Block Allograft Technique versus Standard Guided Bone Regeneration: A Randomized Clinical Trial

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ABSTRACT

Purpose: The aim of this randomized clinical trial was to compare the potential of deproteinized bovine bone added to autologous bone or corticocancellous allograft block with or without the addition of recombinant human platelet-derived growth factor-BB (rhPDGF-BB) to regenerate mandibular atrophic ridges.

Materials and Methods: Trial design: parallel, allocation ratio of 1:1 using a split-mouth model. Eligibility criteria for patients: adult patients; bilateral atrophic edentulous areas in the posterior area of the mandible; a preoperatory cone beam computed tomography scan; and absence of systemic diseases affecting the bone metabolism. Bone graft intervention for control group consisted of bone chips collected with a scraper mixed with deproteinized bovine bone covered with a resorbable membrane. Bone graft intervention for test group consisted of a corticocancellous allograft block, shaped before surgery, and protected with a collagen membrane. In addition, both groups received rhPDGF-BB or a saline solution as control. As primary outcome quantity, bone variation after a 1-year healing period was considered. A *p*-value of .05 was considered statistically significant.

Results: Sixteen patients were enrolled in this trial. A total of 50 implants and 32 bone grafts were placed. All patients concluded the study (no dropouts). Change at 1 year in bone volume was not significantly different between the two groups (*p*-value = .25). Effect of treatment in terms of change in bone volume at 1 year was not significant (*p*-value = .89) when saline solution was used while was at limit of significance when rhPDGF-BB was used (*p*-value = .052). After 1 year, all the implants were successfully integrated.

Conclusions: The block allograft and the standard regenerative procedure showed similar results in terms of regenerated bone volume after 1 year of functional loading. The rhPDGF-BB positively influenced soft-tissue healing.

KEY WORDS: allograft, augmentation, bone graft, dental implant, guided surgery, resorption

INTRODUCTION

Bone augmentation is often necessary when the alveolar crest is reabsorbed and standard implants cannot be placed in a prosthetically driven position.[1] Literature has validated several techniques by considering autogenous graft as the gold standard, especially for large defects. Several authors have pointed out that the outcome in large defects is better with a block graft rather than with a particulate one.[2–4] Autogenous blocks need to be harvested from intraoral or extraoral sites, and this process raises the morbidity and complication rates, thereby limiting this procedure to selected patients. Moreover, the quantity of bone that can be collected from intraoral sites is limited and often it is not possible to repeat the harvesting if another area needs to be treated in the same patient.[5,6] When patients refuse intraoral harvesting or cannot stand these invasive procedures, the surgeon has several other suitable materials to use like animal-derived bone or allografts.

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The use of allogenic bone graft, first tested in intraoral defects in the 1970s,[7] avoids the complications and the morbidity of harvested sites and it has no limitations in terms of quantity. Fresh-frozen allogenic onlay graft has a risk of potential disease transmission.[8,9] Processed bone allogenic bone comprises several steps including delipidization, oxidation, dehydration, and gamma irradiation, lowering the risk of disease transmission.[10]

In the last few years, guided surgery has become an argument of discussion in modern implant treatment.[11] Computer-aided oral implant surgery may offer several advantages over the traditional approach. Even regenerative surgery may have some advantages by using computer software planning. Through a computer analysis, it is possible to obtain a surgical template for implant insertion, gain information about the exact quantity of the bone defect, and fabricate a three-dimensional stereolithographic model of the patient's jaw by using a nylon polyamide thermoplastic material that is capable of withstanding autoclave sterilization.[10]

In case of deficient ridge height or severe ridge atrophy, block bone grafting is often necessary to restore the hard-tissue anatomy to renew a proper bone anatomy. The use of mineralized corticocancellous bone allograft can eliminate the additional surgical procedure required to harvest an autograph: the allograft can be prepared made on a sterile field before surgery, enabling the surgeon to evaluate the material from different views without intraoral obstacles and to optimize the perfect adaptation of the graft on the model. The allograft can then be transferred from the sterile model the specimen directly to the same location in the patient's jaws without the need necessity of any other preparation handling.[11,12]

The stability, effectiveness, and predictability of such a technique in horizontal defects are yet to be validated, especially when compared with the autogenous particulate mixed with demineralized bovine-bone technique.[13]

Moreover, recombinant human platelet-derived growth factor-BB (rhPDGF-BB) has been combined with various matrices to accomplish periodontal regeneration and both horizontal and vertical bone augmentation prior to implant therapy.[14–18]

The efficacy and the safety of rhPDGF were largely showed in many studies from the last 20 years especially for the treatment of periodontal osseous defects.[14–20]

It has been shown to stimulate angiogenesis and to be both chemotactic and mitogenic for osteoblasts and gingival fibroblasts, thus, being capable of promoting hard- and soft-tissue healing.[19,20] Deproteinized bovine-bone blocks infused with rhPDGF-BB when applied to severely resorbed ridges have demonstrated promising clinical and histological results both preclinically and in patients.[17,21,22]

Considerable new vital bone formation was found throughout the grafted areas in a majority of test sites (rhPDGF-BB), and there was a significant positive effect on soft-tissue healing. The aim of this single blind randomized clinical trial was to evaluate the 1-year clinical and radiographical outcomes of dental implant rehabilitations inserted in an allogenic bone graft or an autogenous bone chip graft mixed with deproteinized bovine-bone particulate in a split-mouth model with or without rhPDGF- BB.

MATERIALS AND METHODS

Sixteen patients were included in this single-center, split-mouth, two parallel-armed (1:1 ratio) randomized clinical trial. The CONSORT guidelines were used as the framework for this research (Figure 1). The study was conducted following the ethical principles founded in the Declaration of Helsinki; a written informed consent was obtained from all eligible patients before enrollment. The median age of patients at the baseline (BL) was 59.5 year (minimum 32 year, maximum 72 year). Split-mouth study was chosen because it allows obtaining the control group (CG) from the same patients and increases the statistical efficiency measure as well.

Participants

They were enrolled based on the following inclusion criteria: adult patients; patients presenting bilateral atrophic posterior edentulous areas in the mandible; a preoperatory cone beam computed tomography (CBCT) scan of the lower arch; and absence of systemic diseases affecting the bone metabolism. Data obtained from the CBCT were processed using computer software planning (SimPlant OMS, Materialise, Leuven, Belgium); defects should be symmetrical and show the same amount of horizontal resorption (Figure 2). One operator consecutively treated all the subjects, whereas data were collected and analyzed at the Genoa University, Health Science Department.

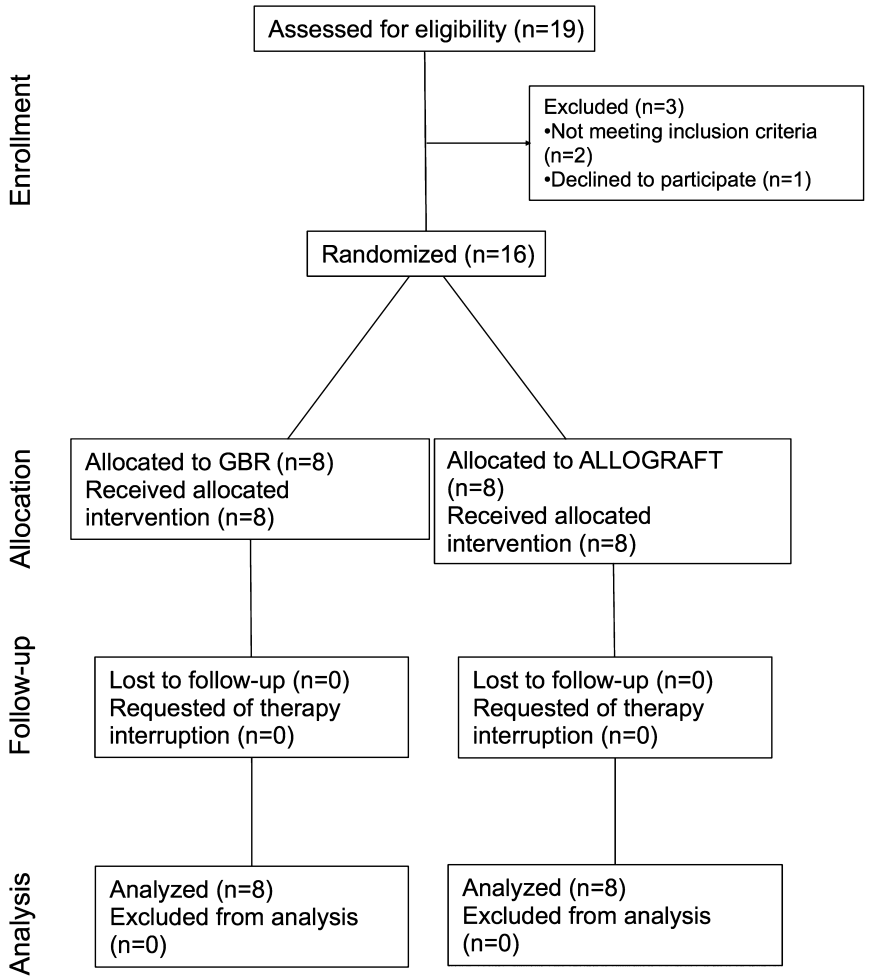

Figure 1 CONSORT statement 2010 flow diagram. GBR = guided bone regeneration.

Interventions

Two main intervention arms were planned: in the first one (test group [TG]), a block allograft technique was used, whereas in the second group (CG), a conventional guided bone regeneration (GBR) technique was chosen. Furthermore, it was decided to blindly subgroup the two arms by using only saline solution in subgroup A (A) or rhPDGF-BB in subgroup B (B) during the graft procedure.

Test Intervention Protocol (TG)

The study of the bone stereolithographic reconstructions allowed the setting up of the mineralized bone allograft before surgery. Corticocancellous iliac block allografts (Puros Block Allograft; Zimmer Dental, Carlsbad, CA, USA) were used in this procedure. The donor's tissues are strictly controlled in order to reduce any possible presence of infectious disease. The bone was collected according to the manufacturing practices required by the US Food and Drug Administration by a certified tissue bank and subjected to a five-step proprietary process (Tutoplast Process; Tutogen Medical, Neunkirchen am Brand, Germany) including delipidization, osmotic contrast treatment, oxidation treatment with hydrogen peroxide, solvent dehydration in acetone baths, and limited-dose gamma irradiation (17.8 Gy). All these passages retain the natural mineralization, collagen, and bone morphogenetic proteins (BMPs) of the native bone tissue.

The software allowed previewing the amount of bone to be regenerated and to optimize time during the surgery. An overcorrection of the defect was calculated in order to limit the forthcoming resorption. Prior to the surgery, the stereolithographic model of all the patients were sterilized; the bone blocks were prepared by aseptic surgery using the same procedures of conventional grafting surgery. Using a low speed bur, the allografts were shaped in order to have the maximum bone

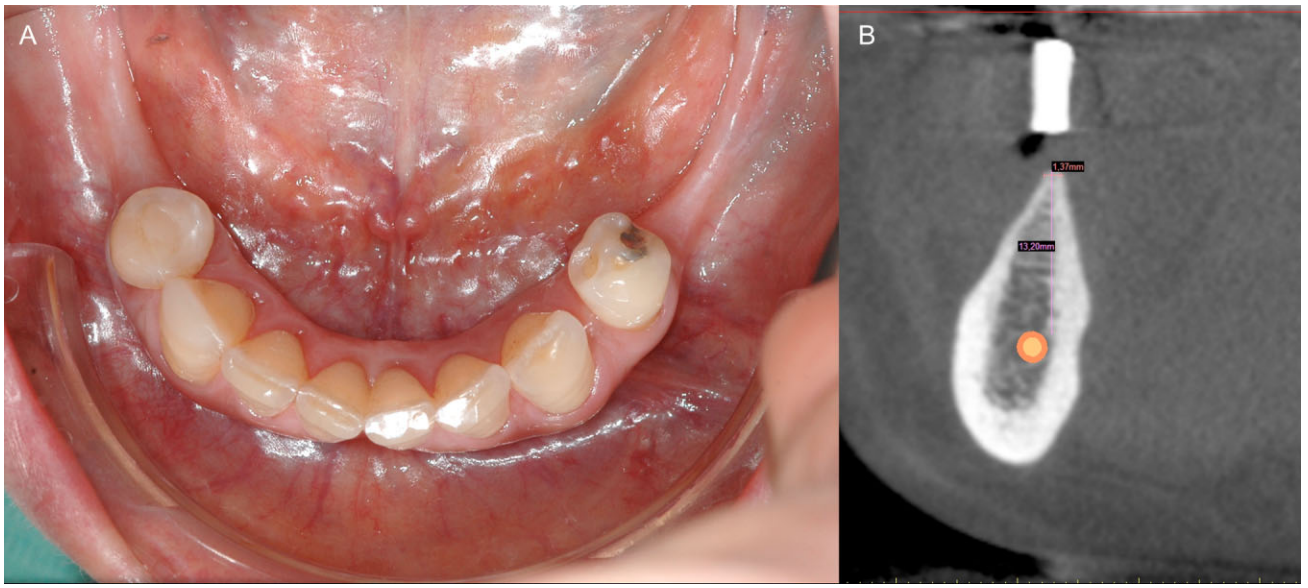

Figure 2 (A) Occlusal view of a patient showing the atrophic ridges. (B) Cone beam computed tomography scan: defect area in correspondence of the prosthetically driven implant site.

contact and stability to the atrophic area. Finally, the blocks were secured with osteosynthesis screws to the model similar to how it would be in the patient's mouth. The sinterized models with the allografts were packaged in two sterile envelopes. On the day of surgery, after a full thickness flap elevation, implant beds were prepared using a teeth-supported stereolithographic guide and all the implants were placed without passing through the guide.

Overall, 25 Straumann® SLActive Bone Level implants were inserted (Straumann AG, Basel, Switzerland; 3 had a diameter of 3.3 mm and 22 were of 4.1 mm–diameter; length ranged from 8 to 12 mm and 56% of them were of 10 mm length).

After implant insertion, the graft procedures were performed. The prepared blocks were screwed with an osteosynthesis screw to the receiving bone and covered with a resorbable membrane (Bioguide®, Geistlich AG, Wolhusen, Switzerland). Prior to use, the allografts have been removed from the model and rehydrated with a sterile physiologic solution by expelling the air inside.

The original blocks were trimmed to obtain the planned volume. To this amount, the bone chip collected during the reduction was added to the regenerated area.

Then, syringes with saline solution in subgroup or rhPDGF-BB (GEM 21S® Osteohealth, Luitpold Pharmaceuticals, Shirley, NY, USA) were extracted from sealed packages and the grafts were infused and left in immersion in them until fixation on the patients. For each patient, the weight (milligram) and volume (cubic centimeter) of allograft bone were evaluated and recorded. Allograft augmentations procedure took an average of 30 minutes, excluding the implant insertion and the suture (Figure 3).

Control Intervention Protocol (CG)

On the day of surgery, after a full thickness flap elevation, the implant beds were prepared using a teeth-supported stereolithographic guide and all the implants were placed without passing through the guide. Autologous chips of bone were harvested with a bone scraper from the posterior mandible, positioned directly on the implant site followed by the deproteinized bovine bone (Bioss®, Geistlich) in the defect and covered with a double layer of resorbable collagen membrane (Bioguide®, Geistlich). A total of 16 packages each of 125 mg were inserted in the regenerated area, as well as autogenous bone chips of the same quantity as that of the planned graft volume. In order to stabilize the regeneration material, osteosynthesis screws were inserted.

Overall, 25 Straumann® SLActive Bone Level implants were inserted (3 had a diameter of 3.3 mm and 22 were of 4.1 mm–diameter; length ranged from 8 to 12 mm and 56% of them were of 10 mm length). For each patient, the weight (milligram) and volume (cubic centimeter) of autologous bone and Bioss were evaluated and recorded.

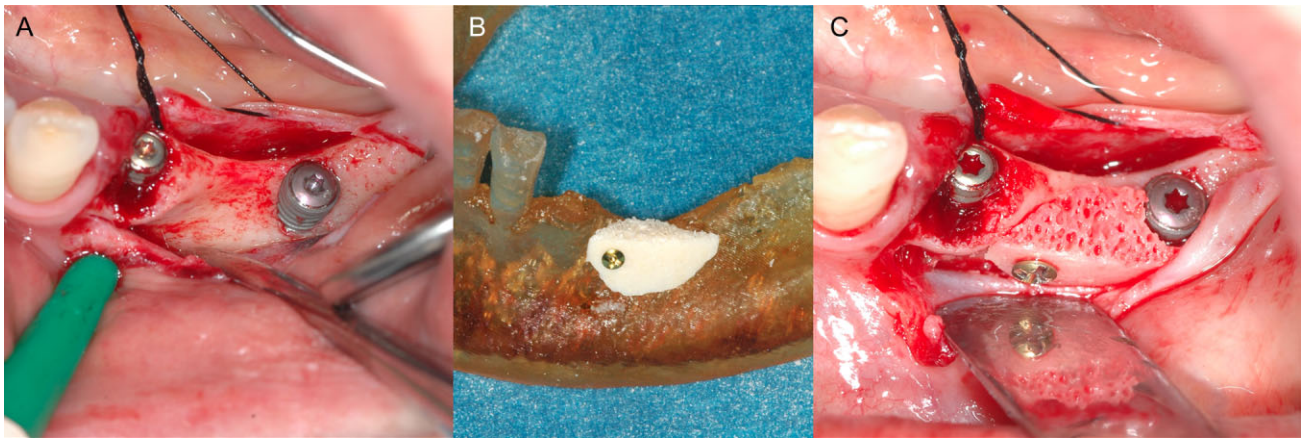

Figure 3 Test group. (A) Augmentation site exposed with implants in position. (B) Bone-block adaptation to the model. (C) Allograft block secured to the defect area.

Then, syringes with saline solution in subgroup or rhPDGF-BB were extracted from sealed packages and the grafts were infused before the covering of the membrane.

Soft-tissue closure was achieved without tension, with large periosteum incisions and sutured with 6-0 expanded polytetrafluoroethylene (Gore-Tex suture; Gore, Flagstaff, AZ, USA) suture. For each patient, the weight (milligram) of deproteinized bovine bone and that of autologous bone were evaluated and recorded. Bioss + autogenous augmentation procedure took 45 minutes, excluding the implant insertion and the suture (Figure 4).

Prosthetic Procedure

Patients were observed once a month for 6 months. Healing was uneventful except for two patients from the CG, subgroup A, who had early exposure of the membrane and they were treated with local antiseptics (rinse with chlorhexidine 0.2% sol and application with chlorhexidine gel). Minimal swelling was observed and the patients required minimal analgesics. At 6 months after implant placement, radiographs of the implant sites were obtained, and the implants were restored with 15 partial fixed prosthesis, 1 total fixed prosthesis, 12 single crowns, and 2 bar-retained overdentures (Figure 5).

Outcomes

Following a 1-year healing period from the definitive prosthesis delivery, a second CBCT evaluation was carried out for all patients to evaluate the stability and volume of the augmented areas. As a primary outcome, bone volume changes among different graft procedures in the regenerated area were considered. The preoperative and postoperative CBCT scans were aligned

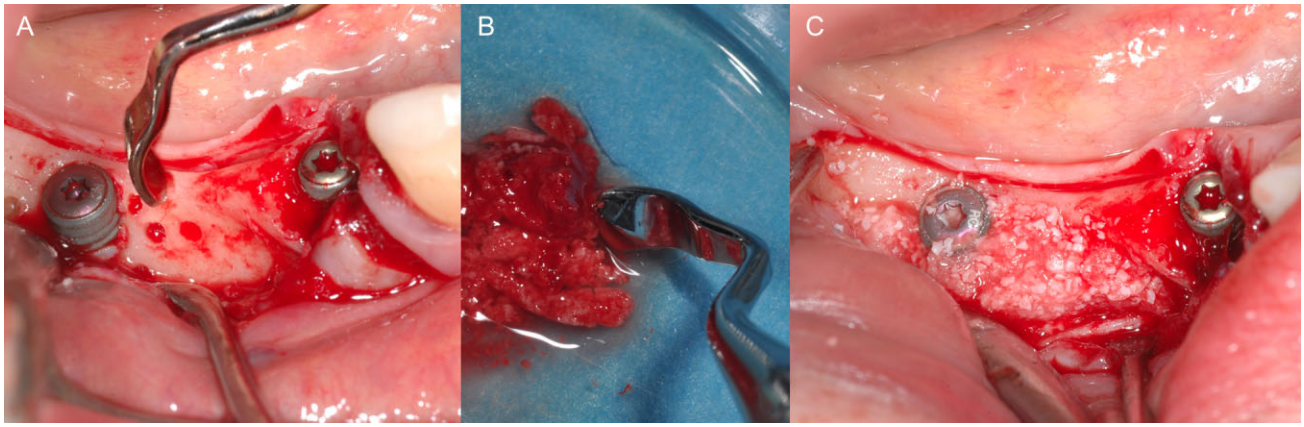

Figure 4 Control group. (A) Bone defect at control site. (B) Autologous bone chips collected. (C) Deproteinized bovine bone mixed with autogenous bone chips positioned on the opposite defect area.

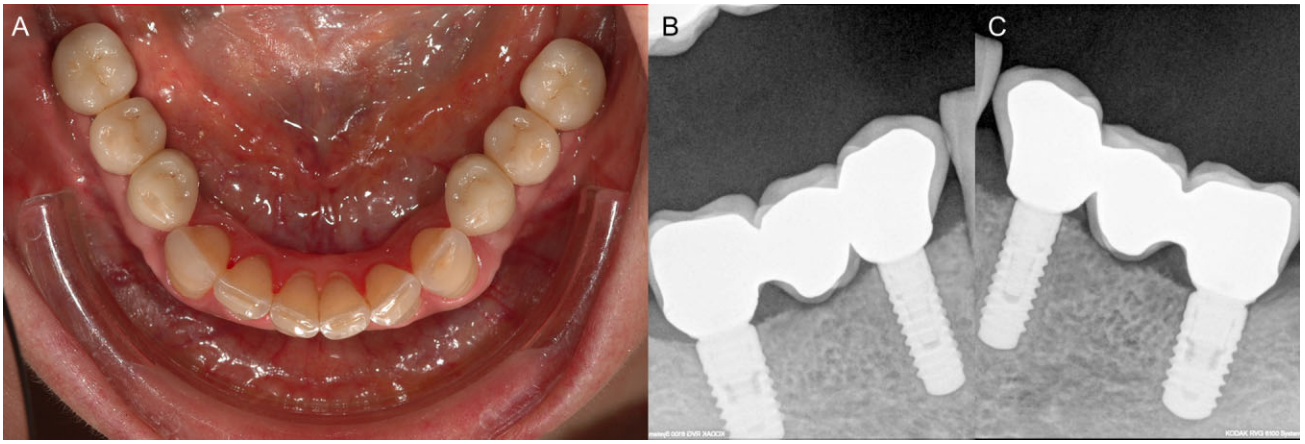

Figure 5 (A) Occlusal view of the final prosthesis after 1-year follow-up. (B) Control site radiograph 1 year after functional loading. (C) Test site radiograph 1 year after functional loading.

pairwise using an iterative closest point algorithm, which allowed for comparison between the bone defect and the actual bone correction. One operator performed all measurements using Simplant OMS software (Materialise). It was possible to quantify the regenerated bone status by underlaying the areas from the difference between the two superimposed bone profiles using a software program (Bone Grafting, Materialise) that allowed calculating the exact resulting volumes (Figure 6).

As secondary outcomes, stability and health status of the augmented area were evaluated in different healing periods clinically and with standardized radiographs. The following four indexes were used: (1) mean marginal bone loss (mMBL); (2) bleeding on probing (BOP); (3) modified plaque index; and (4) probing pocket depth (PPD). mMBL was measured using intraoral apical radiographs obtained with the long-cone paralleling technique and it confirmed good implant integration. mMBL was carried out by

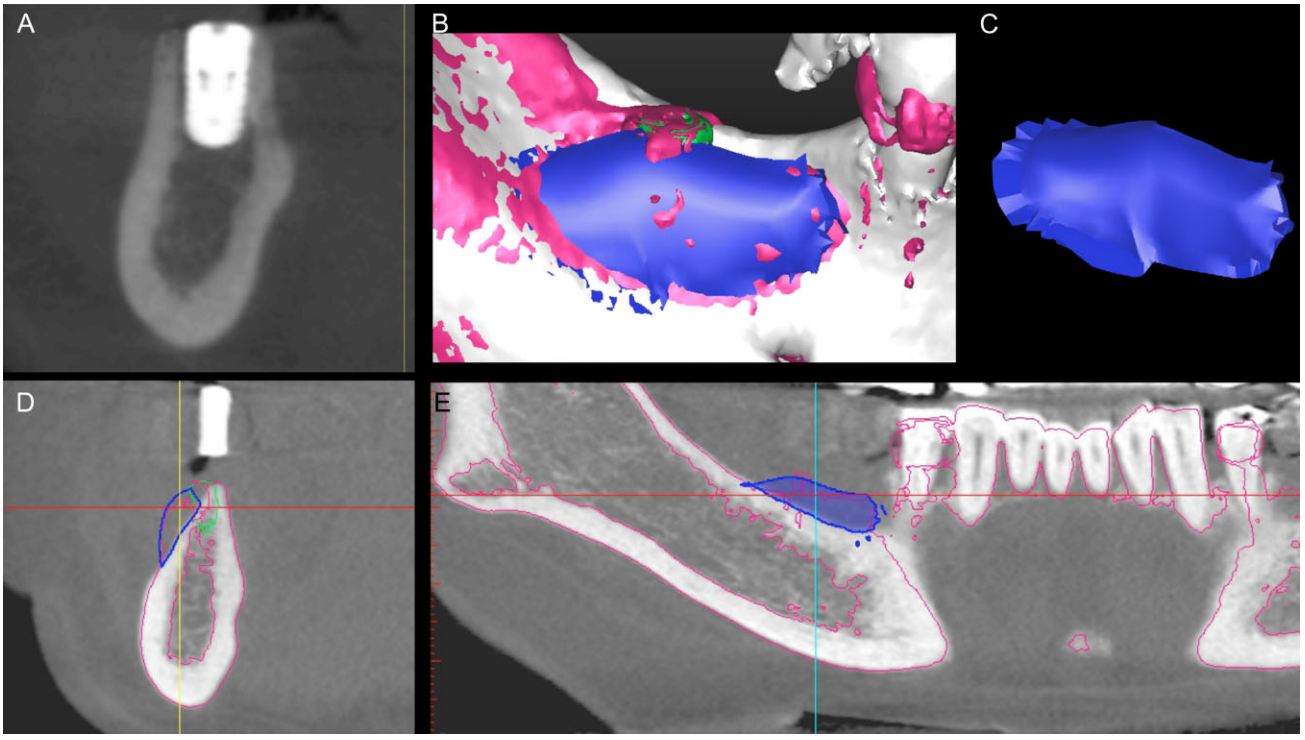

Figure 6 Bone volume changes evaluation method. (A) Cone beam computed tomography (CBTC) after 12 months of the grafted area. (B,C) Evaluation of bone augmentation 1 year after surgery: three-dimensional superimposition image. (D,E) Evaluation of bone augmentation 1 year after surgery: superimposition of the bone surfaces (pink lines represent the postop CBCT).

standardizing the distance on the x-ray with the known implant length (Nevins and colleagues 2005). The healing periods were at the reopen procedure (BL), at the crown insertion (CI) stage, 6 months after CI, and 1 year from CI.

Randomization

Specifically customized Java software (Oracle Corp., Redwood City, CA, USA) was developed to generate a randomized sequence by a statistician. After insertion of patient data, if all inclusion criteria were respected, the software allocated the left side of the patient in the group 1 or group 2 and in the subgroup A or B. Allocation results were delivered to an operator who assisted the surgeon. Concealment of treatment was possible only for the subgroups when the assistant prepared and gave the saline solution or the PDGF to the surgeon.

Patients were enrolled in a private practice by one clinician, where a third operator performed data collection and bone volume analysis. All the data were collected in a blinded file and returned to the statistician.

Statistical Analysis

Mean and standard deviation or median and interquartile range were reported for continuous measurements. Nonparametric Wilcoxon test for paired data was first used to assess differences between treatments on change at T1 of bone volume and on resorption.

Generalized estimating equation (GEE) model, taking into account correlation between the measurements from same patients, was also used to assess the differences in bone volume change between treatments and between different materials (subgroup A and B) used during surgery. Significance of interaction between treatment and material on bone volume difference was also assessed. Similarly, assessment of impact of treatment and of materials used on mMBL and on PPD was done.

McNemar's test was used to assess if a change occurred between TG and CG for modification of plaque index and BOP at different time points. Correlation between continuous characteristics was assessed by means of the nonparametric Spearman's rank correlation. A p-value of .05 was considered statistically significant. SPSS (v.19, IBM Corp., Armonk, NY, USA) and GPower (Dusseldorf, Germany) were used for computation.

RESULTS

Primary Outcome

Bone volume at BL (T0) and 1 year (T1) and differences between 1 year and BL (T1 – T0), expressed both as absolute and percentage difference, for CG and TG are shown in Table 1. Changes in bone volume at T1 were not significantly different in the two groups (p-value = .25). Similarly, there were no significant differences in percentage resorption in the two groups (p-value = .17).

For a sample of 16 patients and by applying the Wilcoxon signed-rank test for matched pairs and a hypothesized correlation between pairs of 0.9, using post hoc power calculation, it was found that the power of the test was 80.6%.

Bone volume for subgroups at T0 and T1 and differences between 1 year and BL, expressed both as absolute and percentage difference, detected by the interaction of treatment and the material used during surgery, are shown in Table 2.

Change of bone volume showed significant difference between subgroup A and subgroup B (p-value < .001), irrespective of the treatment group,

TABLE 1 Median Bone Volume at Baseline and after 1 Year, and Both Absolute and Percentage Median Difference in TG and CG

Characteristics	GBR (CG) Median (IQR)	Allograft (TG) Median (IQR)	p-Value
Bone volume baseline (cm^3)	0.19 (0.14 to 0.25)	0.19 (0.14 to 0.25)	—
Bone volume 1 year (cm^3)	0.18 (0.13 to 0.24)	0.16 (0.13 to 0.20)	
Bone volume difference (T1 – T0) (cm^3)	–0.01 (–0.03 to 0.01)	0 (–0.03 to 0)	.25
Bone volume difference (T1 – T0) (%)	–3.8 (–12.1 to 5.4)	–3.3 (–16.2 to 0)	.17

CG = control group; GBR = guided bone regeneration; IQR = interquartile range; TG = test group.

TABLE 2 Bone Volume at Baseline and after 1 Year, and Both Absolute and Percentage Difference Considering Subgroups Detected by Treatment and Materials Used during Surgery. A: Saline Solution. B: rhPDGF-BB

	GBR (CG)		Allograft (TG)		
	(A)	(B)	(A)	(B)	
Characteristics	Median (IQR)				*p*-Value
Bone volume baseline (cm^3)	0.20 (0.17 to 0.26)	0.15 (0.11 to 0.23)	0.20 (0.13 to 0.25)	0.16 (0.14 to 0.25)	.90
Bone volume 1 year (cm^3)	0.19 (0.15 to 0.21)	0.16 (0.13 to 0.25)	0.17 (0.12 to 0.20)	0.16 (0.13 to 0.22)	.44
Bone volume difference (T1 – T0) (cm^3)	−0.03 (−0.05 to −0.01)	0.01 (0 to 0.02)	−0.03 (−0.04 to −0.01)	0 (0 to 0)	<.001
Bone volume difference (T1 – T0) (%)	−12.1 (−19.3 to −5.3)	5.4 (0 to 11.8)	−11.8 (−21.9 to −4.3)	0 (−3.3 to 0)	<.001

CG = control group; GBR = guided bone regeneration; rhPDGF-BB = recombinant human platelet-derived growth factor-BB; TG = test group.

and particularly the change between BL and 1 year was significant for subgroup A (*p*-value < .001) with an absolute decrease of bone volume while change was not significant for subgroup B (*p*-value = .89).

Both at the BL (*p*-value = .90) and at 1 year (*p*-value = .44), no significant difference between the subgroups was highlighted.

Interaction between treatment and materials was significant (*p*-value < .001); thus, the change of bone volume with time was different for different treatments and materials. Particularly, the effect of treatment on change in bone volume at 1 year was not significant (*p*-value = .89) when saline solution was used. However, it had limited significance when rhPDGF-BB was used (*p*-value = .052).

Correlation between bone volume at BL and percentage of resorption was statistically significant (rho = −0.37; *p*-value = .035).

When correlation between measurement from same patients was taken into account, the association between resorption and bone volume at BL was always significant (*p*-value = .047; GEE model) without differences between CG and TG (*p*-value for interaction = .85; GEE model). Relation between resorption and BL bone volume was also not statistically different between subgroups detected by treatment and materials used (*p*-value = .93).

Secondary Outcomes

Considering secondary outcomes, the mMBL was found to significantly change during healing time (*p*-value = .023), and this change resulted in significant difference between the two treatments (*p*-value = .05) and between the two materials used (*p*-value < .001); however, it was not significantly different between the subgroups based on treatments and materials (*p*-value = .26). Particularly, a higher change for TG at both 6 and 12 months was observed. The differences in PPDs during healing time were significant (*p*-value < .001) but not between CG and TG (*p*-value = .51) and between subgroup A and subgroup B (*p*-value = .16) and so also between subgroups of treatments and materials (*p*-value = .63 for interaction among time, treatment, and material).

Correlation between mMBL and resorption was significantly different between the subgroups (*p*-value < .001). In fact, a significant and negative correlation was found for GBR-saline solution (rho = −0.56; *p*-value = .045), allograft-saline solution (rho = −0.76; *p*-value = .003), and allograft-rhPDGF-BB (rho = −0.68; *p*-value = .015), while a practically null correlation was found in GBR-PDGF-BB group (rho = 0.023; *p*-value = .94).

For a total of five patients (one implant for patients), a modification of plaque index was found for CG at 12 months, while only one of these patients had a modification in TG (McNemar's test: *p*-value = .13) at the same time point. Considering BOP, three patients had values of 1 at 12 months in CG, while all patients had a value of 0 in TG (Table 3).

DISCUSSION

Autogenous bone is widely used for bone grafts because of its positive cell stimulation, optimal integration into the host tissues, and for its osteogenic, ostoeoconductive, and osteoinductive characteristics.

TABLE 3 Comparison of Biological Parameters of All the Investigated Groups (A1 GBR Plus Saline; A2 GBR Plus rhPDGF; B1 Allograft Plus Saline; B2 Allograft Plus rhPDGF) at BL, PI, 6 Months, and 1 Year

	GBR (CG)			ALLOGRAFT (TG)			
	A	B		A	B		
	Mean (SD)/*n* (%)		*p*-Value	Mean (SD)/*n* (%)		*p*-Value	*p*-Value
Baseline (BL)							
mMBL	0.31 (0.31)	0.23 (0.28)	.51	0.35 (0.36)	0.15 (0.22)	.34	.62
BOP			—			—	
0	13 (100)	12 (100)		13 (100)	12 (100)		
1	0	0		0	0		
mPI			—			—	
0	13 (100)	12 (100)		13 (100)	12 (100)		
1	0	0		0	0		
PPD	0.0 (0.0)	0.0 (0.0)	—	0.0 (0.0)	0.0 (0.0)	—	—
Prosthesis insertion (PI)							
mMBL	0.46 (0.23)	0.23 (0.28)	.011	0.43 (0.33)	0.24 (0.24)	.33	.72
BOP			—			—	
0	13 (100)	12 (100)		13 (100)	12 (100)		
1	0	0		0	0		
mPI			.48			.74	.57
0	13 (100)	11 (91.7)		12 (92.3)	11 (91.7)		
1	0	1 (8.3)		1 (7.7)	1 (8.3)		
PPD	1.75 (0.56)	1.99 (0.69)	.53	1.77 (0.59)	1.95 (0.55)	.42	.94
6 months							
mMBL	0.55 (0.34)	0.23 (0.28)	.009	0.65 (0.42)	0.39 (0.36)	.32	.093
BOP			—			—	
0	13 (100)	12 (100)		13 (100)	12 (100)		
1	0	0		0	0		
mPI			—			—	
0	13 (100)	12 (100)		13 (100)	12 (100)		
1	0	0		0	0		
PPD	1.76 (0.54)	2.01 (0.67)	.48	1.77 (0.59)	1.96 (0.56)	.38	.85
1 year							
mMBL	0.62 (0.40)	0.23 (0.28)	.007	0.78 (0.52)	0.45 (0.47)	.29	.03
BOP			.096			—	.12
0	13 (100)	9 (75)		13 (100)	12 (100)		
1	0	3 (25)		0	0		
mPI			.46			.48	.055
0	11 (84.6)	9 (75)		13 (100)	11 (91.7)		
1	2 (15.4)	3 (25)		0	1 (8.3)		
PPD	1.76 (0.54)	2.07 (0.69)	.31	1.77 (0.59)	2.00 (0.58)	.28	.81

	Global *p*-Value for Difference in Time between Allograft and GBR	Global *p*-Value for Difference in Time between Subgroups of Treatment and Material
mMBL	0.05	0.26
PPD	0.51	0.63

BOP = bleeding on probing; CG = control group; GBR = guided bone regeneration; mMBL = mean marginal bone loss; mPI = modified plaque index; PPD = probing pocket depth; rhPDGF-BB = recombinant human platelet-derived growth factor-BB; SD = standard deviation; TG = test group; —: not calculable.

The graft can be harvested from intraoral or extraoral donor sites. Side effects involved using this technique could appear during the surgical procedures or as postoperative drawback; the incisions and scarring could lead to blunting of papillae, injury of the inferior alveolar, lingual and mental nerves, and lesions of the submental and sublingual arteries. In the postoperative phase, reduced sensitivity of anterior teeth, chin ptosis, hemorrhage, increased pain, and risk of infection and incision dehiscence in the donor area could appear.[2,23–27]

The risk of intraoperative and postoperative complications could reduce the amount of patients compatible with this surgical technique.

Bone allografts have been used successfully in orthopedic surgery for decades and the histologic events involved in allograft incorporation have been reviewed on multiple occasions.[28–32]

Even tough the corticocancellous allogenic blocks are widely used in contemporary orthopedics,[33,34] only a few researches have established the clinical efficacy of this graft technique to place dental implants where alveolar ridge augmentation is needed.

As alternative to autogenous bone grafts, allogenic substitutes in particulate form have been used alone or combined with alloplastic, xenogeneic, or autogenous materials for long time.[35–37] Little or no advantages were reported in using an autograft over an allograft because free autogenous cortical block grafts are ultimately nonviable.[38,39] Allograft scaffolds are effective to support a new bone growth,[36,39–42] and they also provide osteoinduction, releasing BMPs when demineralized.

The alveolar bridge augmentation and the new bone deposition are supported by mesenchymal cells recruited from the host site; this process could be implemented and protected using membranes as barrier for GBR.[39,43,44]

The clinical behavior of an allograft depends on two different factors: the method with which the harvested bone is processed and the harvested bone itself. The results described in this study were obtained with aseptically excised and processed allografts that were shaped in a sterile field prior to surgery.

Patients and providers usually concern the incidence of disease transmission from tissue bank allografts, including human immunodeficiency virus, hepatitis B and C viruses, human T-lymphotropic virus, and transmission of Creutzfeldt-Jakob disease[39]; for this reason, allogenic tissues must be obtained from an accredited tissue procurement organization that guarantees strict guidelines in the screening and processing of all grafts.

As used in this study, the corticocancellous block provides predictable results. The cancellous component allows for vascular infiltration leading to integration, and the cortical component allows for rigid fixation and resistance to resorption: autogenous and allogenic block grafts result similar for manipulation and surgical technique; however, unlike the autogenous block technique, the clinician has the possibility to use the patient's jaw's stereolithographic model as a template to shape the graft without any visual impediment, concerns about hemostasis, and any pressure to work in a compatible time frame. This can help to enhance the accuracy and the fit of the preparation. It is important to underscore that the allogenic bone blocks need rehydration in saline solution for 45 minutes before insertion.

Eliminating the need to prepare the block allograft during the surgical procedures can shorten the time of the entire surgery, which helps to justify the additional costs required for this technique.

Early vascularization of the graft is a major factor in the integration of the graft and the maintenance of its stability.[45] Enneking and Mindell showed that the extent of new bone formation between the graft and the host junction is correlated with revascularization and healing time.[46]

Furthermore, the use of screws for the rigid fixation of the graft to the recipient site using titanium minisscrews has been found to be essential in the prevention of fibrous ingrowth between the allograft and the host. A movement of just 10 to 20 μm during the early stages of wound healing is enough to direct differentiation of the mesenchymal cells into fibroblasts instead of osteoblasts,[47] ultimately leading to failure of the allograft. The perfect adaptation of the graft to the recipient site increases graft stability and promotes intramembranous bone formation.

The periapical radiographs taken at 6 and 12 months after implant placement showed no pathological signs of bone resorption, but a statistically significant increase of MBL of the TG was reported at 1 year of follow-up. The use of PDGF seemed to have no influences on MBL.

Traditional radiographic imaging is limited in terms of the detail provided: a radiograph transforms a three-dimensional structure into a two-dimensional image,

while a computed tomographic scan could result in a more useful assessment of the bone augmentation and contour.[48] In this study, measurements made between the preoperative and postoperative CBTC did not reveal a significant difference between the bone resorption of the two grafted sites: both augmentation procedures showed good results and were more than sufficient to restore the proper anatomical shape considering both differences of volumes between the time points and the percentage of volume of bone loss.

However, CT is too costly to be used on a routine basis even if newer CT technologies such as cone beam CT have reduced the radiation dosage. Using both a detailed clinical and a radiographic examination, it is possible to obtain an adequate assessment of bone graft healing.[49]

In the literature, the use of rhPDGF-BB is associated with greater bone regeneration when compared with those without growth factors, and this finding is moderately favorable in terms of the impact of rhPDGF-BB on bone regeneration.[15–18,50] Better healing of soft tissues of the regenerated areas was also evidenced when the graft materials were infused with rhPDGF-BB.[19,20] rhPDGF-BB stimulates angiogenesis and by being both chemotactic and mitogenic for osteoblasts and gingival fibroblasts is capable of promoting hard- and soft-tissue healing.[19,20] In this study, the infusion of rhPDGF-BB, independently by the group (test or control), stabilized bone regeneration by limiting the resorption after 1 year almost to the level of the BL. The saline solution subgroup registered a statistically significant decrease of bone volume from the initial quantity. Only the use of rhPDGF-BB in the CG revealed an augmentation from the initial graft volume. That was in agreement with an animal study that showed how deproteinized bovine-bone granules, more than other graft materials, have the capacity to absorb the growth factors and release them during the healing phase.[21] The allogenic block bone graft shows different advantages: they are easy to access, a donor site is not necessary, they are readily available, and they can be provided in unlimited quantities. The graft is structured combining a cortical plate that allows screw fixation and prevention of resorption, and a cancellous marrow part that works to increase osteoconductivity and vascular infiltration by creating an intimate contact with native bone. The disadvantages of the graft are the use of cadaveric tissue, lack of vitality, deficiency of osteogenic potential, and greater economic expense.

CONCLUSIONS

The present study showed that if all bone integration principles were applied, a successful use of allogenic corticocancellous bone block is possible. A correct use of barrier membrane, rehydration of the allogenic bone, perfect adaptation of the graft, and tension-free wound closure are mandatory issues. No evidence of bone or soft-tissue infection, wound dehiscence, or other clinical problems was observed postoperatively. Surgical exposure revealed clinically well-integrated grafts and suitable conditions for implant prosthetic procedures. Of the two types of bone regeneration materials, the allograft showed a slightly greater quantity of resorption, which did not prevent placement of dental implants in appropriate positions. None of the implants used failed to integrate. These findings, in association with the less invasiveness of the surgical technique, make allogenic bone-block grafts in conjunction with a resorbable membrane a viable alternative to autogenous bone-block grafts in selected patients with alveolar ridge deficiencies. The use of rhPDGF-BB positively influenced soft-tissue healing and guaranteed a better preservation of the regenerated bone, in particular, when used in association with the deproteinized bovine-bone material. Considering the relatively short follow-up (12 months), further study and long-term data accumulation are required to ensure long-term bone graft stability and implant survival.

This study took in consideration bone regeneration using allogenic corticocancellous bone blocks and showed to be successful. Careful rehydration and accurate adaptation of the graft, barrier membrane placement, and closure of the wound without tension are the key factors for the overall success.

REFERENCES

1. Chiapasco M, Casentini P, Zaniboni M. Bone augmentation procedures in implant dentistry. Int J Oral Maxillofac Implants 2009; 24(Suppl):237–259.
2. Misch CM. Comparison of intraoral donor sites for onlay grafting prior to implant placement. Int J Oral Maxillofac Implants 1997; 12:767–776.
3. Pikos MA. Mandibular block autografts for alveolar ridge augmentation. Atlas Oral Maxillofac Surg Clin North Am 2005; 13:91–107.
4. McAllister BS, Haghighat K. Bone augmentation techniques. J Periodontol 2007; 78:377–396.
5. Esposito M, Grusovin MG, Kwan S, Worthington HV, Coulthard P. Interventions for replacing missing teeth: bone

augmentation techniques for dental implant treatment. Cochrane Database Syst Rev 2008; (3) CD003607.
6. Zouhary KJ. Bone graft harvesting from distant sites: concepts and techniques. Oral Maxillofac Surg Clin North Am 2010; 22:301–316.
7. Narang R, Ruben MP, Harris MH, Wells H. Improved healing of experimental defects in the canine mandible by grafts of decalcified allogenic bone. Oral Surg Oral Med Oral Pathol 1970; 30:142–150.
8. Lyford RH, Mills MP, Knapp CI, Scheyer ET, Mellonig JT. Clinical evaluation of freeze-dried block allografts for alveolar ridge augmentation: a case series. Int J Periodontics Restorative Dent 2003; 23:417–425.
9. Nissan J, Romanos GE, Mardinger O, Chaushu G. Immediate nonfunctional loading of single-tooth implants in the anterior maxilla following augmentation with freeze-dried cancellous block allograft: a case series. Int J Oral Maxillofac Implants 2008; 23:709–716.
10. Jacotti M. Simplified onlay grafting with a 3-dimensional block technique: a technical note. Int J Oral Maxillofac Implants 2006; 21:635–639.
11. Hämmerle CHF, Stone P, Jung RE, Kapos T, Brodala N. Consensus statements and recommended clinical procedures regarding computer-assisted implant dentistry. Int J Oral Maxillofac Implants 2009; 24(Suppl):126–131.
12. Pendarvis W, Sandifer J. Localized ridge augmentation using a block allograft with subsequent implant placement: a case series. Int J Periodontics Restorative Dent 2008; 28:509–515.
13. Waasdorp J, Reynolds M. Allogeneic bone onlay grafts for alveolar ridge augmentation: a systematic review. Int J Oral Maxillofac Implants 2010; 25:525–531.
14. Nevins M, Camelo M, Nevins ML, Schenk RK, Lynch SE. Periodontal regeneration in humans using recombinant human platelet-derived growth factor-BB (rhPDGF-BB) and allogenic bone. J Periodontol 2003; 74:1282–1292.
15. Nevins ML, Camelo M, Nevins M. Minimally invasive alveolar ridge augmentation procedure (tunneling technique) using rhPDGF-BB in combination with three matrices: a case series. Int J Periodontics Restorative Dent 2009; 29: 371–383.
16. Camelo M, Nevins ML, Schenk RK, Lynch SE, Nevins M. Periodontal regeneration in human class II furcations using purified recombinant human platelet-derived growth factor-BB (rhPDGF-BB) with bone allograft. Int J Periodontics Restorative Dent 2003; 23:213–225.
17. Simion M, Rocchietta I, Dellavia C. Three-dimensional ridge augmentation with xenograft and recombinant human platelet-derived growth factor-BB in humans: report of two cases. Int J Periodontics Restorative Dent 2007; 27:109–115.
18. Simion M, Rocchietta I, Monforte M, Maschera E. Three-dimensional alveolar bone reconstruction with a combination of recombinant human platelet-derived growth factor BB and guided bone regeneration: a case report. Int J Periodontics Restorative Dent 2008; 28:239–243.
19. Joyce ME, Jingushi S, Scully SP, Bolander ME. Role of growth factors in fracture healing. Prog Clin Biol Res 1991; 365: 391–416.
20. Kiritsy CP, Lynch AB, Lynch SE. Role of growth factors in cutaneous wound healing: a review. Crit Rev Oral Biol Med 1993; 4:729–760.
21. Simion M, Rocchietta I, Kim D, Nevins M, Fiorellini J. Vertical ridge augmentation by means of deproteinized bovine bone block and recombinant human platelet-derived growth factor-BB: a histologic study in a dog model. Int J Periodontics Restorative Dent 2006; 26:415–423.
22. Thoma DS, Jung RE, Hänseler P, Hämmerle CHF, Cochran DL, Weber FE. Impact of recombinant platelet-derived growth factor BB on bone regeneration: a study in rabbits. Int J Periodontics Restorative Dent 2012; 32: 195–202.
23. Joshi A. An investigation of post-operative morbidity following chin graft surgery. Br Dent J 2004; 196:215–218.
24. Von Arx T, Hafliger J, Chappuis V. Neurosensory disturbances following bone harvesting in the symphysis: a prospective clinical study. Clin Oral Implants Res 2005; 16: 432–439.
25. Nkenke E, Radespiel-Troger M, Wiltfang J, Schultze Mossgau S, Winkler G, Neukam FW. Morbidity of harvesting of retromolar bone grafts: a prospective study. Clin Oral Implants Res 2002; 13:514–521.
26. Booij A, Raghoebar GM, Jansma J, Kalk WW, Vissink A. Morbidity of chin bone transplants used for reconstruction alveolar defects in cleft patient. Cleft Palate Craniofac J 2005; 42:533–538.
27. Silva FM, Cortez AL, Moreira RW, Mazzonetto R. Complications of intraoral donor site for bone grafting prior to implant placement. Implant Dent 2006; 15:420–426.
28. Heiple KG, Chase SW, Herndon CH. A comparative study of the healing process following different types of bone transplantation. J Bone Joint Surg Am 1963; 45:1593–1612.
29. Goldberg VM, Stevenson S. Natural history of autografts and allografts. Clin Orthop Relat Res 1987; 225:7–16.
30. Gotfried Y, Yaremchuk MJ, Randolph MA, Weiland AJ. Histological characteristics of acute rejection in vascularized allografts of bone. J Bone Joint Surg Am 1987; 69:410–425.
31. Stevenson S, Horowitz M. The response to bone allografts. Current concepts review. J Bone Joint Surg Am 1992; 74: 939–949.
32. Stevenson S, Quing X, Davy DT, Klein L, Goldberg VM. Critical biological determinants of incorporation of nonvascularized cortical bone grafts. J Bone Joint Surg Am 1997; 79:1–16.
33. Tomford WW, Mankin HJ. Bone banking: update on methods and materials. Orthop Clin North Am 1999; 30:565–570.

34. Mnaymneh W, Malinin TI, Makley JT, Dick HM. Massive osteoarticular allografts in the reconstruction of extremities following resection of tumors not requiring chemotherapy and radiation. Clin Orthop Relat Res 1985; 197:76–87.
35. Von Arx T, Cochran DL, Hermann JS, Schenk RK, Buser D. Lateral ridge augmentation using different bone fillers and barrier membrane application. A histologic and histomorphometric pilot study in the canine mandible. Clin Oral Implants Res 2001; 12:260–269.
36. Hellem S, Astrand P, Stenstrom B, Engquist B, Bengtsson M, Dahlgren S. Implant treatment in combination with lateral augmentation of the alveolar process: a 3-year prospective study. Clin Implant Dent Relat Res 2003; 5:233–240.
37. Trentz OA, Hoerstrup SP, Sun LK, Bestmann L, Platz A, Trentz OL. Osteoblasts' response to allogeneic and xenogenic solvent dehydrated cancellous bone in vitro. Biomaterials 2003; 24:3417–3426.
38. Bassett CAL. Clinical implications of cell function in bone grafting. Clin Orthop Relat Res 1972; 87:49–59.
39. Bauer TW, Muschler GF. Bone graft materials. An overview of the basic science. Clin Orthop Relat Res 2000; 371:10–27.
40. Block MS, Finger I, Lytle R. Human mineralized bone in extraction sites before implant placement: preliminary results. J Am Dent Assoc 2002; 133:1631–1638.
41. Feuille F, Knapp CI, Brunsvold MA, Mellonig JT. Clinical and histologic evaluation of bone-replacement grafts in the treatment of localized alveolar ridge defects. Part 1: mineralized freeze-dried bone allograft. Int J Periodontics Restorative Dent 2003; 23:29–35.
42. Minichetti JC, D'Amore JC, Hong AY, Cleveland DB. Human histologic analysis of mineralized bone allograft (Puros) placement before implant surgery. J Oral Implantol 2004; 30:74–82.
43. Cetiner D, Parlar A, Balos K, Alpar R. Comparative clinical study of connective tissue graft and two types of bioabsorbable barriers in the treatment of localized gingival recessions. J Periodontol 2003; 74:1196–1205.
44. Rothamel D, Schwarz F, Sager M, Herten M, Becker J. Biodegradation of differently cross-linked collagen membranes: an experimental study in the rat. Clin Oral Implants Res 2005; 16:369–378.
45. Wilson JW, Rhinelander FW, Steward CL. Vascularization of cancellous chip bone grafts. Am J Vet Res 1985; 46:1691–1699.
46. Enneking WF, Mindell ER. Observation on massive retrieved human allografts. J Bone Joint Surg Am 1991; 73:1123–1142.
47. Hurzeler MB, Quinones CR, Morrison EC, Caffesse RG. Treatment of peri-implantitis using guided bone regeneration and bone grafts, alone or in combination, in beagle dogs. Part 1: clinical findings and histologic observations. Int J Oral Maxillofac Implants 1995; 10:474–484.
48. Fortin T, Bosson JL, Coudert JL, Isidori M. Reliability of preoperative planning of an image-guided system for oral implant placement based on 3-dimensional images: an in vivo study. Int J Oral Maxillofac Implants 2003; 18:886–893.
49. Jung R, Schneider D, Ganeles J, Wismeijer D, Zwahlen M, Hämmerle CHF. Computer technology applications in surgical implant dentistry: a systematic review. Int J Oral Maxillofac Implants 2009; 24(Suppl):92–109.
50. Nevins M, Giannobile WV, McGuire MK, et al. Platelet-derived growth factor stimulates bone fill and rate of attachment level gain: results of a large multicenter randomized controlled trial. J Periodontol 2005; 76:2205–2215.