

ALVEOLAR RIDGE AUGMENTATION: A COMPARATIVE LONGITUDINAL STUDY BETWEEN CALVARIA AND ILIAC CREST BONE GRAFTS

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KEY WORDS

Alveolar ridge augmentation
 Bone graft
 Calvaria
 Iliac crest
 Preprosthetic surgery

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Insertion of endosseous implants is often difficult because of lack of supporting bone. In the case of severe atrophy of the jaws, a large volume of autogenous bone can be harvested from the iliac crest and calvaria. Both grafts undergo partial resorption with time, but the rate of bone loss has not been fully elucidated. The aim of this study was to evaluate the alveolar bone height gain (ABHG) obtained with iliac crest and calvaria bone grafts. Twenty-five patients had mandibular bone grafts, 32 had maxillary bone grafts, and 11 had both mandibular and maxillary bone grafts. Measures were made on preoperative, postoperative, and follow-up radiographs. A general linear model was used to evaluate the rate of ABHG plotted against months elapsed from the time of the operation to the time of follow-up. General linear model output showed a statistically significant effect for only the type of donor bone graft ($P = .004$), with a better ABHG for calvaria. The iliac crest bone grafts lost most of the ABHG in the first 6 months, whereas calvaria bone grafts lost ABHG over a greater interval of time. The type of bone graft is the strongest predictor of ABHG, and calvaria bone graft had a higher stability than did iliac bone graft. However, the gap in ABHG between the 2 grafts tended to decrease over time.

INTRODUCTION

The anatomic limitations of the residual alveolar bone can cause problems for the insertion of dental implants.¹ Less-than-ideal sites can result in an esthetic and functional compromise¹ because implant placement requires an adequate quantity and quality of bone.² In many

cases, however, this anatomic problem can be solved with autogenous bone grafts, which are the most predictable and successful material available.¹

The individual implant success rates with maxillary and mandibular bone grafts vary from 61% to 98%.^{1,3} Insertion of endosseous implants in atrophic jaws is often complicated because of lack of supporting bone. To increase

the residual alveolar ridge, several options have been proposed: bone grafts,⁴⁻⁶ allografts,^{7,8} inferior alveolar nerve transposition,^{9,10} and distraction osteogenesis.¹¹ Indications to the use of each option varies according to site, amount of the residual alveolar bone, cause of resorption, and compliance of the patient.

It is important to know which donor sites can consistently provide the most quantity of bone for a graft.² In the case of severe atrophy, surgeons can use iliac crest and calvaria bone grafts to harvest a significant amount of autogenous bone. However, embryology, histology, and mechanical properties of these 2 bone grafts are different and may affect the short- and long-term alveolar ridge augmentation.

One of the main problems with the use of iliac bone graft is its high resorption rate.^{12,13} Binger and Hell¹⁴ reported an average vertical loss of about 3 mm in the first year with the use of microsurgically vascularized bone grafts for mandible augmentation, whereas Verhoeven et al¹⁵ reported a 36% mean resorption rate of the graft mainly during the first year. Some researchers have suggested that membranous bone grafts (calvaria) undergo less resorption than do endochondral grafts (iliac).^{16,17} A greater volume maintenance has been reported for calvarial grafts than for iliac bone grafts (72% vs 32%).¹⁸ Donovan et al¹⁶ reported an 85% retention of calvarial grafts compared with a 34% retention of grafted iliac bone, with calvarial onlay grafts showing more than a 2-fold greater radiographic density when compared with iliac grafts.

The final result in terms of stability of the implants and facial morphology depends on bone resorption.^{18,19} A slower revascularization of the calvaria has been

proposed as the explanation for the lesser and slower resorption.²⁰ Calvarial grafts have been used for orbital wall reconstruction,²¹ alveolar cleft grafts, Le Fort I osteotomies, midface onlay grafts, mandibular continuity defects,²² Apert and Crouzon syndromes,²³ sphenoid wing defects of the posterior orbit and frontal and middle cranial fossae,²⁴ dorso-nasal reconstruction,²⁵ and sinus lift techniques for preprosthetic purposes.²⁶

Our aim was to evaluate of a group of 68 patients with severe atrophy of the jaws to compare the alveolar bone height gain (ABHG) between calvaria and iliac crest bone grafts.

PATIENTS AND METHODS

Between January 2000 and December 2002, 72 consecutive patients with severe atrophic mandible or maxilla (classes V and VI, according to Cawood and Howell²⁷) were treated at Brescia Civil Hospital, Brescia, Italy. Sixty-eight patients were considered in this study for a minimum follow-up of 6 months, whereas 4 patients (5.5%) with incomplete follow-up were excluded. The mean follow-up was 16.5 ± 7.7 months and the median follow-up was 18 (6–36) months.

The study population consisted of 39 men (57.4%) and 29 women (42.6%). The mean age was 48.2 ± 8.4 years and the median age was 47 (30–70) years at the time of presentation. Twenty-five mandibles (36.8%), 32 maxillae (47.2%), and 11 upper and lower jaws (16.2%) underwent bone grafts.

Measurement of bone deficit

The alveolar bone height (ABH) was measured according to Cawood and Howell²⁷ recommen-

dations. Orthopantomogram and teleradiography (in lateral and antero-posterior projection) were used. Measurements were made on preoperative, postoperative, and follow-up radiographs.

In the upper jaw, the floor of the maxillary sinus was taken as the measurement of the upper limit, whereas the lower limit was the margin of the alveolar ridge. Three points were determined on the maxilla to measure the ABH at the floor of maxillary sinus: point A, corresponding to the lower part of the mesial wall of the maxillary sinus; point P, corresponding to the distal wall; and point I, the median point between points A and P. For the premaxillary region, the measurement from the floor of the nasal fossae to the margin of the alveolar ridge was taken (point N at the lower part of nasal floor).

In the mandible, the line passing through the 2 mental foramina was taken as inferior alveolar limit, whereas the free border of the alveolar ridge was taken as superior limit. Point S was the midpoint of the line joining the 2 mental foramina. To take measurements in the region of the body of the mandible, 3 points were determined: point M, corresponding to the mental foramen; point L, corresponding to the mandibular spine; and point K, corresponding to the midpoint between point M and point L projected on the mandibular canal. The bony region underlying the imaginary line joining these points was defined as the basal region; the region above the line was defined as the alveolar region (Figure 1).

Eight measures were taken in the maxilla (ie, right and left A, I, P, and N) and 7 were taken in the mandible (ie, right and left L, K, M, and S in midline). A single mean value was recorded at dif-

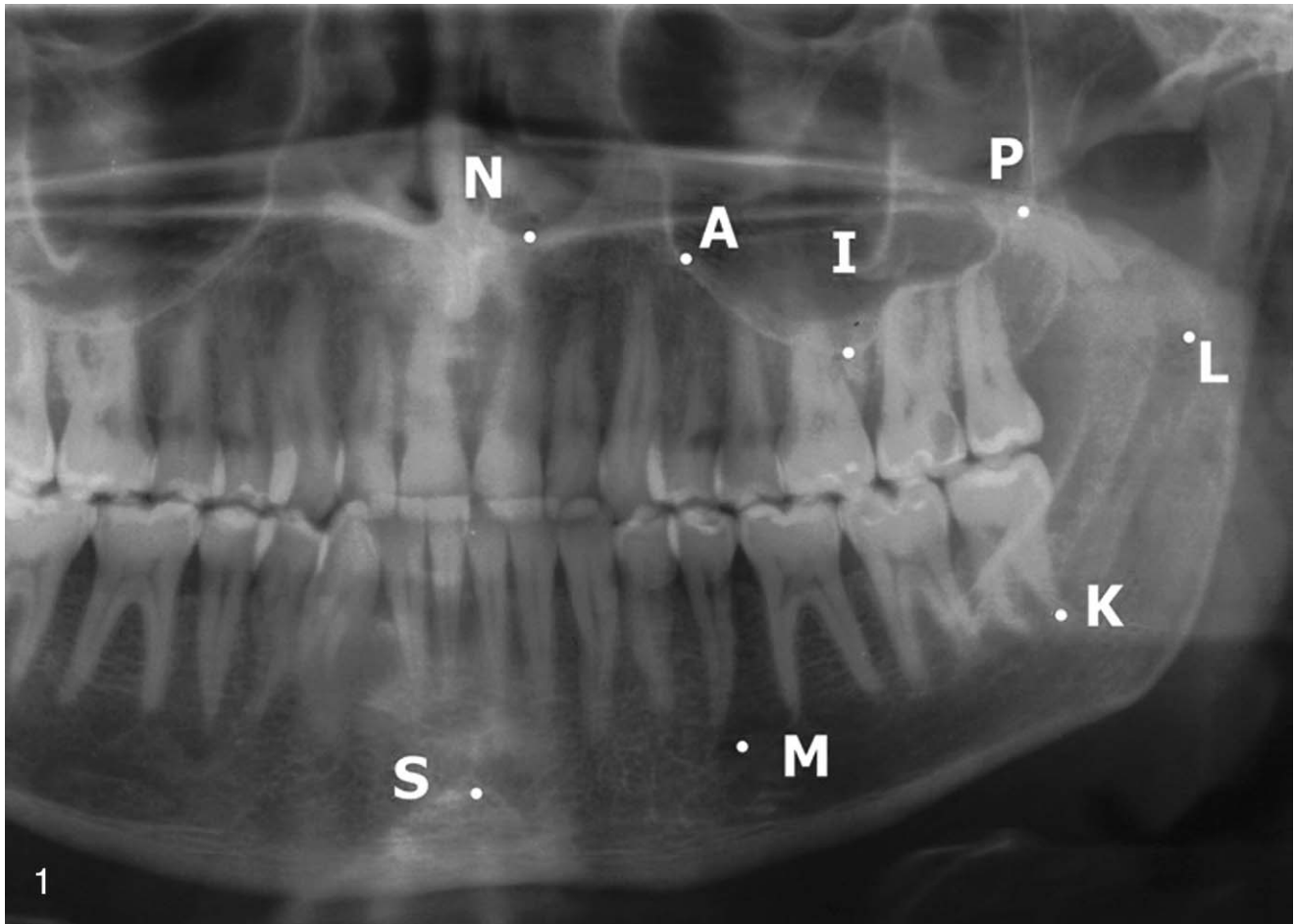


FIGURE 1. Orthopantomogram showing reference points used for measuring.

ferent phases for each patient: presurgery, postsurgery, and after an appropriate follow-up (at least 6 months). The recorded measures were defined as residual alveolar bone height (RABH), postsurgical alveolar bone height (PSABH), and final alveolar bone height (FABH), respectively. The difference between PSABH and RABH as well as between FABH and RABH corresponded to the ABHG, a value that changed over time.

At the time of presentation, the average RABH was 5.04 ± 0.87 mm in the mandible and 3.73 ± 1.17 in the maxilla. In the case of atrophy of both jaws, a mean value was considered for upper and lower jaws to exclude

variables related to a single patient with multiple grafts. The mean RABH was 5.36 ± 0.92 mm. Postoperatively, the average PSABH was 10.7 ± 1.24 mm in the mandible and 16.7 ± 3.63 mm in the maxilla. In the case of atrophy of both jaws, the mean PSABH was 13.5 ± 4.13 mm. At the last follow-up, the average FABH was 9.18 ± 0.88 mm in mandible and 13.35 ± 3.73 mm in the maxilla. In case of atrophy of upper and lower jaws, the average FABH was 11.57 ± 3.53 .

Treatment

Five different surgeons performed surgery with general anesthesia. The donor sites were the

iliac crest in 21 cases (13 men and 8 women; 21 mandibles) and the calvaria in 47 cases (26 men and 21 women; 4 mandibles, 32 maxillae, and 11 upper and lower jaws). Onlay, inlay, and onlay plus split-crest grafts were performed in 57, 7, and 4 cases, respectively. Implants were inserted 6 months after bone grafting, with an average ratio of 1:3 implant to substitute 2 lost teeth. The implants were loaded after another 3 months. Descriptive analysis is reported in Table 1.

Statistical analysis

A general linear model was used to evaluate the rate of ABHG plotted against months elapsed

TABLE 1

Descriptive statistics of the series*

Variable	Mean	SD	Frequency	%
Age (y)	48.2647	8.39619		
RABH	4.38	1.195		
PSABH	14.154	4.2279		
Follow-up (mo)	16.5882	7.74449		
Women			29	42.6
Men			39	57.4
Mandible			26	38.2
Jaws			11	16.2
Maxilla			31	45.6
Calvaria			47	69.1
Iliac crest			21	30.9
Inlay			7	10.3
Onlay			57	83.8
Onlay + split crest			4	5.9

*RABH indicates residual alveolar bone height; PSABH, postsurgical alveolar bone height.

from the time of the operation to the time of last follow-up and stratified for type of bone graft (calvaria or iliac crest). General linear model was adjusted for patients' age. The dependent variable (rate of ABHG) was converted in a Log scale.²⁸

RESULTS

General linear model output (Table 2) showed a statistically significant effect of type of bone graft ($P = .004$). In Figure 2, the ABHG elapsed from the time of the operation to the time of last follow-up was plotted and stratified for types of bone graft. At 10 months, the percentage of surviving bone (ABHG) was 83% for the calvaria and 61% for the iliac crest, with a net difference of

22%. Such a difference was reduced to 10% at 30 months. Interestingly, the iliac crest graft lost most of ABHG in the first 6 months, but the bone loss decreased to almost 0 as the follow-up progressed. The calvaria had a very low loss rate at the beginning of the study, but after 30 months it showed only a 10% difference with the iliac crest bone graft.

DISCUSSION

The treatment of severe maxillary residual ridge resorption involves various grafting materials such as autogenous bone or bone substitutes. Autogenous bone is the "gold standard" of grafting materials; however, it shows a certain amount of resorption, espe-

cially during the first few postoperative months.²⁹⁻³⁴ Reports show that membranous bone is superior to endochondral grafts in maintaining volume, and that the higher tendency to resorption of the iliac onlay grafts compared with the calvaria is due to the different embryonic origin (endochondral vs membranous).^{29,35} It has been hypothesized that the pattern of onlay bone graft resorption is mainly related to the graft microarchitecture (cortical and cancellous composition).³⁶⁻³⁹ The large cortical component of the calvarial bone determines an excellent mechanical strength and a slight tendency to resorption. Usually the calvarial donor site produces less discomfort to the patient than do the rib or iliac crest grafts, and the scar can be hidden in a better way. Insertion of endosseous implants in atrophic jaws is often complicated because of the lack of supporting bone. Among the variables that were evaluated in our study, age, gender, site, and type of surgery were not statistically significant. Both inlay and onlay surgical techniques have been shown to be reliable and comparable procedures.^{40,41} Onlay bone-grafting technique shows worse results regarding bone resorption⁴² and implant survival.⁴³

Among the studied variables, only the type of bone graft showed a statistically significant difference in ABHG. The calvaria bone grafts had a higher stability than did the iliac bone grafts. However, the gap in ABHG between the 2 types of bone grafts tended to decrease over time (Figure 2). We can hypothesize that the early stage resorption can be related to the different proportion of cancellous and cortical bone in 2 grafts, whereas the late-stage resorption

TABLE 2

General linear model output*

Log Parameter	β	t	P Value	95% CI	
				Lower Bound	Upper Bound
Intercept	1.731	16.146	.000	1.517	1.945
Age (y)	1.616 ⁻⁰⁴	.098	.922	-3.141 ⁻⁰³	3.464 ⁻⁰³
Iliac crest vs calvaria	9.551 ⁻⁰²	2.980	.004	3.144 ⁻⁰²	.160
ABHG	-1.786 ⁻⁰³	-.153	.879	-2.507 ⁻⁰²	2.150 ⁻⁰²
Follow-up (mo)	-1.735 ⁻⁰³	-.902	.370	-5.579 ⁻⁰³	2.109 ⁻⁰³

*ABHG indicates alveolar bone height gain.

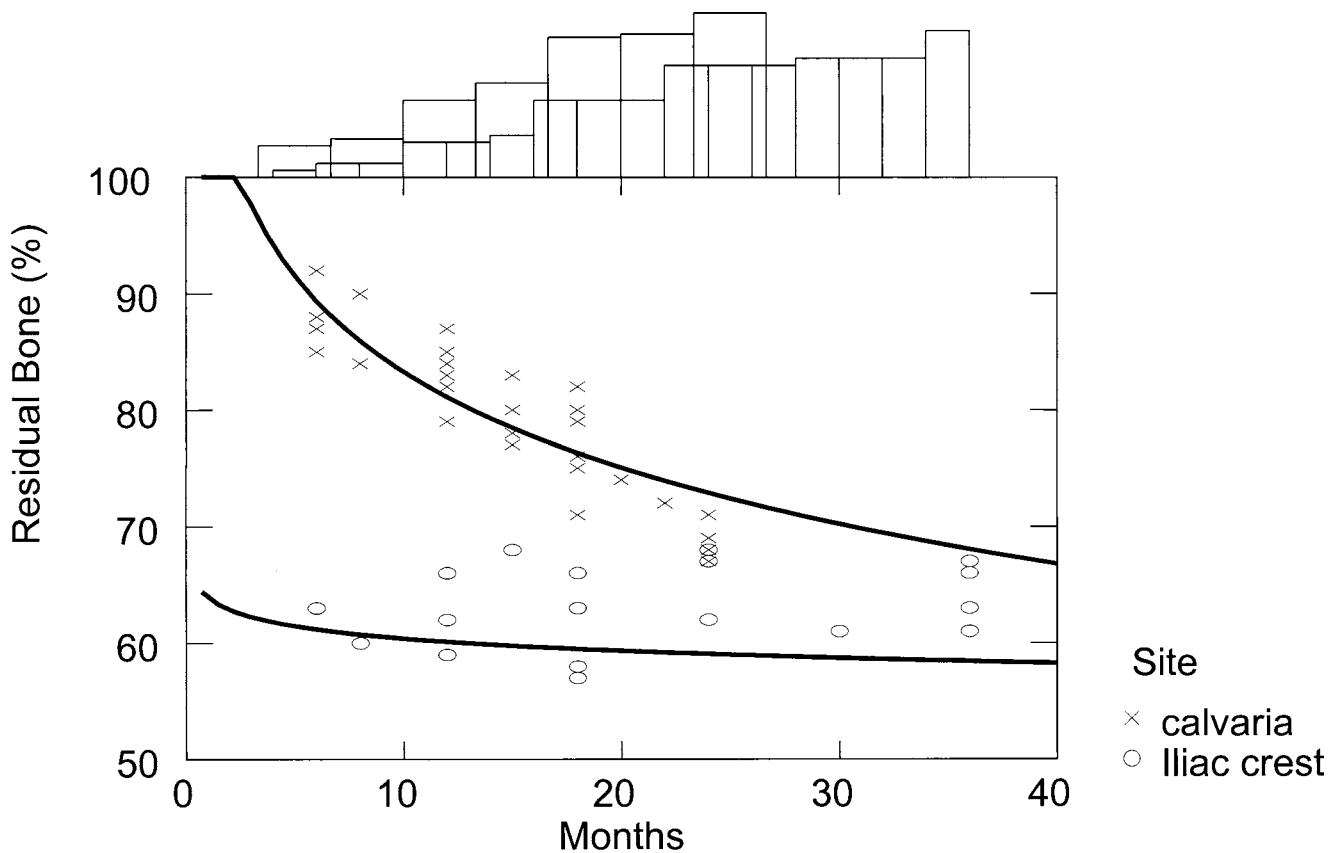


FIGURE 2. Plot of the alveolar bone height gain elapsed from the time of operation to the time of last follow-up and stratified according to the type of grafts.

can be related to vascular and mechanical rearrangement.

Only 2 studies have previously compared calvaria with iliac crest grafts. Because particulate and not block bone was used and cleft patients were considered, a comparison with our results is difficult. In the first study, 135 secondary alveolar cleft bone graft procedures were analyzed. The group of patients (n = 108) who had particulate cancellous bone obtained from the iliac crest had an 89.8% success rate. The group (n = 27) who had calvarial bone as the donor material had a success rate of only 63%. This result was related to the procurement technique.⁴⁴ A second study showed a similar quantity of bone for calvaria and iliac crest bone grafts. Differences were found

within the group of patients grafted with calvaria because this bone was harvested by 2 different techniques.⁴⁵

No complications were reported in our study, but donor-site morbidity after bone harvesting still remains a crucial problem in alveolar ridge augmentation. Minor complications associated with iliac crest bone graft harvesting are a high amount of blood loss, length of hip incision, duration of time until postoperative ambulation, and duration of hospitalization.⁴⁶ Major complications are rare.⁴⁷ Preoperative knowledge of skull thickness before harvesting cranial bone grafts would be ideal to help minimize intracranial complications, because regional variations in calvaria thickness have

been demonstrated.⁴⁸ Computerized axial tomography⁴⁸ and ultrasound⁴⁹ are accurate preoperative methods of skull-thickness measurement.

In conclusion, the calvaria bone graft has a higher ABHG compared with the iliac crest bone graft. Age, gender, site, and type of surgery do not produce statistically significant differences in ABHG.

ACKNOWLEDGMENTS

This study was supported by grants from Unife 60% (F.C.) and Unibo (A.F.) and was partially supported by the National Research Council, Rome, Italy; by the Ministry of Education, University, and Research, Rome, Italy; and by the Research

Association for Dentistry and Dermatology, Chieti, Italy.

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