effort to increase the bony support for oral implants (Boyne & James 1980; Lundgren et al. 1997; Groeneveld et al. 1999). The incorporation of the graft and the integration of the implants are both complex healing situations and must result in a direct contact between the implant and the remodelled, grafted bone. The maxillary sinus floor seems to be ideally suited for the use of various bone substitutes, because it has a high osteoregenerative potential.

In totally edentulous patients and in cases of serious local atrophy, a two-stage technique is the correct choice (Lundgren et al. 1997). The first step is the sinus floor grafting, which requires a longer time to be revascularized and incorporated. The second step is the implant placement, several months later; this promotes an immediate healing response, similar to that in natural viable bone. At the same time, histological

analysis of bone biopsies taken from the grafted site allows an evaluation of the integration and resorption of the bone substitute used.

Bilateral sinus grafting in the same patient, under nearly identical circumstances, is an excellent method for comparison of the bone-regenerating effects of different graft materials (Moy et al. 1993; Groeneveld et al. 1999; Tadjoeidin et al. 2000). As autogenous bone grafting is regarded as the gold standard, such an insertion is favored as a control method (Wood & Moore 1988; Klinge et al. 1992; Becker et al. 1994).

Clinical and radiological evaluations are widely used to assess the results of bone regeneration. However, the quantity and structural quality of the healing cancellous bone can be exactly assessed only by means of histologic and histomorphometric methods.

Histologic and histomorphometric examination of 68 bone biopsies taken from the 17 cases in the present study indicated nearly equal activities of bone regeneration on the two sides. The bone density data in the augmented sinus floor were similar, irrespective of whether autogenous bone or Cerasorb particles had been applied.

New bone formation was concentrated primarily on the surface and in the pore system of the Cerasorb granules on the experimental side. Penetrating inward bone growth reflected a gradual biological degradation of the bone-substitute material. Zerbo et al. (2001) histologically observed active osteoclastic resorption of Cerasorb granules. Accordingly, the rate of remodelling may be the main factor causing loss of the graft particles. Other mechanisms, primarily physical dissolution, can also operate in the removal of this graft material. The histologic findings in the present study did not support osteoclastic graft resorption; however, small cytoplasmic Cerasorb particles in the mononuclear macrophages suggested active cellular elimination.

In the present study, there were three cases with unilateral lower rates of bone regeneration, on the control side in one patient and on the experimental side in two. One case on the experimental side could be explained by a local inflammatory reaction; in the other case, the biopsy sample was crowded by graft remnants.

On the control side, there was no plausible explanation for the minimal bone healing. These cases supported the role of local factors such as microvascular deficiency of the atrophied bone (Solar et al. 1999).

In two cases of the present study, there was only minor bone formation on both sides. One of them involved the oldest patient, while the other case was a postmenopausal woman.

Statistically evaluable morphometric results are not available with respect to Cerasorb-grafted sinus floor elevations in humans. The effect of bioactive glass mixed with autogenous bone particles was earlier compared with that of bone particles alone in bilateral sinus floor augmentation cases (Tadjoeidin et al. 2000). After 6 months, the trabecular bone densities were higher than the present data, on both the experimental and control sides (44% and 38%, respectively).

Maxillary sinus floor augmentation with a mixture of Bio-Oss xenograft and autogenous bone was also studied (Yildirim et al. 2001). The histomorphometric results revealed a markedly lower bone density (18.9%) and a higher graft density (29%) as compared with the present data. However, the average density of the bone-graft complex was close to 50%, which was similar to the present findings.

The combination of Bio-Oss and venous blood in human maxillary sinus elevation cases yielded modest results (Yildirim et al. 2000). The average density of the newly formed bone was only 14.7%, while the proportion of the xenogenic graft residue remained at 29.7%.

In addition to the bone quantity, another factor requiring consideration is the bone microarchitecture. TBPf measurements on grafted bone samples give rise to special problems, depending on the nature of the graft. In porous, alloplastic materials, the intragranular weblike bony network exhibits many thin branching-free endings, and this will negatively influence the trabecular connectivity measurements. In the present study, the better trabecular connectivity resulted in lower TBPf values on the control side. However, these differences did not prove significant.

Graft biodegradation is also an important factor in bone substitution (Zerbo et al. 2001; Suba et al. 2004). In our cases, graft resorption was followed by new bone de-

position on both sides. However, after 6 months, the graft density was significantly higher on the experimental side than on the control side. A further question is whether persistence of the graft inclusions can affect the stability of the newly formed bone. The present results revealed that there was no significant difference in bone density between the two sides. This suggests that alloplastic granules persisted predominantly on account of the bone marrow space.

The size of the biopsy samples can also influence the quantitative comparison of the effects of bone substitutes, as the grafted bone samples are not homogeneous. The greater the bone area, the more representative the measurement. In our study, the areas of the bone biopsies from the two sides did not differ significantly.

In clinical practice, long-term studies under prosthetic loading will be necessary to clarify the success rate of implantation in the augmented regions. However, histologic and histomorphometric results can predict the load-bearing capacity of the bony bed, and reveal the weakest points requiring more careful handling.

Résumé

L'insertion d'un greffon peut augmenter de manière efficace la régénération de l'os affaibli. Les effets d'un matériel de remplacement osseux alloplastique, le phosphate β -tricalcique (Cerasorb) et un greffon osseux autogène ont été comparés. Chez dix-sept édentés, le plancher sinusal maxillaire était extrêmement atrophié à telle enseigne que tout placement implantaire s'avérait impossible. La membrane de Schneiderian a été chirurgicalement élevée bilatéralement par l'insertion de Cerasorb (site expérimental) ou d'os autogène (site contrôle). Après la chirurgie, la guérison a été suivie cliniquement et radiographiquement. Après six mois, 68 cylindres osseux ont été prélevés des zones greffées et des implants ont été insérés à ces endroits. Les échantillons osseux ont été enfouis dans la résine et l'ostéointégration des greffons a été évaluée histologiquement. Le volume osseux trabéculaire (TBV) et le facteur du modèle osseux trabéculaire (TBPf) ont été quantifiés par histomorphométrie. Le Cerasorb était un matériau de remplacement osseux efficace montrant une ostéoconductivité, qui était capable d'une désintégration graduelle, apportant ainsi un espace pour l'os régénéré. La densité de l'os néoformé n'était pas significativement différente entre les sites expérimentaux et contrôles (respectivement $32 \pm 11\%$ et $35 \pm 12\%$). Cependant, la biodégradation du greffon était significativement plus lente au niveau du site expérimental qu'au niveau du contrôle. La valeur TBPf était inférieure au niveau du site contrôle vis-

à-vis de l'expérimental ($-0.53 \pm 1.7 \text{ mm}^{-1}$ et $-0.11 \pm 1.4 \text{ mm}^{-1}$) mais cette différence n'était pas significative. Six mois après l'insertion des greffons, l'os du plancher sinusal épaissi était fort et acceptable pour le placement d'implants dentaires que cela soit de l'os autogène ou des particules de Cerasorb qui avaient été utilisés.

Zusammenfassung

Ziel: Das Einsatz eines Transplantates kann die Regeneration von verlorengegangenen Knochen effektiv beschleunigen. Man verglich die Einflüsse eines alloplastischen Knochensatzmaterials, dem β -Tricalciumphosphat (Cerasorb), und einem autologen Knochenransplantat.

Material und Methode: Bei 17 zahnlosen Patienten war der Boden des Sinus maxillaris so extrem tief abgesunken, dass die verbleibende Knochendicke am Sinusboden für die Implantation nicht ausreichte. Daher hob man in einem chirurgischen Eingriff beidseits die Schneider'sche Membran ab und füllte den Hohlraum mit Cerasorb (Testseite) oder autologem Knochen (Kontrollseite) auf. Nach dem operativen Eingriff verfolgte man klinisch und histologisch die weitere Entwicklung. 6 Monate später entnahm man 68 bei der Implantation als Nebenprodukt entstehende Knochenzylinder aus den aufgebauten Regionen und setzte in die entstandenen Bohrstollen je ein Implantat. Die Knochenbiopsien bettete man in Kunststoff ein und prüfte histologisch die Osteointegration der Transplantate. Histomorphometrisch bestimmte man anschließend das Knochenvolumen des trabekulären Knochens (TBV) und einen Faktor, der den Knochensatz des trabekulären Knochens wieder spiegelt (TBPf).

Resultate: Cerasorb zeigte sich als effizientes Knochensatzmaterial mit Osteokonduktivität; es kann schrittweise aufgelöst werden und hinterlässt hierbei Raum für den sich regenerierenden Knochen. Die Knochendichte des sich neu bildenden Knochens unterschied sich nicht signifikant von der Kontrollseite ($32.4 \pm 10.9\%$, beziehungsweise $34.7 \pm 11.9\%$). Der biologische Abbau des Transplantates erfolgte aber auf der Testseite langsamer als auf der Kontrollseite. Der TBPf-Wert war auf der Kontrollseite kleiner als auf der Testseite ($-0.53 \pm 1.7 \text{ mm}^{-1}$, beziehungsweise $-0.11 \pm 1.4 \text{ mm}^{-1}$); dieser Unterschied war aber nicht signifikant.

Zusammenfassung: Sechs Monate nach dem Einbringen der Transplantate war der Knochen im aufgebauten Sinusbodenbereich stabil und zur Verankerung von Zahnimplantaten geeignet, unabhängig davon ob autologer Knochen oder Cerasorb-Partikel verwendet worden waren.

Resumen

Objetivos: La inserción de injertos puede efectivamente realzar la regeneración de hueso debilitado. Se compararon los efectos de un material de sustitución

ósea aloplástico, β -fosfato tricálcico (Cerasorb), y de injerto de hueso autógeno.

Material y métodos: En 17 pacientes edéntulos, el suelo del seno maxilar estaba extremadamente atrófico hasta tal extremo que la colocación de implantes fue imposible. Se elevó quirúrgicamente la membrana de Schneider bilateralmente insertándose Cerasorb (lado experimental) e injerto de hueso autógeno (lado de control). Tras la cirugía, la recuperación fue seguida clínica y radiográficamente. Tras seis meses, se extirparon 68 cilindros de hueso de las áreas injertadas y se insertaron implantes en su lugar. Las muestras de hueso se embecieron en resina, y se estudió histológicamente la osteointegración de los injertos. Se cuantificaron por histomorfometría el volumen de hueso trabecular (TBV) y el factor de patrón de hueso trabecular (TBPf).

Resultados: El Cerasorb demostró ser un material sustituto óseo efectivo con osteoconductividad; fue capaz de una desintegración gradual, por ello suministrando un espacio para el hueso de regeneración. La nueva densidad ósea no fue significativamente diferente en los lados experimentales y de control ($32.4 \pm 10.9\%$ y $34.7 \pm 11.9\%$ respectivamente). De todos modos, la biodegradación fue significativamente más lenta en el lado experimental que en el lado de control. El valor del TBPf fue menor en el lado de control que en el lado experimental ($-0.53 \pm 1.7 \text{ mm}^{-1}$ y $-0.11 \pm 1.4 \text{ mm}^{-1}$, respectivamente); pero esta diferencia no fue significativa.

Conclusiones: Seis meses tras la inserción de los injertos, el hueso del suelo del seno aumentado era fuerte y adecuado para el anclaje de implantes dentales, sin tener en cuenta si se había aplicado hueso autógeno o partículas de Cerasorb.

要旨

目的: 移植材料の埋入は、弱体化した骨の再生を効果的に促進できる。人工骨代替材料の一つである β 燐酸 3 カルシウム (Cerasorb) と自家骨移植を比較した。

材料と方法: 無歯顎患者 17 名において上顎洞が極度に萎縮しており、インプラントの埋入が不可能であった。Cerasorb (実験部位) と自家骨移植片 (対照部位) を両側に埋入し、シュナイデル膜を外科的に挙上した。術後の回復を、臨床的検査とレントゲンによって経過観察した。6 カ月後に 68 箇所 of 移植部位で骨床を形成し、インプラントを埋入した。切除した骨標本を樹脂に包埋し、移植片の骨性結合を組織学的に検討した。海綿骨量 (TBV) と海綿骨パターン・ファクター (TBPf) を組織形態計測法によって定量化した。

結論: Cerasorb は骨伝導性を有する有効な骨代替材料であることが証明されているが、徐々に分解していき、再生骨のための空間を提供した。新生骨の密度について、実験部位と対照部位の間に統計学的有意差はなかったが (各々 $32.4 \pm 10.9\%$ と $34.7 \pm 11.9\%$)、移植片の生体分解の速度は対照部位より実験部位が有意に遅かった。TBPf 値は、実験部位より対照部位の方が低かったが (各々 $-0.53 \pm 1.7 \text{ mm}^{-1}$ と $-0.11 \pm 1.4 \text{ mm}^{-1}$)、この差は有意差ではなかった。

結果: 移植片埋入後 6 カ月後に造成された上顎洞底の骨は、自家骨あるいは Cerasorb のいずれにおいても、インプラントの固定に適した強度であった。

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