Marcus Gerressen
Benita Hermanns-Sachweh
Dieter Riediger
Ralf-Dieter Hilgers
Hubertus Spiekermann
Alireza Ghassemi

Purely cancellous vs. corticocancellous bone in sinus floor augmentation with autogenous iliac crest: a prospective clinical trial

Authors' affiliations:
Marcus Gerressen, Dieter Riediger, Alireza Ghassemi, Department of Oral, Maxillofacial and Plastic Facial Surgery, University Hospital of the Aachen University (RWTH), Aachen, Germany
Benita Hermanns-Sachweh, Institute of Pathology, University Hospital of the Aachen University, Aachen, Germany
Ralf-Dieter Hilgers, Institute of Medical Statistics, University Hospital of the Aachen University, Aachen, Germany
Hubertus Spiekermann, Department of Prosthodontics, University Hospital of the Aachen University, Aachen, Germany

Correspondence to:
Dr Dr Marcus Gerressen
Department of Oral, Maxillofacial and Plastic Facial Surgery,
University Hospital of the Aachen University (RWTH)
Pauwelsstraße 30, 52074 Aachen,
Germany
Tel.: +49241 8035438
Fax: +49241 8082430
e-mail: marcus.geressen@post.rwth-aachen.de

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Abstract

Objectives: Among the different graft materials being applied in sinus elevation surgery autogenous bone, especially from the iliac crest, is considered to be the graft of choice. The goal of this prospective study was to investigate whether purely cancellous transplants of this donor site lead to significantly better results regarding bone quantity and quality when compared to corticocancellous iliac bone grafts.

Material and methods: Fifteen patients suffering from extreme maxillary atrophy underwent bilateral sinus floor augmentation with grafts from the iliac crest consisting of purely cancellous bone (PCB) for the right side and a mixture of 50% cancellous and 50% cortical bone for the left side, respectively. Bone samples that were taken during implant insertion were examined histologically for semiquantitative assessment. In addition, bone density was measured histomorphometrically. Data were statistically analyzed by a repeated measures analysis of covariance model and post hoc paired *t*-tests as well as Pearson's correlation analysis.

Results: Semiquantitative analysis of bone quality resulted in comparable results for both graft preparations while bone density was significantly higher in the PCB group. Without consideration of the different transplant groups, there was neither a significant correlation between patients' age and bone density nor bone quality. Differences between the genders could not be observed either.

Conclusions: Because of better bone density, the PCB graft from the iliac crest remains our gold standard. Even in elderly patients, autogenous grafts can be utilized without losses in the properties of the resulting bone.

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Treatment of the atrophic edentulous posterior maxilla with a fixed partial denture or a fixed prosthesis is a major challenge. Insertion of dental implants into this region poses a problem for the surgeon in that bone volume is insufficient and bone quality is poor due to resorption of the alveolar ridge with decrease of trabecular bone density and due to increasing pneumatization of the maxillary sinus following tooth loss (Aimetti et al. 2001; Vachiramon et al. 2002; Ozyuvaci et al. 2003). Among the grafting techniques developed to provide adequate bone stock for osseointegrated implants, sinus floor elevation – as first described by Tatum at the implant meeting held in Birmingham, Alabama, in 1976 and published subsequently by Boyne & James (1980) – is probably the most widely used and best-studied method (Boyne & James 1980; Tatum 1986).

Innumerable grafting materials have been proposed and utilized for the augmentation procedure including allografts, xenografts, alloplastic materials as well as composite grafts composed of different types of transplants and even tissue-engineered bone (Yildirim et al. 2000; Schimming & Schmelzeisen 2004; Szabo et al. 2005; Serra E Silva et al. 2006). However, in spite of the continuous development of bone-substitute technologies, the autogenous bone graft is currently still considered the gold standard (Haas et al. 1998; Jensen et al. 1998; Lundgren et al. 1999; Yildirim et al. 2000; Jakse et al. 2001; Karabuda et al. 2001; Allegrini et al. 2003) due to its superiority in osteoinductivity, osteoconductivity and non-immunogenecity (Moy et al. 1993; Triplett & Schow 1996; Serra E Silva et al. 2006). Particularly, autogenous spongiosa is regarded to be of high biological value (Jensen et al. 1990, 1998; Tidwell et al. 1992; Lazzara 1996; Jakse et al. 2001).

The most common extraoral donor site for autogenous bone grafts is the ilium. In the past, iliac crest bone transplants turned out to be highly suitable for maxillary augmentation, especially when large amounts of both cancellous and cortical bone are needed (Chanavaz 1990; Khoury 1999; Jakse et al. 2001; Karabuda et al. 2001). In order to reduce the donor site morbidity compared with the conventional technique, Caminiti et al. (1999) suggested the use of a power-driven trephine penetrating the bone through a stab incision to the periosteum for the procurement of the iliac bone. Thus, up to 3.2 cm^3 of bone can be obtained. For the traditional open approach, the overall incidence of complications is estimated at 8–10% (Younger & Chapman 1989; Kline & Wolfe 1995).

Although there are numerous donor sites available for autogenous bone grafts, such as the proximal tibiae offering a suitable alternative to harvest large amounts of spongiose bone (Jakse et al. 2001), cancellous bone from the iliac crest still remains the graft of choice for sinus elevation surgery (Lazzara 1996). In general, the ilium contains a higher quantity of cortical compared with cancellous bone. Therefore, we investigated in a prospective clinical trial the effect of a purely cancellous iliac bone graft on the resulting bone quantity and bone quality of the recipient site when compared with a mixture of 50% spongiosa and 50% cortical bone for grafting.

Material and methods

Patients

The purpose of this investigation was to obtain information on the resulting bone characteristics of different preparations of iliac crest grafts. Fifteen patients, nine women and six men, their age ranging from 38.9 to 72.4 years (mean 54.9 years) were recruited into this study. All suffered from a severely atrophic posterior maxilla with a residual crest height of <5 mm (2.3 mm on average). In all study participants, a bilateral sinus elevation procedure was carried out with autogenous bone grafts from the anterior iliac crest using pure spongiosa to elevate the respective right-sided sinus floors (purely cancellous bone side = PCB side), whereas the respective left sides were augmented with a mixture of 50% cancellous and 50% cortical bone (corticocancellous bone side = CCB side). Ten patients showed maxillary atrophy of such an extent that onlay bone grafting with corticocancellous grafts harvested from the anterior ilium became necessary in addition to sinus lifting. None of the selected patients showed clinical or radiological signs of maxillary sinusitis preoperatively and during surgery sinus mucosa appeared to be free of inflammation in all of them.

Surgical procedure and harvesting of the bone samples

All augmentation procedures took place under general anesthesia. The operation technique for the sinus floor elevations corresponded to Tatum's classical description (Tatum 1986). Simultaneously with maxillary exposure, a bone graft was harvested from the anterior iliac crest by a second surgical team. Starting with a skin incision in the direction of the tension lines 3–4 cm cranial to the anterior superior iliac spine, the abdominal muscles were divided by sharp dissection, and then the iliac crest and the inner surface of the iliac ala were exposed over a length of about 5–6 cm. Subsequent to completion of the osteotomy to the desired size, a corticocancellous block graft was removed with preservation of the outer cortical layer and further cancellous bone was collected from the adjacent marrow space using appropriately sized Volkmann's spoons. After the cancellous bone had been carefully divided from the block graft, both the cortical graft and the spongiosa were particulated in a Tessier bone mill (Stryker-Leibinger, Freiburg, Germany) separately from each other. With the aid of a 20 ml syringe, a mixture of equal parts of the particulated cancellous and the particulated cortical bone was produced and used as graft material for the newly created space between the bony sinus floor and the Schneiderian membrane on the left side (CCB side). In contrast to this, the right-sided sinuses were, respectively, augmented with PCB (PCB side). In cases ($n = 10$) in which the advanced maxillary atrophy made an additional onlay grafting necessary, the harvested corticocancellous block graft was first segmented into smaller bone blocks, which were trimmed and adjusted to the buccal and/or the crestal contour of the alveolar ridge before they were fixed by miniscrews. The remaining bone gaps were filled with spongiosa.

Provided there were no known allergies and no general contraindications, clindamycin at a dosage of 600 mg three times per day for 1 week and 180 mg gentamicin once daily for 3 days were given intravenously as antibiotic prophylaxis. All sutures intraorally and at the hip were removed on the 10th postoperative day. During the first 7–10 days, nutrition was provided via a thin nasogastral feeding tube. Patients were not allowed to blow their nose and advised to administer decongesting nose drops (xylometazoline 0.1%) five to six times per day in both nasal cavities over a period of 2 weeks. They were also instructed not to wear their maxillary prosthesis for at least 14 days.

During implant surgery after a mean healing time of 5.2 months (range: 4–7.3 months), at least one bone biopsy from each augmented maxillary sinus was taken using a trephine burr with an inner diameter of 2 mm and an outer diameter of 3 mm (Fig. 1). The drill speed was defined to be 800 rounds per minute. After fixation in a 3.5% formaldehyde solution, the bone samples were forwarded to the Institute of Pathology of the Aachen University Hospital for histological examination.

Histology and histomorphometry

Histological sections were prepared in the longitudinal direction of the specimens and

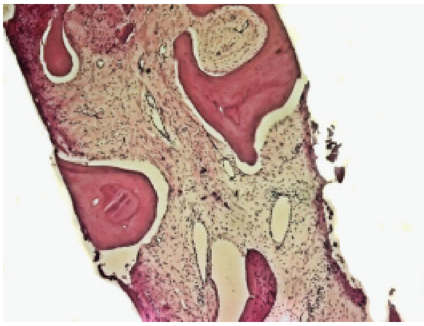

Fig. 1. Longitudinal section of a bone cylinder with hematoxylin–eosin staining at $\times$ 4 objective magnification.

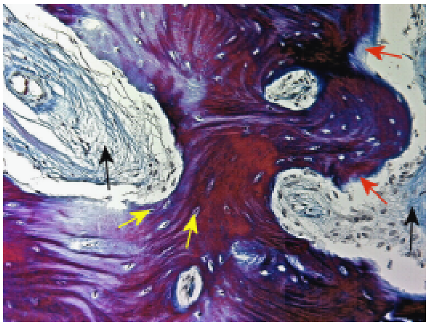

Fig. 2. Histological slide with Ladewig's trichrome stain revealing bone trabecula containing osteocyte lacunae with vital osteocytes (yellow arrows). The trabecula are covered by a sparse seam of osteoblasts providing bone apposition (red arrows). In between, fibrosed marrow spaces (black arrows). At $\times$ 16 objective magnification.

***Table 1*. Assessing criteria and points system for semiquantitative analysis of bone quality (bone quality index)**

Histological criteria	Intensity	Points value*
Inflammatory signs	None	0
	Little	−1
	Moderately	−2
	Much	−3
Cell content and degree of maturation of the bone	None	0
	Little	1
	Moderately	2
	Much	3
Signs of bone remodeling and osteoid formation	None	0
	Little	1
	Moderately	2
	Much	3
Cellular elements in the trabecular spaces	None	0
	Little	1
	Moderately	2
	Much	3

*In not clear findings half points were given.

they were stained with hematoxylin–eosin and Ladewig's trichrome in the customary manner (Fig. 2). From these bone sections, bone quality, as well as bone density were assessed. For ascertaining bone quality a semiquantitative assessment scheme was used, which is composed of the following four evaluation criteria (Schultze-Mosgau et al. 2001): (1) inflammatory signs, (2) cell content and degree of maturation of the bone, (3) signs of bone remodeling and osteoid formation and (4) proportion of cellular elements in the trabecular spaces. According to the histological findings, a value ranging from one point to three points (in case of 'inflammatory signs' with a negative sign) was assigned to each feature, resulting in a quality index. Thus, a higher score of quality index indicates better bone quality (Table 1).

In order to determine bone density defined as the percentage proportion of mineralized tissue to the entire tissue, a computer-based histomorphometric analysis system was utilized comprising a Zeiss light microscope (model diaplan, Carl Zeiss MicroImaging GmbH, Göttingen, Germany), connected to a personal computer via a charged coupled device camera, and the analysis software Leica QWin (Leica Mikrosysteme Vertriebs GmbH, Bensheim, Germany). With the camera's live image being displayed on the PC screen, the sections of each sample were first surveyed at a magnification of $\times$ 40 in order to identify the pristine sinus bone and the possible onlay bone graft. Then they were scrutinized at a magnification of $\times$ 160. Areas on the slides with bone of the original sinus floor or parts of the onlay bone graft were not included for analysis. In 50 visual fields per augmented sinus, the area of mineralized tissue within the measuring frame of 229,456.7 μm^2 determined by the software was measured. For this purpose, all bony structures within the frame were outlined with the mouse cursor whereupon the included area was colored, calculated and added up automatically by the software (Fig. 3). Subsequently, the sum of all measured areas was placed in proportion to the overall area of the 50 measuring frames and, thus, bone density was determined.

Statistical analysis

In addition to descriptive data analysis, a repeated measures analysis of a covariance model was fitted to study the effect of the grouping factor gender and the covariables healing time and age on the treatment-dependent observations of the bone quality and bone density. Moreover, we used post hoc paired *t*-tests to compare the difference in bone quality and bone density resulting from the intraindividual treatment applications. *P*-values resulting from the statistical test that fell below the 5% margin were considered as significant. Statistical computations were performed using the Statistical Analysis System (SAS) software and the Statistical Package for Social Sciences (SPSS), version 14, under Windows XP.

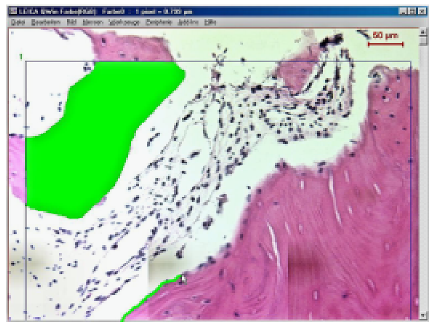

Fig. 3. Screenshot of the working window of the Leica QWin software used during determination of the bone area: after the trabecula have been outlined by the mouse cursor in their entire circumference, they are dyed green and their area is ascertained automatically by the software.

Results

Clinical observations

In none of the patients did postsurgical complications such as wound infection, infection of the graft, major bleeding or

Table 2. **Survey of the included patients' data**

Case no.	Age (years) Gender	Healing time (months)	Bone density(%)		Bone quality (points)	
			Purely cancellous bone (PCB) side	Corticocancellous bone (CCB) side	PCB side	CCB side
1	43.25 w	4	22.63	29.08	4	2.5
2	46 w	5	60.37	30.78	5	5
3	72.4 m	5	23.78	26.04	5.5	6
4	66.8 m	4.4	36.27	28.18	2.5	4.5
5	43.1 m	6	52.32	32.22	4.5	3.5
6	60.6 w	4.3	31.30	25.22	5.5	6.5
7	62.75 w	6	42.91	28.89	3.5	4.5
8	57.75 w	4.2	44.90	39.48	2.5	3.5
9	54.16 w	7.3	44.21	29.79	4	3.5
10	38.9 m	6	43.94	25.68	2.5	5
11	48.4 m	4.3	24.84	25.13	6.5	5
12	64.3 w	6.4	26.98	31.70	4	4.5

w, woman; m, man.

Fig. 4. Histological section of the purely cancellous bone side of patient no. 2 with vital spongy bone trabecula enclosing plenty of osteocytes with their lacunae. Only sporadically inflammatory cells (black arrow). hematoxylin–eosin stain, × 16 objective magnification.

persisting swelling occurr. In all cases proper wound healing of both oral and iliac wounds could be observed. The hospitalization time ranged from 5 to 12 days, with a mean of 7 days. Although during surgery, a small perforation of the Schneiderian membrane that was, respectively, closed primarily with absorbable sutures had taken place in two sinuses, neither clinical nor radiological signs of a maxillary sinusitis were noted in the postoperative course. With regard to donor site morbidity at the iliac crest, none of the study participants experienced residual complaints like sensory disturbances of the lateral femoral cutaneous nerve or gait problems. At the time of implantation, all patients were fully recovered.

In one case, the bone samples removed from one side were too small to enable a representative examination. In another two patients, the bone volume of one maxillary side was insufficient for implant placement, which is why no bone biopsies could be performed. In fact, one side had been elevated with PCB, whereas the maxillary side concerned in the second case had been augmented with a mixture of cortical and cancellous bone. Thus, three of the 15 operated patients could not be included in the analysis, so that the final data processing was confined to the remaining 12 patients. (As the values for bone quality and bone density of the three patients' respective other side are within the simple standard deviation of the 12 evaluated patients' data, they can be left out without distorting the result.)

Histological and histomorphometric analysis

On the whole, both types of transplant, the purely cancellous and the corticocanellous one, result in reliably good bone quality suitable for osseointegration of dental implants (Table 2). In no case was a marked inflammation of the grafted bone observed, and the degree of bone maturation covered a range from at least acceptable to almost excellent (Fig. 4).

The repeated measures ANCOVA model indicated no significant effect of age ($P = 0.3004$), healing time ($P = 0.7895$) and gender ($P = 0.6598$) on the difference of the bone quality as well as on the mean individual bone quality levels (age: $P = 0.4965$, healing time: $P = 0.6527$ and gender $P = 0.5855$). The *t*-test for paired data applied on the differences in bone quality does not indicate any treatment differences ($P = 0.3822$). Thus, the calculated quality index is marginally more high for the CCB side, but the difference compared with the PCB side is not statistically significant (Fig. 5).

Similarly, bone density turned out very well in both kinds of transplant, with a minimum of 22.6% in the PCB side and 25.1% in the CCB side, while the maxiumum values ranged between 39.5% in the CCB side and >60% in the PCB side (Table 2, Fig. 6). Moreover, no significant effect of age ($P = 0.2160$), healing time ($P = 0.2756$) and gender ($P = 0.9508$) was found on the difference of the bone density as well as on the mean individual bone density levels (age: $P = 0.3141$, healing time: $P = 0.4118$ and gender: $P = 0.4984$). The *t*-test for paired data applied on the differences in bone density results in a *P*-value of 0.0219 and thus shows significant treatment differences. The mean bone density differs by −15.55 to −1.491 (95% confidence interval).

In summary, both graft types provide comparably good results with regard to bone quality, whereas the PCB transplant is distinctly superior concerning the resulting bone density. These findings are neither dependent on gender nor on healing time or on age.

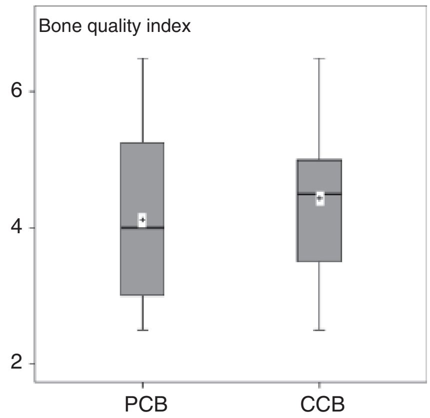

Fig. 5. Boxplots for comparison of the quality indices (in points), respectively, calculated for the purely cancellous bone (PCB) side and the corticocancellous bone (CCB) side.

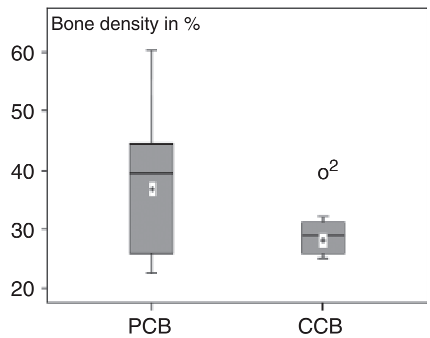

Fig. 6. Comparative presentation of bone density arisen for the purely cancellous bone (PCB) and the corticocancellous bone (CCB) side.

Further statistical analyses

In an additional step, we focused on the autogenous iliac graft as such without differentiating between the above-mentioned two preparations. For this purpose, we performed the statistical analysis on the mean values out of both sides for bone quality and bone density. There was no significant gender difference in bone density or in quality (Table 3). Rather, the confidence intervals suggest equality of these two characteristics in both genders.

As far as age dependence is concerned, our data did not yield any significant correlation either for bone density (Pearson's correlation coefficient $r = -0.33$) (Fig. 7) or for quality ($r = 0.23$) (Fig. 8). The analogous applies to the dependence of bone density on healing time ($r = 0.3$) (Fig. 9). Regarding the relationship between healing time and bone quality, no significant correlation was found either ($r = -0.18$) (Fig. 10).

***Table 3.* The influence of gender on bone density and bone quality**

	Sex	Mean value	Standard deviation	*T*-test	
				P-value	95% confidence interval
Bone density	Male	31.8%	7.3	0.498	[− 6.6; 12.6]
	Female	34.9%	7.4		
Bone quality	Male	4.55 points	1.1	0.565	[− 0.37; 0.37]
	Female	4.18 points	1.0		

On balance, bone quality as well as bone density turned out to be stable within the examined age interval from 38.9 to 72.4 years and, furthermore, they remain almost constant over a period from about 4 to 7 months after surgery. The bone graft properties are not gender specific.

Discussion

The primary purpose of this investigation was to prospectively examine the effect of different preparations of iliac bone grafts on the histological and histomorphometrical bone outcome in sinus lift surgery. As a second important issue, the properties of autogenous bone grafts with regard to healing time, age dependence and gender specifity were analyzed. Thus, precise information about the merits as well as the possible disadvantages of autogenous bone grafting could be obtained.

Bone-substitute materials as an alternative to autogenous bone grafting have been enjoying growing popularity over the past years, particularly in connection with sinus floor elevation surgery, as the harvesting of autogenous bone is said to be inextricably associated with donor site impairment and patient discomfort (Younger & Chapman 1989; Kline & Wolfe 1995; Yildirim et al. 2000; Szabo et al. 2005). Innumerable examinations have been performed in order to compare these substitute materials with autogenous bone with regard to different aspects.

Szabo et al. (2005) reported encouraging results with the β-tricalcium phosphate graft (β-TCP) Cerasorb® (Curasan AG, Kleinostheim, Germany). In a prospective multicenter study, bilateral sinus floor augmentation was performed on 20 selected patients using β-TCP on the experimental side and autogenous bone on the control side. In the histological and histomorphometric examination of bone biopsies taken after 6 months of healing during implantation, no statistically significant difference was observed between the β-TCP side and the control side concerning the quantity and the rate of ossification so that the authors concluded Cerasorb® to be a satisfactory graft material. However, in four of the 20 cases bone density was markedly lower on the side grafted with β-TCP as a result of an inflammatory reaction in one case and a delayed resorption of the alloplastic material in the remaining three cases.

Comparable results were obtained by Suba et al. (2006) in a similarly structured study performed in 17 edentulous patients. Similarly, the authors observed that graft biodegradation was significantly slower on the experimental side grafted with β-TCP. A further investigation by Zerbo et al. (2004) confirmed this delayed rate of bone formation of β-TCP in comparison with autologous bone and, in contrast to the other studies, found a significantly lower bone density for the test side with β-TCP. Considering this, it remains unclear whether dental implants should already be inserted after a graft healing time of 6 months as recommended by the advocates of this alloplastic bone-replacing material (Horch et al. 2004; Suba et al. 2006).

Another popular and widely used bone-substitute material is the xenogenic Bio-Oss® (Geistlich, Wolhusen, Switzerland) comprising bovine bone from which all organic components have been extracted. This inorganic bone material also distinguishes itself through slow resorption and thus delayed formation of new mature bone as compared with autogenous bone grafts. In a prospective investigation of sinus floor augmentations with a mixture of Bio-Oss® and venous blood in 11 patients, Yildirim et al. (2000) observed new bone formation of on average 14.7% after 6.8 months, whereas the xenogenic Bio-Oss® granules

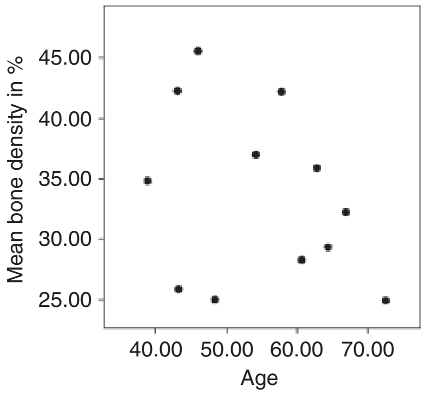

Fig. 7. Relationship between mean bone density and patients' age revealing no significant correlation ($r = -0.33$).

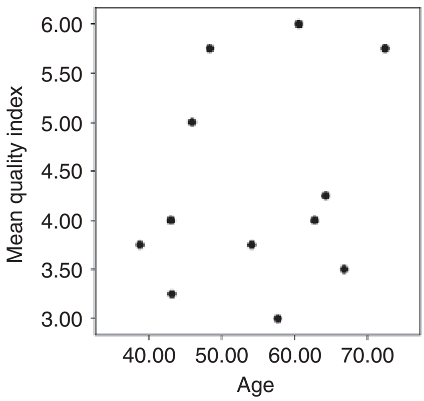

Fig. 8. Points cluster for illustration of the relation between mean bone quality and patients' age not being statistically significant ($r = 0.23$).

held an area of 29.7% in the measured specimens (Yildirim et al. 2000). Other authors even report that residues of anorganic bovine bone particles were still histologically detectable after 4 years (Karabuda et al. 2001).

In contrast to the above observations, our data suggest that there are no significant changes in bone density or quality over a period of 4 to 7 months after grafting with autogenous iliac bone and there is a suitable amount of vital bone for anchorage of dental implants within this time interval.

Contrary to our expectations, neither bone density nor quality was age- or gender dependent, so that general factors, influencing bone metabolism, do not appear to have the same importance in jaw bone as in the rest of the skeletal system. Similar observations have already been described in previous studies (Friberg et al. 2001; Smolka et al. 2006).

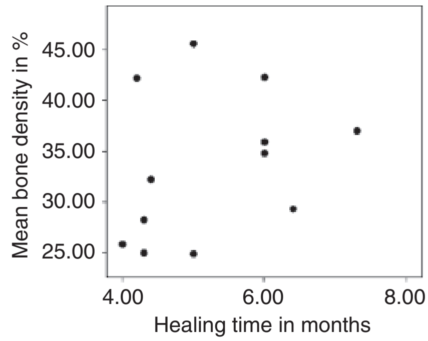

Fig. 9. Points cluster showing no significant dependence of mean bone density on healing time for the time interval examined ($r = 0.3$).

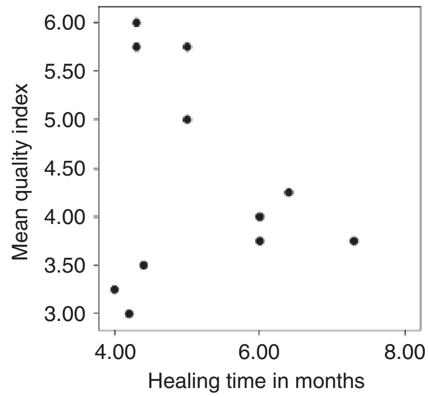

Fig. 10. No significant correlation between mean bone quality and healing time ($r = -0.18$).

There are only a few studies published similar to our report concerning the resulting bone quantity or the quality of different preparations of autogenous bone. Thorwarth et al. (2005) studied 57 patients receiving sinus floor augmentations with autogenous bone from different donor sites (Thorwarth et al. 2005). At the recipient sites, a difference in mineralization was observed depending on the origin of the transplants and even 6 months after grafting the recipient site bone could be assigned to its origin. In a similar manner, we obtained varying results for the different preparations of our grafts from the iliac crest. The purely cancellous graft seems to result in a significantly higher bone density, which means that the PCB graft induces better new bone formation, leading to a narrower network of mineralized tissue and, consequently, to a larger bone surface for implant incorporation. The values determined for bone density correspond to those obtained for autogenous bone grafts in the above-mentioned works (Zerbo et al. 2004; Szabo et al. 2005; Suba et al. 2006).

Unlike this, the outcome with regard to bone quality is comparably good for both types of transplant. Thus, irrespective of the graft composition the resulting bone allows the insertion and osseointegration of dental implants, which is the ultimate treatment goal. Likewise, in the literature, the autogenous graft is regarded to have the best prognosis as an implant site (Kent & Block 1989; Yildirim et al. 2000). Nevertheless, due to the significantly higher bone density and bone quality comparable to the CCB transplant, the PCB graft may have a better osteogenetic potential as it provides a higher amount of osteoinductive and osteoconductive material in the recipient site. This assumption has to be examined in a further investigation concerning the long-term survival of the inserted implants.

However, neither bone density nor bone quality enables us to draw conclusions about the final bone stock. We refrained from measuring the height of bone regeneration in the panoramic X-rays because they would have led to lack of information due to two dimensionality. As an alternative, CT scans or DVTs would have provided more reliable information. Another possibility to detect the amount of bone formation would have consisted in direct measurement of the removed bone specimens, but not all samples were removed in the maximum possible amount. Instead, we relied on the surgeons' impressions during implant insertion: in none of the cases included in the analysis did the surgeons observe a marked difference between the PCB and the CCB side regarding the resulting amount of bone. Of course, this observation remains rather subjective.

In conclusion, our investigation confirms that autogenous bone graft is an excellent graft in sinus elevation surgery irrespective of whether a purely cancellous graft or a mixture containing cortical bone is used. However, due to its significantly better outcome concerning bone density PCB from the iliac crest remains our gold standard. A healing time of 4–7 months until implant insertion seems to be appropriate. In elderly patients, maxillary sinus surgery with autogenous iliac grafts is possible with good outcomes irrespective of gender.

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