The Volume Behavior of Autogenous Iliac Bone Grafts After Sinus Floor Elevation: A Clinical Pilot Study

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Iliac crest is still regarded as one of the most viable source of autogenous graft materials for extensive sinus floor elevation. Three-dimensional resorption behavior has to be taken into account in anticipation of the subsequent insertion of dental implants. We performed 3-dimensional volume measurements of the inserted bone transplants in 11 patients (6 women and 5 men; mean age = 2.3 years) who underwent bilateral sinus floor elevation with autogenous iliac crest grafts. In order to determine the respective bone graft volumes, cone-beam computerized tomography studies of the maxillary sinuses were carried out directly after the operation (T0), as well as 3 months (T1) and 6 months (T2) postoperatively. The acquired DICOM (Digital Imaging and Communications in Medicine) data sets were evaluated using suitable analysis software. We evaluated statistical significance of graft volumes changes using a linear mixed model with the grouping factors for time, age, side, and sex with a significance level of \( P = .05 \). 38.9% of the initial bone graft volume, which amounted to 4.2 cm\(^3\), was resorbed until T1. At T2, the average volume again decreased significantly by 18.9% to finally reach 1.8 cm\(^3\). The results show neither age nor side dependency and apply equally to both sexes. Without functional load, iliac bone grafts feature low-volume stability in sinus-augmentation surgery. Further clinical and animal studies should be done to detect the optimal timing for implant placement.

Key Words: iliac crest graft, sinus lifting surgery, three-dimensional resorption, healing time

INTRODUCTION

Tooth loss in the posterior maxilla and the resulting alveolar ridge resorption often cause difficulties regarding prosthetic restoration. Inadequate treatment results are increasingly leading to more patient requests for an implant-supported dental prosthesis.\(^1\)\(^-\)\(^3\) However, treating the edentulous maxilla with endosteal implants represents a distinct challenge. Because of the insufficient bone height and the poor bone quality caused by atrophy, the surgical conditions for primary insertion of implants are unsuitable in some patients. This is because in addition to the resorption of the alveolar ridge with a marked reduction of cancellous bone, the maxillary sinuses expand in a caudal direction.\(^4\)\(^-\)\(^6\) Among all treatment procedures that restore a sufficient bone height for surgical implantation, sinus floor elevation—as first described by Tatum\(^7\) at the Alabama Implant Congress in 1976 and published by Boyne and James\(^8\) in 1980—is probably the most widely used and best-studied method; it is established today as a standard technique mastered and applied by many surgeons. The question about what graft material should be used for the sinus lifting procedure is, in practice, largely divisive. Therefore, numerous materials, including allografts, xenografts, alloplastic materials, composite grafts composed of different types of transplants, and even tissue-engineered bone have been proposed and used to date.\(^9\)\(^-\)\(^14\) Nevertheless, despite the outstanding treatment results with bone substitute materials, autogenous bone is still a proven and frequently applied graft material.\(^9\)\(^,\)\(^15\)\(^-\)\(^21\) This is especially due to its osteoconductive and osteoinductive qualities, as well as its immunologic harmlessness,\(^14\)\(^,\)\(^22\)\(^,\)\(^23\) whereby the most favorable biological characteristics are ascribed to the cancellous bone.\(^15\)\(^,\)\(^16\)\(^,\)\(^24\) Nonetheless, transplants harvested locally from the mandible or maxillary tuber region do not provide enough bone material for a complete bilateral sinus floor elevation, which requires about 10–15 mL of graft volume.\(^25\)\(^,\)\(^26\) For this reason, in most cases of extensive augmentations, bone from the iliac crest or proximal tibia, which both provide a sufficiently large bone stock, is used.\(^15\)\(^,\)\(^27\) However, the proximal tibia has the disadvantage that the cortical portion of the transplant is limited to only the access window,\(^27\) so that if only bone grafting is necessary in addition to the sinus lifting procedure, the iliac
crescent is indispensable as a donor site.28 Regarding the favorable time for implant insertion, exact information about the 3-dimensional resorption of iliac crest grafts, such as are used in sinus floor elevation, would be very helpful, but there is a lack of sufficient investigations on this matter thus far.6,29–31 Furthermore, the resorption must be taken into consideration for treatment planning in order to find a sufficient bone volume during the subsequent implantation.

The aim of the present clinical study was therefore to quantify the graft’s volume loss after sinus lift surgery with autogenous iliac bone and further to specify the temporal course of transplant resorption.

**Materials and Methods**

A total of 20 patients (12 women and 8 men) ranging in age from 34 to 67 years (mean = 55.2 years) were initially included in the study. All suffered at least unilaterally from an advanced maxillary ridge atrophy with residual crest heights of, on average, 2.7 mm (range = 0.4–4.2 mm), which did not allow primary implantation. For this reason, in all study participants, a unilateral or bilateral sinus lift was initially performed; in 14 patients the procedure was combined with an additional onlay bone grafting. Of the 20 patients, 2 received tibial bone within the augmentation; another patient received autogenous bone mixed with a xenogenic graft material (BioOss, Geistlich, Switzerland). In the remaining 17 patients, sinus augmentation surgery was carried out using autogenous iliac bone exclusively, in 14 of these bilaterally. Only these cases of bilateral sinus floor elevation with autogenous iliac grafts and a complete follow-up were incorporated in the final analysis, but because 3 of the 14 patients did not participate in at least one of the follow-up cone-beam computerized tomographies (CBCTs), final data processing was confined to a total of 11 patients.

These 11 patients, 6 women and 5 men with a mean age of 52.3 years, were all nonsmokers and showed an inconspicuous general anamnesis at the time of surgery. Preoperatively, they showed no clinical or radiological signs of maxillary sinusitis and, intraoperatively, the sinus mucosa was free of inflammation in all patients.

According to the routine follow-up of our clinic, all patients underwent CBCT (slice thickness 0.15 mm; Galileos Comfort, Sirona, Bensheim, Germany) of the maxilla immediately after surgery (T0), as well as 3 months (T1) and 6 months (T2) postoperatively.

**Surgical procedure**

All operations were performed under general anesthesia. The surgical technique for the sinus floor elevations followed Tatum’s classic description with a bone window prepared in the lateral antral wall, which was created piezosurgically in all patients.7

Simultaneously with the exposure of the upper jaw, a second surgical team gathered a monocortico cancellous bone graft from the anterior iliac crest in the typical manner while preserving the outer cortical layer. The maximum possible amount of cancellous bone was then collected using Volkmann’s spoons of suitable size from the opened marrow spaces. In 8 patients, in whom advanced maxillary atrophy necessitated an additional onlay bone grafting, bone blocks were shaped from the harvested corticocancellous graft according to the buccal and/or crestal contour of the alveolar ridge. Subsequent to sinus lifting they were fixed at the maxilla by microscrews and, where necessary, by microplates. The remaining portions of the block graft—and in the patients without onlay grafting, the entire bone blocks—were then particulated with the aid of a Tissier bone mill (Stryker-Leibinger, Freiburg, Germany), and, together with the uncrushed spongy bone, they were inserted into the newly created space between the bony sinus floor and the Schneiderian membrane. Meticulous care was taken to provide sufficient condensation and an even distribution of the graft material (Figure 1).

All patients were treated under stationary conditions and received clindamycin intravenously at a dosage of 600 mg after the induction of anesthesia and 3 times daily for 5 to 7 days postoperatively as antibiotic prophylaxis. During the stay in the hospital (mean duration = 6.3 days; range = 4–10 days), nutrition was provided via a thin nasogastral feeding tube. From discharge until suture removal on day 10 postoperatively, a strictly liquid diet was recommended. The gradual pain-dependent mobilization began on the third postoperative day, and from the evening before surgery until discharge, a weight-adapted thrombosis prophylaxis was given subcutaneously with a low-molecular-weight heparin. Patients were not allowed to blow their nose and were advised to administer decongesting nose drops (xylometazoline 0.1%) 5 to 6 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.

The healing phase of the bone graft until implant placement lasted at least 5.9 months, with an average of 6.4 months and a maximum of 7.2 months. In total, 59 implants (Camlog Screw-Line, Altatec GmbH, Wimsheim, Germany) were inserted into the augmented sinuses.

**Determining graft volumes**

After importing the DICOM (Digital Imaging and Communications in Medicine) data sets acquired by CBCT scan into the
commercially available planning and navigation software (iPlan CMF 3.0, BrainLAB, Feldkirchen, Germany), the bone grafts located on the sinus floor were segmented based on all available standard section planes (axial, coronal, sagittal). For this purpose, a drawing tool is available in iPlan by which the target object can be exactly outlined in each section plane using a mouse cursor. Additionally, the program also permits a gray-scale-based interpolation of up to 8 layers, which facilitates the segmentation process and makes it more precise (Figure 2). From these data the software automatically calculates a 3-dimensional image of the segmented object, which appears directly in the plan content of iPlan, as well as the object volume (Figure 3). All measurements were conducted by 2 experienced examiners who first undertook a practice round until the definite volumetric determinations were performed. Subsequently, the mean value of both examiners was calculated and entered as the final analysis.

**Statistical analysis**

In addition to descriptive data analysis, a linear mixed model was adapted to the data, with the model building grouping factors such as sex and age (continuous) and the within-subject factors side (right or left) and time (0, 3, and 6 months). Initially, we included all 2-way interaction terms and varied the covariance structure of the within-subject factors. Furthermore, we inspected the distribution of the residuals and checked for
influencing observations. Thus, we noticed that the data of patient No. 6 exerted a high influence on the parameter and covariance parameter estimates. The best-fitting model resulted from a model with main effects only. Effects were considered to be significant if the $P$ values did not exceed the 5% level. Statistical computations were performed using proc mixed from the Statistical Analysis System software (SAS, 9.1, TS1M3) and the Statistical Package for Social Sciences (version 14, SPSS, Chicago, Ill).

This study was approved by the Aachen University Hospital institutional review board, and all participants signed an informed consent agreement.

RESULTS

Clinical observations

None of the observed patients experienced postoperative complications, such as wound infection, infection of the transplant, major bleeding, or persisting swelling. In all patients, proper healing of the oral and iliac wounds could be ascertained. Although intraoperatively, a small perforation of the Schneiderian membrane, closed primarily with absorbable sutures, had arisen in 1 sinus, neither clinical nor radiologic signs of a maxillary sinusitis were noted in the postsurgical course. None of the study participants experienced residual complaints, such as sensory disturbances of the lateral femoral cutaneous nerve or persistent gait problems. At the time of implantation, after an average of 5.4 months, all patients had fully recovered.

Volume measurements

At T0, the average graft volume of the 22 maxillary sinuses, measured in the 11 patients who were considered in the final analysis, amounted to 4.2 cm$^3$. Up to T1, significant resorption ($P = .0001$) of 38.9% occurred to a mean bone volume of 2.6 cm$^3$. During the period from T1 to T2, graft volume again decreased significantly ($P = .0002$) by 18.9% (in terms of the initial volume) to a total of 1.8 cm$^3$, so that at T2, on average 57.8% of the originally transplanted bone was resorbed (Figure 4, Table).

Within the observed age interval there was no age-specific dependency ($P = .8813$) (Figure 5). Likewise, side specificity could be statistically ruled out ($P = .078$).

Furthermore, gender did not exert any consistent effect on the resorption process ($P = .4367$) (Figure 6). Already at T1, all grafts were integrated to host bone on the CBCT scans (Figure 7).

DISCUSSION

As far as sinus floor elevation surgery is concerned, autogenous bone grafts are still considered favorably.9,17,25,27,32 If there is a marked bony deficit, as in the severely atrophied edentulous maxilla, it is inevitable in most patients to draw on extraoral bone donor sites.16,33 The best studied and most widely used extraoral donor site for autogenous bone grafts is undoubtedly the iliac crest.8,16,23,34 Amounts of 7 to 40 mL can be obtained from this site.23,35 Nevertheless, one needs to be aware that a second surgical approach with a certain comorbidity and general anesthesia has to be accepted. In fact, local hematoma, sensory disturbances of the lateral femoral cutaneous nerve, hernias, and fractures of the pelvis are described as possible complications of graft harvesting from the iliac crest.36 Younger and Chapman37 indicated an 8.6% rate of serious complications in the conventional open harvesting technique, which we, however, consider to be too high according to our own clinical experience. To reduce the possible complications, Caminiti et al38 recommended the open removal of bone cylinders with suitable trephine drills, by which, however, only small amounts of bone between 2.3 to 3.2 mL can be gathered. Also, intraoral donor sites, such as the ascending mandibular ramus and the chin region provide a maximum volume of cortical and cancellous bone of only 2 to 5 mL.25,26—enough to fill up small defects, such as extraction wounds or periodontal lesions, but too low for extensive augmentations. For a complete bilateral sinus lift, for example, a bone amount of 10 to 15 mL is required.25,26 In the present study, a bone quantity of an average 4.2 mL per sinus was transplanted. Here it should be noted that this is a kind of net volume of the inserted bone after condensation. In 8 patients an additional onlay osteo-
FIGURES 4–6. **FIGURE 4.** Bone volume in cm³ (y-axis) at the time of T0, T1, and T2 (x-axis): a significant resorption of 57.8% between T0 and T2 can be seen. **FIGURE 5.** Pearson’s correlation of age and bone loss between T0 and T2: no age-specific dependency can be observed. **FIGURE 6.** Effect of gender on bone graft’s resorption: no significant effect on the resorption process can be seen.

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plasty was performed, which made an open removal of pelvic bone unavoidable.

Over the course of our investigation, the tremendous volume loss of the transplanted bone became very clear. To be precise, within 6 months 57.8% of the graft was resorbed. This rather high bone loss exceeds the values of 21%–51% stated in the literature, which nevertheless are not based on 3-dimensional measurements.\textsuperscript{21,34,39–41} Basically, the removal technique or the handling of the bone graft, as well as the method of augmentation, could entail major sources of error. Yet, in all surgeries performed within this study, meticulous care was taken to provide gentle treatment and an optimum preparation of the bone graft. Indeed, the removed cancellous bone was not further particulated to preserve the osteoblasts and precursor cells; however, the cortical bone block was minced in a bone mill to increase the surface of osteoinductive and osteoconductive material.\textsuperscript{42} Admittedly, particulated bone grafts are considered to exhibit more intense sintering than block transplants associated with a resorption rate of up to 20%.\textsuperscript{21,43} To minimize this effect, great importance was extended to equal distribution and sufficient compaction of the graft material. During the preparation of the recipient bed at the maxillary sinus floor, only one case of mucosa perforation occurred. This was primarily closed with absorbable sutures. To overcome the high failure rate of implants in connection with transplanted bone during single-stage surgery, the implant

\textbf{FIGURE 7.} Bone graft at the time of T1: the transplant presents itself fully osseously integrated.
placement was carried out in 2 stages. However, what further factors could be responsible for the observed distinctly high resorption rate? Certainly, lack of physiologic load of the grafted bone is one major problem in terms of volume stability. Accordingly, Sbordone and coworkers report on negligible resorption rates of less than 7% 1 year after implant insertion into sinuses elevated by particulated crest grafts. Evidence also suggests that microbial contamination might be associated with an increased loss of bone volume subsequent to sinus lifting surgery with autogenous bone. Finally, the method of volume measurements could be sensitive to analysis bias; however, all definite measurements were performed by 2 experienced examiners after undertaking a practice round, and there was a difference of less than 13% between both volume determinations. Because of this, and the small sample size, we abstained from calculating the kappa value to determine interexaminer variability. In this context it should also be emphasized that the grey-scale values of the CBCT were not based on Hounsfield units, which is why we refrained from bone density measurements; this, of course, is a weakness of the current investigation that the chosen method does not allow a statement on the density of the remodeled bone graft compared with the host bone.

The findings of the current study stand in sharp contrast to the volume stability of bone substitute materials, which, according to Gaßmann and Dawirs, can be successfully compared with the host bone. However, the volume stability of bone substitute materials, which, compared with the host bone, allow a statement on the density of the remodeled bone graft. Furthermore, the results of the current investigation that the chosen method does not allow a statement on the density of the remodeled bone graft compared with the host bone.

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Conclusions

In conclusion, in sinus floor elevation autogenous iliac bone grafts are characterized by a high resorption rate, at least as long as they are not functionally loaded. Therefore, a healing time of 6 months until implant insertion is definitely too long. Surgical strategies must be considered to reduce resorption of the graft volume observed when using iliac autogenous bone.

Abbreviation

CBCT: cone-beam computerized tomography

References


