Volume Changes of Iliac Crest Autogenous Bone Grafts After Vertical and Horizontal Alveolar Ridge Augmentation of Atrophic Maxillas and Mandibles: A 6-Year Computerized Tomographic Follow-Up

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Purpose: To evaluate by computerized tomography the long-term volume resorption of autogenous corticocancellous grafted bone harvested from the ilium and used in an alveolar augmentation procedure followed by endosseous dental implant placement.

Patients and Methods: Eleven maxillary grafts (8 positioned horizontally) and 13 mandibular grafts (10 positioned vertically) were placed in 16 patients. Using software programs, pre- and postsurgical computerized tomographic scans were used to compare volumes of grafts over time (up to 6 yr) to determine the annual percentage of remaining bone and the overall percentage of bone resorption that could be expected. Yearly measurements of volumes and percentages of remaining bone were then compared statistically.

Results: At the 6-year survey for blocks grafted in the mandible, an average resorption rate of 87% was obtained; for maxillary grafts at the same survey, complete resorption of the grafts (mean, 105.5%) was recorded. In general, bone resorption appeared slow, except for that recorded in the first 2 years of healing, the only period in which statistical comparisons among all time points showed significant differences for all variables.

Conclusions: Volumetric measurements of the grafts and their related percentages of remaining bone attested to a progressive and unavoidable bone resorption of almost all the grafted bone in the maxilla

Received from the School of Medicine, University of Salerno, Salerno, Italy.

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This study was supported in part by grant PRIN 2008K4XXF8_02 (CUP G51J10000030001) to Prof L. Sbordone from the Ministero dell' Istruzione, Università e Ricerca Scientifica (MIUR Italian Department of Education, University and Scientific Research).

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0278-2391/12/7011-0$36.00/0
http://dx.doi.org/10.1016/j.joms.2012.07.040

and mandible. Although the present data were from a heterogenous group of defects treated with horizontal and vertical procedures, clinicians, when performing alveolar bone augmentation with an autogenous hip bone, should aim at titanium dental implant osseointegration, not only in the augmented bone but also in the native bone below the graft.

J Oral Maxillofac Surg 70:2559-2565, 2012

Currently, predictable results are reported for a fixed prosthesis supported by an endosseous dental implant using alveolar bone augmentation techniques for atrophic edentulous jaws. Nevertheless, autogenous bone is only 1 of many standard materials applied in grafting procedures,[1] with good results having also been obtained using diverse bone augmentation techniques in which several procedures and sources were used.[2,3]

It had generally been assumed that bone graft maintenance was a direct consequence of a perfect osseointegration of the dental implants positioned in the augmented bone and of the prosthetic functioning of these implants.[4,5] Although bone block graft failure, defined as "excessive graft loss resulting in inability of implant insertion,"[6] was generally very infrequent,[5] the acquired data from a short-term survey of autogenous corticocancellous grafts regarding bone remodeling suggested an early resorption by the graft's cortex during the first half year, whereas bone density increased for the spongiose area and for the remaining overlying cortex during the second half year.[7] Long-term data on graft remodeling, obtained by radiodiagnostic imaging (primarily panoramic views), have shown a rate higher than 51% for bone resorption after 7 years for avascular onlay fibular grafts used in mandibular reconstructions.[5] Even the limited amount of data in relation to the volumetric analysis of grafts have allowed various investigators to perceive an important remodeling phenomenon, although those studies that have verified this result had a short follow-up: for iliac crest onlay grafts, a mean resorption percentage of 47% in the first 6 months was recorded[8]; whereas, in a different survey, the degree of resorption ranged from 42% to 59% during the year after the procedure.[9]

The purpose of the present study was to evaluate the long-term remodeling of autogenous corticocancellous grafted bone harvested from the ilium and used in alveolar augmentation procedures followed by endosseous dental implant placement. Pre- and postsurgical computerized tomographic (CT) scans were used to compare the bone graft volumes (V) over time (annually for 6 yr) and to determine the annual percentage of remaining bone (%R) and the overall percentage of bone resorption that could be expected. A survey on implant survival also was performed.

Patients and Methods

STUDY DESIGN/SAMPLE

A retrospective chart review of patients who underwent onlay graft procedures for dental implant positioning was conducted. The patients included in this study were treated from January 2000 to December 2003. The patients' personal information, such as age (years), gender, and smoking habits, and that relating to the type of grafting procedure (horizontal or vertical, number, location, and source), dental implant placement, outcome of the surgical treatment, subsequent surgical procedures, and the numbers and time points of performed CT scans were reviewed.

Patients who had undergone alveolar ridge augmentation with corticocancellous iliac crest bone were included in the study. No patient had undergone bone resection as part of an oncologic treatment. Maxillomandibular CT scans up to 72 months postoperatively were considered. The study was approved by the scientific ethics committee of the University of Pisa.

SURGERY

Preoperative CT scans were used to assess the need for alveolar bone grafting with autogenous iliac crest bone in those patients showing advanced alveolar atrophy and requiring an abundant volume of donor graft for the reconstruction. All surgery was performed under general anesthesia. Two percent mepivacaine with epinephrine (20 ± 12.5 mg/mL) was administered locally to decrease bleeding. The iliac crest graft was obtained according to the technique described by Grillon et al[10] using a cutaneous approach through elective lines of incision. Horizontal bone augmentation was deemed necessary in cases in which the residual crest, although having adequate bone height, presented a width narrower than 6 mm.[11] Vertical augmentation was adopted in cases of an available residual crest height taller than 7 mm.[12] The recipient site was approached as described by Triplett and Schow.[13] All corticocancellous blocks were positioned as onlays, with the cancellous portion toward the pristine residual bone, using a "lag

screw" technique to secure the bone blocks.[11] If required after the graft molding, autogenous bone chips were used to fill any possible gaps between the grafts and the recipient area. No other grafting methods, such as membrane coverage, or sources, such as mixtures of autogenous bone and other substitutes, were used. All patients underwent appropriate antibiotic, analgesic, and anti-inflammatory therapies. Titanium dental implants (root-form, external-hex, and/or rough-surfaced screws) were inserted into the graft areas 3 to 5 months after the reconstructive stage.[14] All patients received fixed prosthetic metal ceramic restorations, which were cemented over a custom metal abutment or a University of California, Los Angeles (UCLA)-type abutment.

VARIABLES AND DATA COLLECTION

As part of the standard treatment protocol, patients had CT scans (High Speed Double Detector CT scanner; General Electric Medical System, Milwaukee, WI) taken immediately before bone grafting, 3 to 5 months after grafting,[14] just before implant insertion (time 1), and after implant insertion. Clinical and radiologic examinations were performed annually, as provided in the postoperative maintenance program (times 2, 3, 4, and so on); a dental implant survey was also conducted. The CT scans were timed to allow data ranking, with the 6 intervals being set as 0 to 12 months (T_1), 13 to 24 months (T_2), 25 to 36 months (T_3), 37 to 48 months (T_4), 49 to 60 months (T_5), and 61 to 72 months (T_6); T_0 represented the moment of alveolar bone augmentation surgery and preoperative time represented the time before the operation.

Data relating to the linear dimension of each grafted bone block (length, height, and thickness) were measured intraoperatively using a standard surgical caliper or ruler by the same calibrated examiner (L.S.); intraoperative block volumes were extrapolated by linear measurements, as described by Verdugo et al,[15] after the shaping, made possible by the perfect adaptation of each graft to its respective receiving site.

The V values were obtained using axial CT slices having a thickness of 1 mm: before volume computation, the CT scan data were inserted into a software program, which allowed the superimposition of pre- and postoperative axial images (Image Processing Toolbox, MatLab 7.0.1; MathWorks, Natick, MA) according to a recent suggestion by Sbordone et al.[16] Three-dimensional data were modified so that on the reoriented axial images all palatine vaults (for maxillary data) and the lower border of all mandibles (for mandibular data) were shown as parallel to each other. Measurements of the volume of the augmented area (VA) for each follow-up time point were performed using Segment Tool in SimPlant Pro 12.02 (Materialise Dental Italia, Rome, Italy) according to Smolka et al.[17] From the first postsurgical CT scans (at T_1), an apical limit for the volume measurement for each patient was preset as the distance from the apical portion of the onlay graft to the palatine vault in the maxilla or the lower border in the mandible, as performed by Krennmair et al[18] for the calculation of vacuum sinus volume. The V value for each postoperative time was determined by subtracting the VA measurement obtained before the grafting procedure from the VA obtained for each postoperative follow-up (T_1 to T_6). Each V value, measured as before (V_1, V_2, V_3, V_4, V_5, and V_6), were compared with the intraoperative block volume (V_0) to determine the %R, ie, $\%R_x$ at time x (x = 1, 2, 3, 4, 5, and 6) was obtained as the ratio between the volume at time x (or V_x) and the intraoperative block volume (V_0). Percentages were rounded to the nearest 0.5%. Even if the VAs were always positive, the V and resulting %R could be positive or negative: a negative number would indicate an extensive resorption phenomenon in which a portion of the pristine bone might be involved.

BIAS

A possible bias could arise from the criteria for a patient's enrollment in this review, which were reviewed retrospectively; the measurements of introduced input (VA and V) and outcome (%R) variables; and/or the heterogeneous analysis of data (not ranked according to the type of surgical procedure, ie, horizontal or vertical).

STATISTICAL ANALYSIS

All patient-related data were entered into a database (Access; Microsoft Corp, Redmond, WA), allowing calculations to be performed automatically. Descriptive statistical analyses were performed using a statistical tools package (Statistics Toolbox, MatLab 7.0.1).

A normal distribution for each dataset was carried out, but not confirmed, by the Lilliefors test for data, forming different follow-up intervals. The data are assumed to come from a continuous, symmetrical distribution around a median point. All measurements in the text and tables are described as median and interquartile range (difference between 25th and 75th percentiles). In the comparison tests, to overcome differences between multiple grafting procedures in the same patient, 1 grafted bone block per arch was randomly selected.[19] Because the measurements obtained were not normally distributed, Wilcoxon matched pairs signed rank tests were used to assess the changes between various time points. The level of statistical significance was set at .05 for all analyses.

Table 1. NUMBER OF PATIENTS, GRAFTS, AND IMPLANTS PLACED BY ARCH

Arch	Patients (n)	Grafts (n)	Grafts Enrolled (n)	Implants Placed in Enrolled Grafts (n)	Failed Implants (n)
Maxilla	11	14	11	31	0
Mandible	13	18	13	36	0
Total	16	32	24	67	0

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Results

In this retrospective study, 11 maxillary and 13 mandibular grafts were positioned in 16 patients (11 women and 5 men; median age, 55.4 yr) in whom maxillomandibular atrophy had been resolved by iliac crest alveolar bone grafting, dental implant insertion, and fixed prosthetic loading.

Overall, 32 autogenous bone blocks were grafted into the pristine maxillas of the patients, but only 24 (1 graft per arch; Table 1) were included for subsequent statistical analysis. Table 2 presents the starting volumes of the included grafts and their respective %Rs obtained at the 6-year examination. For blocks grafted in the mandibles, a resorption rate of 87% was obtained; in the maxillary grafts, bone remodeling led to a complete resorption of the grafts as attested by the negative %R value of −5.5% (69.5%). Figure 1 displays box-and-whisker plots of the distribution of bone volumes for the 2 arches.

Statistical comparisons among the time points showed significant differences, with the exception of comparisons related to gap times shorter than 2 years. Among the comparisons with a gap of 1 year, only those between T_1 and T_2 for the V and %R variables were significant for the maxilla and mandible. Statistically significant differences were recorded between the maxillary and mandibular graft volumes at T_1 (1,324 cm^3 [886] and 1,254 cm^3 [915]) and T_2 (490 cm^3 [1,123] and 689 cm^3 [703]; $P = .0039$ and .0024, respectively, for the maxilla and mandible). Statistically significant differences between the maxillary and mandibular %R values at T_1 (99.5% [26.5] and 102% [13]) and T_2 (48.5% [59] and 54% [24]; $P = .0039$ and 2.4×10^{-4} for the maxilla and mandible, respectively) were also found.

Thirty-six dental implants were positioned in mandibular bone grafts, whereas 31 were placed in maxillary reconstructions. No implant failure was recorded;

Table 2. DESCRIPTIVE ANALYSIS OF PATIENT DATA, GRAFTING PROCEDURES USED, BONE BLOCK DIMENSION BEFORE IMPLANT INSERTION, AND PERCENTAGE OF RESIDUAL BONE AT 6-YEAR FOLLOW-UP FOR MAXILLARY AND MANDIBULAR GRAFTS IN ALVEOLAR BONE AUGMENTATION PROCEDURES

				Mandible				Maxilla			
Patient No.	Age (yr)	Gender	Smoking Habit	Block Dimension (cm^3)	Graft Procedure	Implants in Enrolled Grafts (n)	%R	Block Dimension (cm^3)	Graft Procedure	Implants in Enrolled Grafts (n)	%R
1	58.7	F	No	3.0	V	6	13.5	1.5	H	5	−137.0
2	48.7	F	Yes	0.5	V	1	0.5	2.0	V	3	25.0
3	58.7	F	Yes	1.5	H	3	−16.5	1.5	V	3	−5.5
4	37.8	M	No	4.5	H	3	13.0				
5	62.2	F	Yes	0.75	V	2	15.0	2.75	H	4	−27.0
6	52.2	F	Yes	1.25	V	2	−3.0				
7	51.1	M	Yes	3.5	V	6	25.5	0.75	H	2	31.0
8	52.9	F	No	1.25	H	2	−4.5				
9	62.9	F	No	1.5	V	2	10.5				
10	63.3	M	No	0.5	V	3	26.0	0.5	H	2	−48.0
11	58.3	M	No	0.5	V	1	26.0	0.5	H	2	−104.0
12	42.5	F	Yes	0.75	V	2	−2.0	2.0	H	3	29.0
13	37.5	F	Yes	1.75	V	3	29.0				
14	56.1	M	Yes					1.25	H	3	−4.5
15	54.6	F	No					1.25	H	2	33.5
16	56.4	M	No					0.5	V	2	−36.5
Total	55.4 (8.2)			1.25 (1.0)		36	13.0 (27.5)	1.25 (1.0)		31	−5.5 (69.5)

Abbreviations: F, female; H, horizontal; M, male; %R, percentage of residual bone; V, vertical.

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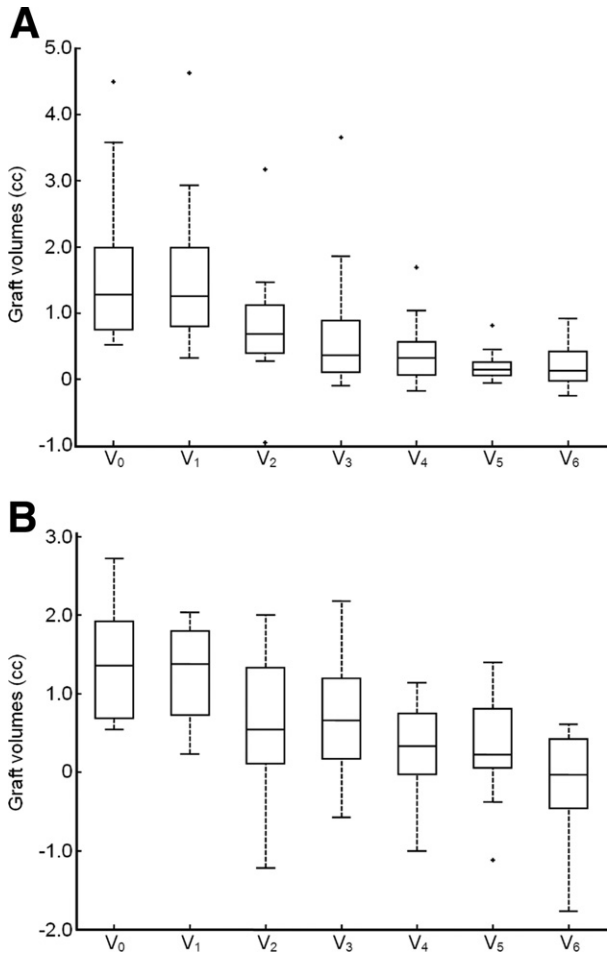

FIGURE 1. Box plots for volume measurements (cubic centimeters) intraoperatively (V_0) and at 0 to 12 months (V_1), 13 to 24 months (V_2), 25 to 36 months (V_3), 37 to 48 months (V_4), 49 to 60 months (V_5), and 61 to 72 months (V_6) in the *A,* mandible and *B,* maxilla groups. Box-and-whisker plots display the lower (*bottom horizontal line*), median (*middle horizontal line*), and upper (*top horizontal line*) quartile values, the remaining data (*whisker lines*), and data outliers (*diamonds*).

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therefore, survival rates were 100% for the maxilla and mandible groups.

Discussion

Remodeling after corticocancellous grafting procedures for alveolar bone augmentation occurred according to a predictable pattern: the first step showed a partial resorption by the graft's cortex, which, in the following steps, proceeded toward a progressive remodeling, whereas bone formation was recorded in the lower spongiose area, characterized by changes in the trabecular structure and an increase in its density during the entire first postoperative year.[7,20]

A broad remodeling phenomenon over time of the free osseous graft was a major side effect of these bone augmentation procedures.[5] Long-term data concerning autogenous iliac bone graft resorption in the human mandible obtained with 2-dimensional image analysis showed a resorption rate ranging from 44% to 50% after 5 years of follow-up.[21] Several investigators who compared 2-dimensional calculations from standard dental radiographs with data obtained from CT scan analysis found widely varying results (under- and overestimations of 21% and 18%, respectively) owing to *1)* an assumption of a correlation between bone height and the total amount of resorption and *2)* enlargement and distortion of conventional radiographic imaging.[22]

For an overall analysis of grafted bone, a 3-dimensional calculation is preferred. A short-term survey on bone remodeling at the 6-month postoperative check (just before dental implant insertion) recorded an average volume decrease of 50% for onlay grafted bone,[8] whereas further bone resorption was recorded at the 1.5-year point of the survey, with a mean percentage ranging from 42% to 46% at 6 to 18 months.[9]

To update the incomplete information on the long-term remodeling of osseous reconstruction, attention was focused on autogenous bone grafts positioned as onlays in the maxilla and mandible. A long-term volumetric survey of the remodeling of grafted bone by CT scan analysis has not yet been reported in the literature: all patients surveyed in this retrospective study underwent alveolar bone augmentation with free autogenous grafts derived from the iliac crest. An analysis of significant differences in volumetric measurements and their related percentages of remaining bone attested to a progressive and unavoidable bone resorption of almost the entire osseous graft in the maxilla and mandible, with resorption rates of 105.5% and 87% for the upper and lower arches, respectively. After combining the results presented in Figure 1 in Table 3, it was clear that the negative remodeling phenomenon occurred very slowly, as shown by the absence of significant differences among the many medians of 2 consecutive years, with the exception of those related to T_1 and T_2, for which a greater and statistically significant level of resorption appeared. Significant differences were not found between the intraoperative volume measurements and those recorded at the first follow-up; these data probably corroborate the presence of only a partial resorption by the graft's cortex from 0 to 6 months. Resorption, although slow, was nonetheless continuous, as attested by the significant differences presented in Table 3. These data challenge what is widely thought to be a characteristic of endosteal titanium dental implants, ie, to promote an absolute volumetric preservation of autogenous bone grafted for alveolar ridge augmentation. Implant loading probably slows vol-

Table 3. STATISTICAL SIGNIFICANCE ANALYSIS COMPARING VOLUMETRIC DIMENSIONS OF BLOCK GRAFTS AND RESPECTIVE PERCENTAGES OF RESIDUAL BONE AMONG DIFFERENT FOLLOW-UP INTERVALS FOR THE MAXILLA AND MANDIBLE

Volumes

Maxilla	V_0	V_1	V_2	V_3	V_4	V_5		
V_6	*	*	*	*	*	*		
V_5	*	*	*	*	NS			V_0
V_4	*	*	NS	*			NS	V_1
V_3	*	*	NS			*	*	V_2
V_2	*	*			NS	*	*	V_3
V_1	NS			NS	NS	*	*	V_4
V_0			NS	*	*	*	*	V_5
		NS	*	*	*	*	*	V_6
	V_6	V_5	V_4	V_3	V_2	V_1	V_0	Mandible

Residual Bone

Maxilla	$\%R_0$	$\%R_1$	$\%R_2$	$\%R_3$	$\%R_4$	$\%R_5$		
$\%R_6$	*	*	*	*	*	*		
$\%R_5$	*	*	*	*	NS			$\%R_0$
$\%R_4$	*	*	NS	*			NS	$\%R_1$
$\%R_3$	*	*	NS			*	*	$\%R_2$
$\%R_2$	*	*			*	*	*	$\%R_3$
$\%R_1$	NS			NS	*	*	*	$\%R_4$
$\%R_0$			NS	*	*	*	*	$\%R_5$
		NS	*	*	*	*	*	$\%R_6$
	$\%R_6$	$\%R_5$	$\%R_4$	$\%R_3$	$\%R_2$	$\%R_1$	$\%R_0$	Mandible

Abbreviations: NS, nonsignificant; $\%R_0$, percentage of residual bone intraoperatively; $\%R_1$ to $\%R_6$, percentage of residual bone at 0 to 12, 13 to 24, 25 to 36, 37 to 48, 49 to 60, and 61 to 72 months, respectively; V_0, volumetric dimension of block graft intraoperatively; V_1 to V_6, volumetric dimension of block graft at 0 to 12, 13 to 24, 25 to 36, 37 to 48, 49 to 60, and 61 to 72 months, respectively.

*Significant by Wilcoxon matched pairs signed rank tests.

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ume resorption, as can be seen from the linear measurements.[5]

This study was limited by its retrospective nature, and thus the enrollment of patients and the surgical procedures they underwent was neither masked nor randomized. Subjects were enrolled from a cohort of consecutively treated patients and characterized by a homogeneous graft source, the same surgical procedure, and a complete radiologic 3-dimensional dataset. Further, an inaccuracy could arise from the type of volumetric calculus used for the grafts. Nevertheless, the methods, some stemming from many years previously,[8,23] have become standardized over time, and because the measurements were performed by clinicians, the results, in terms of input and outcome variables, could have been affected by the level of knowledge of the researchers. Moreover, the duration of the study greatly limited the sample size, so that heterogeneous procedures, such as vertical and horizontal bone grafting, were forcedly grouped together, although the specificity of the surgically augmented areas (ie, maxillary or mandibular sites) was preserved as independent groups.

At the 6-year follow-up, the data suggested that the apparent volumetric graft remodeling was nearly complete, whereas the survival rate of the dental implants was at a maximum, suggesting that bone graft resorption did not imply a loss of implant stability; this was most likely due to the preservation of the osseointegration, at least in its apical portion, where, probably, only native bone was present. A large periimplant osseous resorption was recorded in the maxillary buccal aspect of the grafted areas owing to the prevalence of horizontal bone augmentation (8 of 11 maxillary procedures) in this region. In the mandible, where a prevalence of vertical bone augmentation was seen (in 10 of 13 mandibular procedures), periimplant bone resorption in the buccal and lingual aspects was recorded.

From this point of view, clinicians who plan alveolar bone augmentation with a corticocancellous hip bone graft should consider the possible long-term extensive resorption of the hard tissue and the remaining amount of grafted bone that might support the titanium dental implant. If different surgical bone augmentation procedures have been previously judged inappropriate in a particular case, dental implant positioning should allow the implant apex to be osseointegrated into the pristine bone receiving the graft, so that the relation between the implant surface and native bone will not be too limited. Therefore, more studies are required to confirm these data.

An extrapolation of the present results, ie, the 6-year follow-up %R values of 13% and −5.5% for the mandible and maxilla, respectively, to the behavior of different types of graft or to different surgical procedures might be inappropriate: for example, a xenogenic or synthetic bone substitute showed a remodeling phenomenon in the first 2 years after grafting in sinus elevation procedures to a much lesser extent than that seen with autogenous bone.[24,25] Only a long-term 3-dimensional analysis similar to the present one for each of several surgical procedures and different sources might provide an accurate prediction of probable volumetric graft resorption.

Acknowledgments

Clinical data were collected by the group composed by Prof. Ludovico Sbordone, MD, DDS; Dr. Franco Guidetti, MD; Dr. GiovanBattista Menchini Fabris, DDS (former research fellow Dept. of Surgery, University of Pisa/ U.O.C. Odondostomatology and Implantology A.O.U.P.); Dr. Paolo Toti BSc, DDS, within the study protocol approved by the Ethical Committee of the University of Pisa.

References

1. Chiapasco M, Zaniboni M, Boisco M: Augmentation procedures for the rehabilitation of deficient edentulous ridges with oral implants. Clin Oral Implants Res 17:136, 2006 (suppl 2)
2. Aghaloo TL, Moy PK: Which hard tissue augmentation techniques are the most successful in furnishing bony support for implant placement? Int J Oral Maxillofac Implants 22:49, 2007 (suppl)
3. Chiapasco M, Casentini P, Zaniboni M: Bone augmentation procedures in implant dentistry. Int J Oral Maxillofac Implants 24:237, 2009 (suppl)
4. Carter DR: Mechanical loading history and skeletal biology. J Biomech 20:1095, 1987
5. Li L, Blake F, Heiland M, et al: Long-term evaluation after mandibular reconstruction with fibular grafts versus microsurgical fibular flaps. J Oral Maxillofac Surg 65:281, 2007
6. Pjetursson BE, Tan WC, Zwahlen M, et al: A systematic review of the success of sinus floor elevation and survival of implants inserted in combination with sinus floor elevation. Part I: Lateral approach. J Clin Periodontol 35:216, 2008 (suppl 8)
7. Verhoeven JW, Ruijter J, Cune MS, et al: Onlay grafts in combination with endosseous implants in severe mandibular atrophy: One year results of a prospective, quantitative radiological study. Clin Oral Implants Res 11:583, 2000
8. Johansson B, Grepe A, Wannfors K, et al: A clinical study of changes in the volume of bone grafts in the atrophic maxilla. Dentomaxillofac Radiol 30:157, 2001
9. Sbordone L, Toti P, Menchini-Fabris GB, et al: Volume changes of autogenous bone grafts after alveolar ridge augmentation of atrophic maxillae and mandibles. Int J Oral Maxillofac Surg 38:1059, 2009
10. Grillon GL, Gunther SF, Connole PW: A new technique for obtaining iliac bone grafts. J Oral Maxillofac Surg 42:172, 1984
11. Keller EE, Tolman DE, Eckert S: Surgical-prosthodontic reconstruction of advanced maxillary bone compromise with autogenous onlay block bone grafts and osseointegrated endosseous implants: A 12-year study of 32 consecutive patients. Int J Oral Maxillofac Implants 14:197, 1999
12. Bell RB, Blakey GH, White RP, et al: Staged reconstruction of the severely atrophic mandible with autogenous bone graft and endosteal implants. J Oral Maxillofac Surg 60:1135, 2002
13. Triplett RG, Schow SR: Autologous bone grafts and endosseous implants: Complementary techniques. J Oral Maxillofac Surg 54:486, 1996
14. Sethi A, Kaus T: Ridge augmentation using mandibular block bone grafts: Preliminary results of an ongoing prospective study. Int J Oral Maxillofac Implants 16:378, 2001
15. Verdugo F, Simonian K, D'Addona A, et al: Human bone repair after mandibular symphysis block harvesting: A clinical and tomographic study. J Periodontol 81:702, 2010
16. Sbordone C, Toti P, Guidetti F, et al: Healing of donor defect after mandibular parasymphyseal block harvesting: A 6-year computerized tomographic follow-up. J Craniomaxillofac Surg 40:421, 2012
17. Smolka W, Eggensperger N, Carollo V, et al: Changes in the volume and density of calvarial split bone grafts after alveolar ridge augmentation. Clin Oral Implants Res 17:149, 2006
18. Krennmair G, Krainhöfner M, Maier H, et al: Computerized tomography-assisted calculation of sinus augmentation volume. Int J Oral Maxillofac Implants 21:907, 2006
19. Herrmann I, Lekholm U, Holm S, et al: Evaluation of patient and implant characteristics as potential prognostic factors for oral implant failures. Int J Oral Maxillofac Implants 20:220, 2005
20. Verhoeven JW, Ruijter JM, Koole R, et al: Bone structure changes in iliac crest grafts combined with implants. Clin Implant Dent Relat Res 12:289, 2010
21. Vermeeren JI, Wismeijer D, van Waas MA: One-step reconstruction of the severely resorbed mandible with onlay bone grafts and endosteal implants. A 5-year follow-up. Int J Oral Maxillofac Surg 25:112, 1996
22. Waitzman AA, Posnick JC, Armstrong DC, et al: Craniofacial skeletal measurements based on computed tomography: Part I. Accuracy and reproducibility. Cleft Palate Craniofac J 29:112, 1992
23. Iizuka T, Smolka W, Hallermann W, et al: Extensive augmentation of the alveolar ridge using autogenous calvarial split bone grafts for dental rehabilitation. Clin Oral Implants Res 15:607, 2004
24. Sbordone L, Levin L, Guidetti F, et al: Apical and marginal bone alterations around implants in maxillary sinus augmentation grafted with autogenous bone or bovine bone material and simultaneous or delayed dental implant positioning. Clin Oral Implants Res 22:485, 2011
25. Covani U, Orlando B, Giacomelli L, et al: Implant survival after sinus elevation with Straumann BoneCeramic in clinical practice: ad-interim results of a prospective study at a 15-month follow-up. Clin Oral Impl Res 22:481, 2011