Autogenous Bone Versus β-Tricalcium Phosphate Graft Alone for Bilateral Sinus Elevations (2- and 3-Dimensional Computed Tomographic, Histologic, and Histomorphometric Evaluations): Preliminary Results

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The aim of this research was to compare 2 different graft materials, β-tricalcium phosphate (Cerasorb) and autogenous bone, used in the same patient. Bilateral sinus grafting was performed on 4 selected patients; Cerasorb only was used on the experimental side, and autogenous bone only was used on the control side. In all 4 patients, the maxilla was atrophied to such an extent that the reconstruction included not only sinus grafting but also onlay plasty. The procedure was followed by implant placement 6 months later. In addition to routine panoramic radiographs, 2- and 3-dimensional computed tomographic (CT) examinations were performed pre- and postoperatively and after implantation. Information from CTs is necessary when alveolar bone atrophy is extensive, complications appear probable, and in difficult cases, when exact documentation is important. A total of 16 bone biopsies were taken at the time of implant placement. The histologic and histomorphometric results indicated that when the formation of new bone was slow, it was slow on both sides; when it was fast, then it was fast on both sides. Individual patient factors strongly influenced the fates of the various graft materials in the organism. Comparisons of the present results with the findings of other investigators demonstrated that β-tricalcium phosphate is a satisfactory graft material, even without autogenous bone.
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Autogenous graft or allogeneic graft? For many years, the reconstruction of bone defects has been achieved using a variety of bone substitute materials. The question of the "best" graft material has been addressed intensively by researchers, and as a result, a large number of experimental and clinical publications have appeared on this topic.[1–13] In 1996, a consensus conference on sinus grafting made an attempt to summarize and evaluate the research findings.[14] One of the most important conclusions of the conference was that retrospective analyses did not reveal any bone substitute material that was equivalent to autogenous spongiosa. Accordingly, "… many participants believed that autografts were the most efficacious …" and "the doubts raised revealed the need for controlled prospective multicenter clinical trials."

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In essence, the question lies in how to avoid morbidity at bone graft donor sites.[15,16] It is increasingly clear that, in addition to basic animal experiments, there is a need for clinical investigations that apply the gold standard principle to compare autogenous bone and various bone substitute materials.

An important publication in this respect is that of Groeneveld and coworkers.[17] They compared 4 materials: osteogenic protein 1 (on a collagen carrier), human freeze-dried demineralized bone matrix, autogenous bone, and nongrafted alveolar crest. In a total of 12 patients (3 for each of the materials), histologic and histomorphometric methods were used to detect new bone formation during sinus floor elevation and implantation. All grafted sinuses exhibited an increased proportion of osteoid, as compared with nongrafted sinuses. It was concluded that in human sinus floor elevation, osteogenic protein has a potential bone-inductive capacity; however, the results with this material were inconsistent.

Yildirim and associates[18] used a combination of Bio-Oss and venous blood as a graft material. Six months after sinus floor augmentation, they found 14.7% new bone, 29.7% Bio-Oss, and 55.6% soft tissue in the tissue samples (soft tissue = blood vessels and connective tissue composed of various proportions of fibroblasts and collagenous fibers). It is interesting to compare these results with the data reported in 1991 by Schenk,[19] who found that the bone content of the human iliac crest was 20% to 25%, depending on age. Naturally, one of the problems to be considered in this regard is the extent to which Bio-Oss is resorbed.

In the literature, the resorption of bovine bone substitute materials has been the subject of controversy. Schlegel and Donath[20,21] were able to identify the presence of Bio-Oss granules even after a resting time of up to 7 years. It was demonstrated histologically by Skoglund and colleagues[22] that Bio-Oss particles could be found in the maxilla 44 months after implantation. Some publications based on animal experiments have furnished histologic evidence of the resorption of Bio-Oss.[18,23–25]

An example of control is provided by the paper by Tadjoedin and coworkers.[26] Bilateral sinus grafting was performed on 10 patients; a 1:1 mixture of autogenous bone particles and bioactive glass particles was used on the experimental side, and autogenous bone alone was used on the control side. At 6 months, bone tissue on the experimental side had increased to 32%, differing only slightly from the control side, which contained 38% bone by volume. At 16 months, the total bone volume on the experimental side was similar to that on the control side. After 16 months, the quality and density of bone in the augmented sinus floor were similar, regardless of whether or not bone particles or a mixture of bone particles and bioactive glass particles had been applied.

In addition to histology and histomorphometry,[27–32] modern imaging procedures[33–41] are being applied more frequently for sinus graft examination. At the sinus consensus conference,[14] panoramic radiographs appeared logical for the comparison of a large number of patients. Long-term results of sinus grafting may be monitored by a number of known computer tomographic methods, but these have seen limited use. Kent,[34] for example, examined bone levels from the new sinus floor to the alveolar crest and the apex of the implant. Alveolar bone height was considered satisfactory if the new bone exceeded the apex of the implant by at least 2 mm even after 5 to 10 years.

These data and the consensus conference[14] have raised the question (among others) of how the immediate and long-term success of planned sinus grafting can be monitored, not only histologically, as with delayed implant placement, but also more accurately. When and to what extent is it worthwhile to use a state-of-the-art imaging technique? One of the aims of the present work was to clarify these questions.

The significance of pure-phase β-tricalcium phosphate as a bone substitute material has increased in recent years. It has been used in maxillofacial preprosthetic surgery, implant dentistry, traumatology, orthopedics, and hand surgery.[42–49] The treatment modes in maxillofacial surgery have included the filling of large cysts, sinus grafting, augmentation, and the filling of periodontal lesions. It has been demonstrated that β-tricalcium phosphate is fully resorbed in 12 to 18 months and is replaced by bone that is similar both functionally and anatomically to the original bone. In view of these favorable properties, the authors sought to determine whether this bone substitute alone is an appropriate sinus graft material and whether it is suitable for the filling of large bone cysts.[49] Accordingly, prospective controlled studies were planned in selected patients.

The aim of the present work was to compare 2 different graft materials, β-tricalcium phosphate (Cerasorb, Curasan Pharma GmbH, Kleinostheim, Germany) and autogenous bone, when used in the same patient. Evaluations were performed by means of 2- and 3-dimensional (2D and 3D) computed tomography (CT) and histologic and histomorphometric examinations. The duration of the study was 6 months, which is the usual waiting period after sinus grafting. Answers to the following questions were sought: *(1)* To what extent is 2D and 3D CT reconstruction suitable for assessment of the incorporation of the sinus graft, and *(2)* Can the above methods demonstrate any difference between Cerasorb and autogenous bone as graft materials that would circumvent the use of autogenous bone?

MATERIALS AND METHODS

Patient Selection

Four edentulous patients were scheduled for bilateral sinus floor grafting and concurrent onlay plasty. All patients had conventional denture retention problems because of severe anterior and posterior maxillary alveolar ridge atrophy. All had a residual sinus floor of less than 5 mm in height (bone loss was graded as between 3 and 4 in 1 of the 4 patients and between 5 and 6 in the other 3, according to the classification scale of Cawood and Howell[50]). In all 4 patients, the maxilla was atrophied to such an extent that the sinus graft alone would not have resolved the problem; in all 4, a large part of the residual alveolar arch had thinned to a fine edge in the horizontal and sagittal directions. This situation is clearly demonstrated by the preoperative 3D CT photos (Figs 1a to 1d). The situation of the residual sinus floor is illustrated by the 2D CT photos (Figs 2a to 2d). The ages of these patients (2 men and 2 women) ranged from 42 to 62 years.

After routine oral and physical examinations, patients were selected and bone reconstruction procedures were planned. In all cases, this reconstruction included bilateral sinus floor grafting and onlay plasty in the anterior and part of the posterior maxilla, followed by implant placement 6 months later. All patients were healthy without any disease that could have influenced the treatment outcome (eg, diabetes, immunosuppressive chemotherapy, chronic sinus inflammation, rheumatoid arthritis). The patients were informed extensively about the procedures, including the surgery, the bone substitute material, the implants, and the uncertainties of using a relatively new bone-regenerative material. They were asked for their cooperation during treatment and research. All gave their written informed consent, and the research protocol was approved by the University Ethics Committee.

Methods

Radiographs and Computed Tomograms. In addition to routine panoramic radiographs, 2D and 3D CT examinations were performed pre- and postoperatively and 6 months after implant placement using a General Electric Pro-Speed Plus Instrument (General Electric Medical Systems, Milwaukee, WI). The later exposures were taken in the same plane and direction as preoperatively. For further technical details relating to this procedure, the reader is referred to an earlier publication.[33]

Surgery. In all 4 patients, surgery was carried out under general anesthesia. Before the sinus grafting or at the same time (by a second team), a 3×4 to 3×6-cm^2 piece of cortical bone was taken from the left iliac crest, together with 5 to 6 cm^3 from the spongiosa below it. The bone wound was closed with periosteum, and the soft tissues above it were then sutured.

The bilateral sinus grafting procedure followed Tatum's classical description.[51] In brief, a door was created with a round hollow bur in the lateral maxillary sinus wall. After mobilization, the door was reflected inward. The space created by this procedure was filled on one side only with 1.5 to 2 g Cerasorb (1,000 µm). This was the experimental side; the other side was the control side, which was filled with autogenous spongiosa (3 to 4 cm^3). The sides for the various grafting materials were chosen at random. Care was taken to keep the inner epithelial lining intact in so as to avoid spilling the grafting material.

Onlay Plasty. To enhance successful implantation subsequently, it was necessary to widen the alveolar crest, which had become extremely thin in places. This was performed at the same time as the bilateral sinus grafting. The harvested cortical bone was attached to the lateral half of the anterior and posterior compromised maxilla with microscrews (Figs 3a and 3b). Next, the uneven bone edges were smoothed with spongiosa, the buccal and labial periosteum was extended in the customary way, and the wound was closed in a tension-free manner. The sutures were removed 7 to 10 days later. The following postoperative regimen was applied to avoid infection: Ciprofloxacin 500 mg 2 times daily (Ciprobay, Bayer, Germany); and ibuprofen 400 mg 3 times daily to reduce pain and swelling (Klinge Pharma, München, Germany). The patients were instructed to not wear any removable prosthesis for 30 days and not to blow their noses for 7 days.

After a healing time of 6 months, implants were placed. Sixteen cylindric bone biopsies from the grafted posterior maxilla were taken (2 from the experimental and 2 from the control side) from every patient using a trephine bur (Straumann Instruments, Straumann Institut, Waldenburg, Switzerland) with an inner diameter of 2 mm and an outer diameter of 3 mm. Implants were placed in the osteotomy sites prepared at the time of biopsy sampling. (The cortical bone used for the onlay plasty was not in the sample.)

Figs 1a to 1d Preoperative 3D computerized tomograms of the 4 patients. A large part of the residual alveolar crest has thinned to a fine edge in the horizontal and sagittal directions.

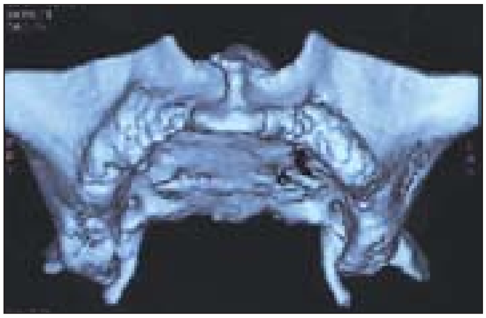


Fig 1a Patient 1.

Fig 1b *(Right)* Patient 2.

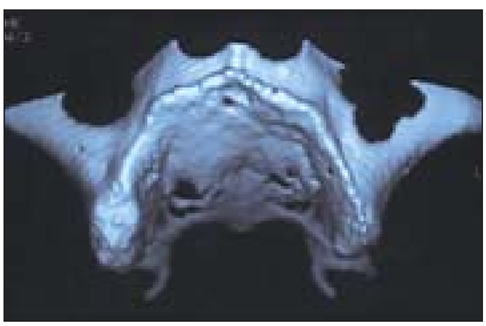


Fig 1c Patient 3.

Fig 1d *(Right)* Patient 4.

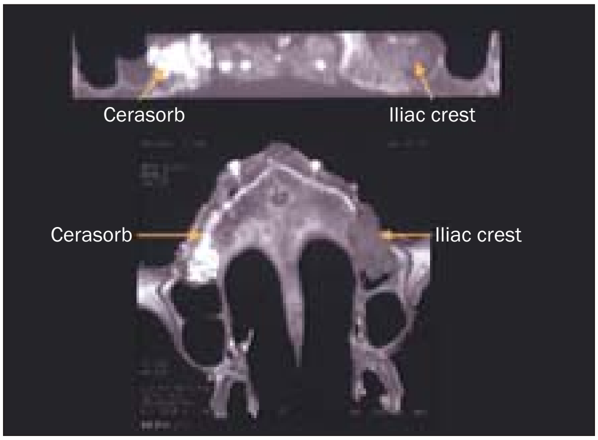
Figs 2a to 2d Preoperative 2D computerized tomograms of the 4 patients. The situation at the residual sinus floors is well illustrated. The bony recesses in the sinus are clearly revealed.

Fig 2a Patient 1.

Fig 2b Patient 2.

Fig 2c Patient 3.

Fig 2d Patient 4.



Figs 3a and 3b Two- and 3-dimensional CT reconstructions of patient 4 after the first surgery. In Fig 3a, the bilateral sinus grafts are easily visible from horizontal and axial photographs. In the 3D rendition (Fig 3b), the onlay plasty is clearly revealed. (The 2 to 3 cm of cortical bone and the microscrews on the lateral wall of the maxilla can be seen.)

Histology and Histomorphometry. Biopsy samples were fixed in 4% formaldehyde, dehydrated in an ascending alcohol series, and embedded in methylmethacrylate resin. Histologic sections were made in the longitudinal plane with a Jung-K microtome. Sections were stained with hematoxylin and eosin, toluidine blue, and Goldner's trichrome method for light microscopy. The Cerasorb particles were achromatic. If they had broken out of the section, their places were recognizable because of their characteristic shape and size, or because of the granule remnants at the interface between the Cerasorb granules and the surrounding tissue.

Sections for histomorphometry were taken from 4 levels of each sample, with an interval of 150 µm between them. Measurements were performed semiautomatically by means of a microscope equipped with a drawing tube (Leitz, Wetzlar, Germany), cursor, and digitizing tables that was connected to a computer using Osteoplan software. The measured values were: total biopsy area (mm^2), bone area (mm^2), graft area (mm^2), and soft tissue area (mm^2).

RESULTS

Clinical Observations

No postoperative complications occurred in any of the patients. Normal wound healing was observed after both the first and the second operations. A minor nosebleed was observed in only 1 patient.

Radiology

General Observations. Routine panoramic radiographs clearly showed the positions of both types of graft material and the height of the new sinus floor. The autogenous bone was initially less visible than the Cerasorb on the radiographs. New bone formation could be clearly followed for both materials. The 2D CTs supplemented the panoramic radiographs. In the planning of surgery, the thickness and width of the alveolar bone and the process of new bone formation could be better assessed with the sagittal and axial images than with a panoramic radiograph image (Figs 3a and 3b). As for the 3D CT reconstruction, most information was provided by the anteroposterior views from among the sagittal exposures (Figs 4a to 4c), the lateral views from among the horizontal photographs, and the inferosuperior views from among the axial exposures (Figs 5a and 5b).

Detailed Observations. In treatment planning, the 2D CTs clearly revealed the bony recesses in the sinus. Simulation of the sinus grafting was more dramatic in the 2D exposures than in the 3D exposures (Figs 6a to 6c).The postoperative sinus graft height and new sinus floor were best seen in the anteroposterior views, and the ossification process was best followed here (Figs 4a to 4c).

With 3D images taken laterally, good assessments could be made of the mass of the sinus graft, the relative conditions of the new sinus floor, and the implants (Figs 6a to 6c). From photographs taken soon after the first surgery, by assessment of the density of the graft, the incorporation could be followed well in the later images (Figs 4a to 4c).

Figs 4a to 4c Consecutive 3D computerized tomograms of patient 1.

Fig 4a Preoperative image. It is clearly visible that, on the right side, continuity of the bony sinus floor is missing for 2 cm. On the left side, it is less than 3 mm.

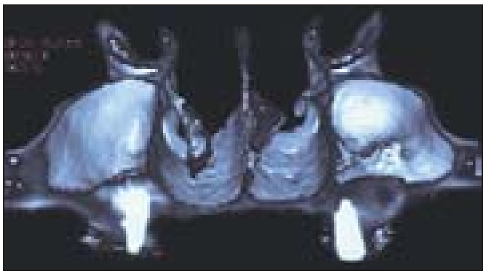


Fig 4b Postoperative picture. The bilateral sinus grafts are clearly visible (Cerasorb in the right maxilla, and autogenous bone in the left maxilla). The symmetric onlays (cortical bone), screwed outside the maxilla, can be seen under the sinus grafts.

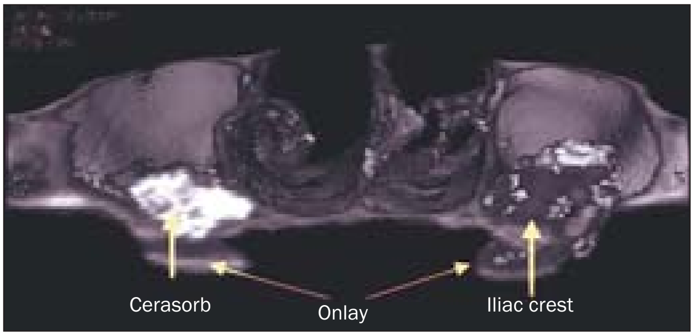
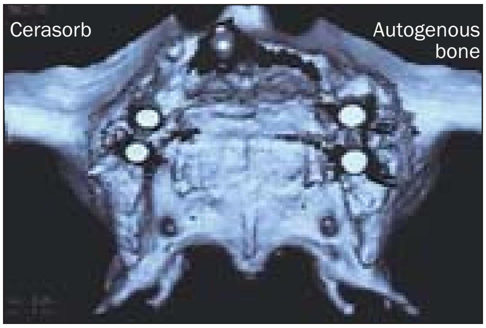
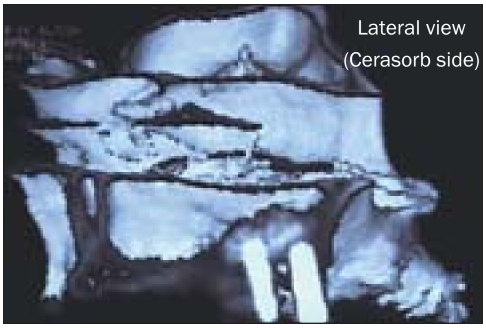


Fig 4c Six months later, just after bilateral implantations, the new sinus floors are clearly visible. On the right side, the Cerasorb graft is less radiopaque than in the postoperative view.





Figs 5a and 5b Three-dimensional CT reconstructions of patient 1 after implantation. *(Left)* The situation of the 4 implants in the reconstructed maxilla is visible. *(Right)* The volume of the incorporated sinus graft, the healed new sinus floor, and the position of the 2 implants may be established.

The 2D axial radiographs were well supplemented by the 3D radiographs. It was possible to assess the intact new sinus floor and, in the consecutive images, to follow the healing of the new sinus floor (Figs 5a and 5b). (The Cerasorb graft is less radiopaque than before, and the autogenous bone is outlined better than previously.)

The consecutive images also clearly revealed changes in the graft materials and their incorporation. Cerasorb is markedly more radiopaque than the autograft. After 6 months, the Cerasorb could be seen to have changed slightly in the CT images; the contour of the bony parts around the graft merely became more defined. Together with the absorption of Cerasorb and the simultaneous formation of new bone, the graft became similar to the bone (Figs 4a to 4c). Decreased graft height was not observed in the 3D computerized tomograms; 2D CT is more suitable for determining this.

Figs 6a to 6c Consecutive 2D CTs of patient 2. Simulation of the bilateral grafting. The postoperative situation is similar to that planned.

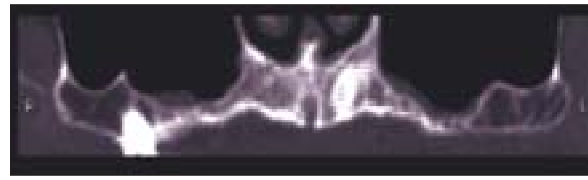


Fig 6a Preoperative situation.

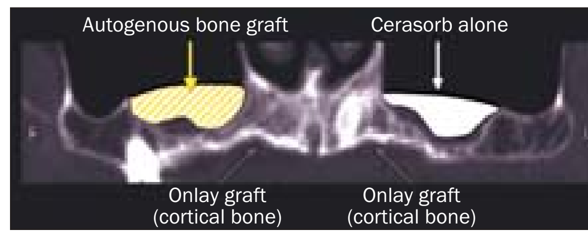


Fig 6b Treatment planning.

Fig 6c Postoperative situation.

Histology

Biopsy samples taken from the control side 6 months postoperatively showed formation of mature lamellar bone. The bone marrow was partly fibrous and partly cellular. In the bone trabeculae, osteocytes could be observed in their lacunae. Signs of remodeling were relatively rare; osteoblast activity at the osteoid surface and lacunar resorption by osteoclasts were rare findings. Autogenous bone graft remnants could be seen in the 4 patients as homogeneous, partially resorbed bone tissue without osteocytes (Fig 7a).

Biopsies from the experimental side contained remnants of Cerasorb granules. Clear identification of some Cerasorb particles in the histologic preparation remained possible after 6 months (Fig 7b). These were embedded in newly formed bone, osteoid tissue, and soft tissue in various proportions. Their form was different because of the partial resorption. The bone tissue was predominantly lamellar type. Bone deposition could be observed frequently along the surface of the remnants of partially resorbed Cerasorb granules. Intermingled with the disintegrated Cerasorb granules, connective tissue proliferation and angiogenesis were the predecessors of bone formation (Figs 8 and 9). Inflammatory reactions or foreign-body giant cell reactions did not occur in the experimental samples.

Histomorphometry

After 6 months, relatively low bone density was observed both on the experimental side and on the control side in the samples from patient 1. On the experimental side, partially resorbed Cerasorb granules were embedded in newly formed bone and soft tissue, their areas comprising 8.1% and 7.7%, respectively, of the 2 samples. The majority of the newly formed bone tissue proved to be of mature lamellar type; it accounted for 21.2% and 29.9% of the total area of the 2 samples. On the control side in the same patient, the graft area was 8.9% and 8.45% and the bone area was 20.16% and 27.75% in the 2 samples examined.

In the second patient, a relatively high quantity of Cerasorb granule remnants could be observed on the experimental side (Fig 10a), with areas of 30.23% and 21.62% in the 2 samples. Newly formed bone comprised 13.9% and 19.35% of the total area. On the control side, some graft remnants could be observed. Newly formed bone was relatively extensive, at 42.2% and 41.2% (Fig 10b).

In the third patient, small remnants of Cerasorb granules covered 9.3% and 8.7% of the total area on the experimental side. The new bone production was relatively high, at 35.8% and 33% for the 2 parallel samples. On the control side, small remnants

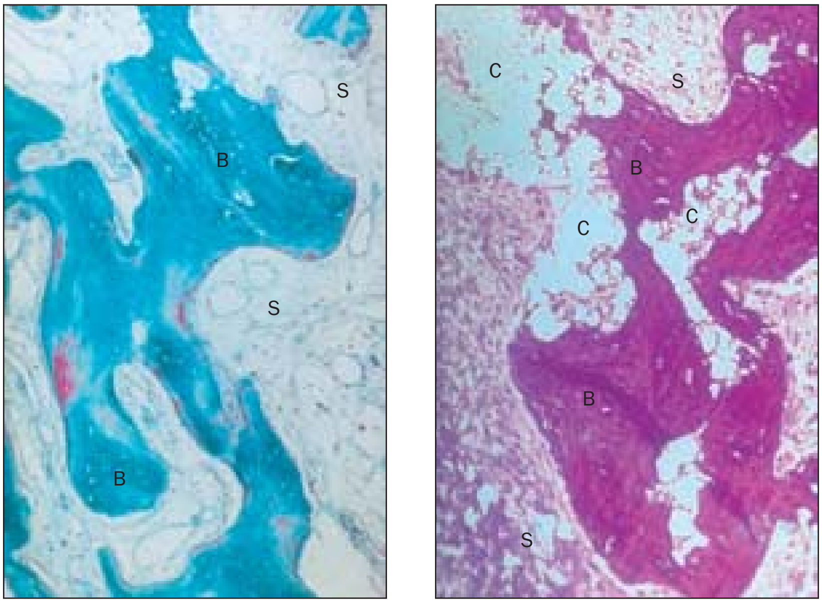


Fig 7a Patient 1, control side. Lamellar bone formation and osteocytes in their lacunae can be seen (Goldner's trichrome; original magnification ×25). B = bone; S = soft tissue.

Fig 7b Patient 1, experimental side. Lamellar bone formation intermingled with Cerasorb remnants can be observed (hematoxylin and eosin; original magnification ×25). B = bone; C = Cerasorb; S = soft tissue.

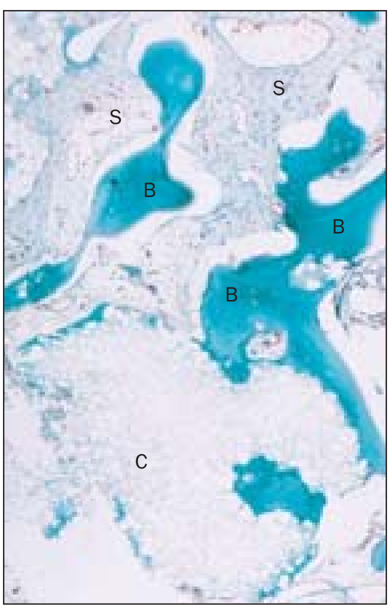


Fig 8 Patient 2, experimental side. New bone formation can be seen along the surface of the resorbing Cerasorb granule (Goldner's trichrome; original magnification ×10). B = bone; C = Cerasorb; S = soft tissue.

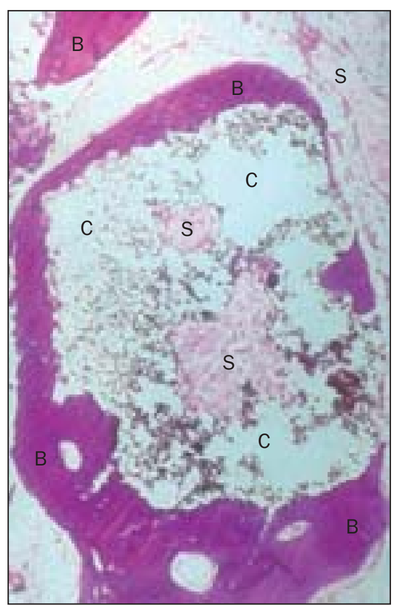


Fig 9 Patient 3, experimental side. Connective tissue proliferation is apparent in the center of the Cerasorb granule, along with peripheral bone apposition (hematoxylin and eosin; original magnification ×40). B = bone; C = Cerasorb; S = soft tissue.

of the old bone graft could be seen. The newly formed bone area was 40.5% and 45.47%.

In the fourth patient, bone production was satisfactory on both sides (Figs 11a and 11b). The area of Cerasorb granule remnants on the experimental side was not very high (11.8% and 9.03%, respectively). The newly formed bone area comprised 37.7% and 44.08% of the 2 samples. On the control side, some old bone particles could be observed (7.99% and 5.52%), while the newly formed bone area made up 42.19% and 36.9% of the samples. In this case, the extent of bone formation was similar on the 2 sides (Table 1).

DISCUSSION

To what degree do 2D and 3D images aid in the planning, control, and evaluation of sinus grafting? What images are necessary, and when and in what situations? In an earlier study[33] in which prospective study methods were used to follow 12 patients with the aid of 2D and 3D CT after sinus elevation with various graft materials, 4 radiographs were obtained: preoperatively, postoperatively, before loading of the implants, and 1 year after loading. In the present study, just 3 exposures were made, since the overall duration of the investigation barely exceeded 6 months.

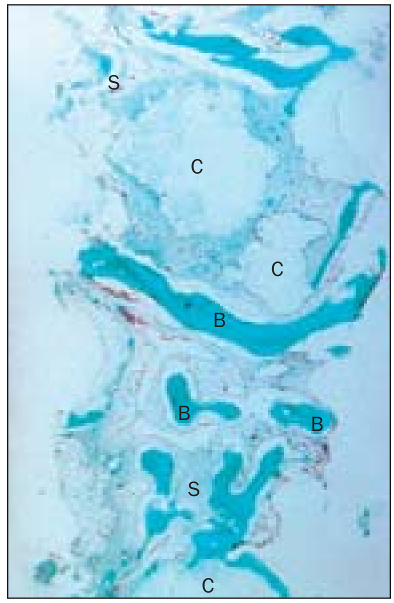
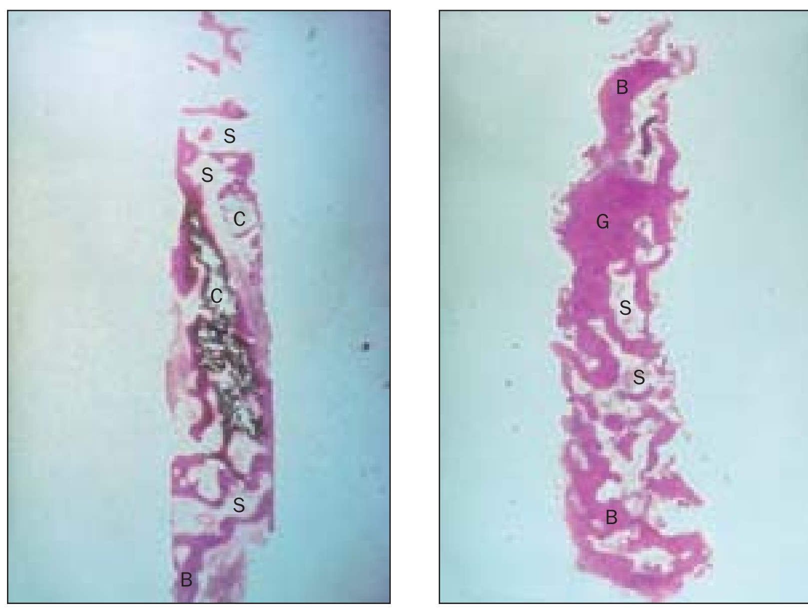


Fig 10a Patient 2, experimental side. Section reveals low bone density and high quantity of Cerasorb granules (Goldner's trichrome; original magnification ×4). B = bone; C = Cerasorb; S = soft tissue.

Fig 10b Patient 2, control side. Satisfactory bone formation is apparent (Goldner's trichrome; original magnification ×4). B = bone; S = soft tissue; G = bone graft.



Figs 11a and 11b Patient 4. A good rate of bone formation is seen on both the experimental side *(left)* and on the control side *(right)* (hematoxylin and eosin; original magnification ×1). B = bone; C = Cerasorb; S = soft tissue; G = bone graft.

Table 1 Morphometric Data of Biopsy Specimens

		Experimental side (Cerasorb)				Control side (autogenous bone)			
		Total area (mm^2)	Graft area (mm^2)	Bone area (mm^2)	Soft tissue area (mm^2)	Total area (mm^2)	Graft area (mm^2)	Bone area (mm^2)	Soft tissue area (mm^2)
1	Sample I	12.63	1.03 (8.1%)	2.67 (21.2%)	8.93 (70.7%)	13.39	1.20 (8.9%)	2.70 (20.16%)	9.49 (70.94%)
	Sample II	10.52	0.82 (7.7%)	3.15 (29.9%)	6.55 (62.4%)	10.90	0.92 (8.45%)	3.02 (27.75%)	6.96 (63.8%)
2	Sample I	4.73	1.43 (30.23%)	0.66 (13.9%)	2.64 (55.87%)	10.43	1.01 (5.7%)	4.40 (42.2%)	5.02 (52.1%)
	Sample II	9.30	2.01 (21.62%)	1.80 (19.35%)	5.49 (59.03%)	9.58	0.70 (11.6%)	3.95 (41.2%)	4.93 (47.2%)
3	Sample I	11.02	1.01 (9.3%)	3.95 (35.8%)	6.06 (54.9%)	5.35	0.53 (10.0%)	2.17 (40.5%)	2.65 (49.5%)
	Sample II	9.26	0.81 (8.7%)	3.06 (33.0%)	5.39 (58.3%)	8.82	0.69 (7.83%)	4.01 (45.47%)	4.12 (46.7%)
4	Sample I	11.15	1.32 (11.8%)	4.21 (37.70%)	5.62 (50.50%)	8.49	0.70 (7.99%)	3.56 (42.19%)	4.23 (49.82%)
	Sample II	10.32	0.96 (9.03%)	4.52 (44.08%)	4.84 (46.89%)	11.08	0.61 (5.52%)	4.09 (36.9%)	6.38 (57.58%)

The preoperative radiographs are indispensable for orientation and planning. The 2D and 3D radiographs can be utilized for classification of the edentulous jaw, and hence for establishment of the parameters that could suggest one form of treatment rather than another (Figs 1 and 2). The 3D CTs permitted a decision in the present patients in favor of bilateral sinus floor elevation and simultaneous onlay plasty. Similarly to the Sim/Plant method (Columbia Scientific, Columbia, MD), planning is simpler from 2D CTs; the simulation was also performed in this way (Figs 5a and 5b). The simulation is more important for educating patients than in preparing the objective surgical plans.

From a comparison of the postoperative CT and the CT of the planned graft, it is possible to establish the height of the graft and to learn whether the graft uniformly fills the planned volume (this refers mainly to the palatinal area). After implants are placed, the distance between the apices of the implants and the new sinus floor may be measured. Conclusions may be drawn as to the incorporation of the graft from the changes in density. The 2D CT images employed in the planning are well known on the basis of the Sim/Plant software. The postoperative examination, however, is not as well known. In fact, in the literature dealing with sinus grafts, radiographs similar to the present study have not been seen.

It should be stressed that CT does not replace panoramic radiographs; no matter how useful the information gained from the various CT images, panoramic radiographs will remain the routine method in the future. Indeed, panoramic radiographs are indispensable for an appropriate evaluation of the CT images. The CT information provided is necessary when:

- Alveolar bone atrophy is so extensive that only a delayed approach is possible;
- Complication appears probable;
- Healing is slower than expected;
- In more difficult situations, exact documentation is necessary for the surgeon and for the patient.

Results of the CT examinations relating to the use of autogenous bone versus Cerasorb permit conclusions concerning the healing and incorporation of the graft. It is not only a question of the opposite changes in density (the density of Cerasorb decreases, while that of the autogenous bone increases as a function of time); the process of normal healing can be well followed. Graft integration can be seen and followed better for Cerasorb than for autogenous bone. Because of the high density of the material, immediate observation can determine whether the granules do not reach the planned site.[33] This is scarcely possible with autogenous bone. Histologic and histomorphometric methodology can be used to demonstrate any apparent differences between autogenous bone and bone substitutes as graft materials.

Comparison of the present results with those of human studies by other authors reveals the following similarities and differences. The data of Tadjoedin and associates[26] and Yildirim and coworkers[18] indicated a similar rate of new bone formation. Tadjoedin and associates[26] applied virtually the same method on the control side, but on the experimental side they mixed autogenous bone with bioactive glass in a ratio of 1:1. In their evaluation, they noted that "… bioactive glass particles in the size range 300 to 355 µm clearly show a bone augmenting capacity, and the cotransplantation of autogenous bone may not be necessary for sinus floor augmentation. However, further studies to reduce the graft amount are necessary." The present work may be considered one such study, since the β-tricalcium phosphate too was totally resorbed. Calcium and phosphorus are needed for bone-building, whereas the role of the silicate in bioactive glass is questionable.

Yildirim and coworkers[18] applied Bio-Oss as a graft material in combination with venous blood. After 6 months, they observed close to 15% new bone formation, while 29% of the Bio-Oss remained. However, there was no direct or indirect control. Moy and colleagues[29] performed 8 sinus augmentations on 5 patients (3 bilateral and 2 unilateral). They employed the same material on both sides (4 different graft materials). Accordingly, a comparison of the use of different materials in the same patient was not possible, and only individual cases were evaluated.

Both the published data and the present findings[42,43,47,49] indicate that pure-phase β-tricalcium phosphate resorbs completely. Furthermore, the current investigation lends support to the view that its use eliminates the necessity for the cotransplantation of autogenous bone. The present study involved only 4 patients; strong patient selection was necessary mainly for ethical reasons. The onlay plasty required autogenous bone, and a control was therefore given. It was considered important that a control be present in the same individual.

Comparison of the bone-production capacity of 2 different graft materials (Cerasorb and autogenous bone) revealed that new bone formation in the surgical area can be influenced by several factors. In patient 1, the relatively low rate of new bone formation was similar on both sides. This supports the idea that slow bone formation is a result not only of local circumstances, but rather of general factors.

In patient 2, the bone-forming capacity was excellent on the control side. On the experimental side, remnants of Cerasorb granules reduced the quantity of bone tissue, but clinically the implants exhibited good primary stabilization. This demonstrated that not only is Cerasorb an adequate, osteoconductive bone-replacing material, but its remnants apparently harden the new bone and promote primary stabilization of implants. Later, as resorption of the Cerasorb occurs, the newly formed bone will ensure stabilization.

Patients 3 and 4 provided good examples of successful bilateral bone grafting. The bone density was quite similar on the 2 sides, and the clinical results were quite satisfactory. In these patients, quantitative measurements confirmed the positive effect of Cerasorb on new bone formation.

CONCLUSIONS

In 3 of the 4 patients, new bone formation was similar on the 2 sides. Where the Cerasorb was less well resorbed, the new tissue formed proved to be good supportive tissue. Accordingly, when comparing the present results with the findings of other authors, β-tricalcium phosphate may be considered a good graft material even without autogenous bone. Through the application of platelet-rich plasma, a relatively simple procedure, the rate of bone formation may be accelerated still further.

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