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CLINICAL RESEARCH

Radiographic evaluation of a bone substitute material in alveolar ridge preservation for maxillary removable immediate dentures: A randomized controlled trial

Christophe Rignon-Bret, DDS, PhD,[a] Claudine Wulfman, DDS, PhD,[b] Fabien Valet, PhD,[c] Alain Hadida, DMD, PhD,[d] Thien-Huong Nguyen, DMD, PhD,[e] Alexis Aidan, DDS,[f] and Adrien Naveau, DDS, PhD[g]

ABSTRACT

Statement of problem. Maxillary bone resorption after multiple extractions can jeopardize the success of an immediate denture, but whether bone volume preservation techniques are effective is unclear.

Purpose. The purpose of this randomized controlled trial was to evaluate the efficacy of socket grafting with a xenogenic bone substitute in participants receiving maxillary immediate removable complete dentures in terms of bone volume preservation (height and width of the bone ridge).

Material and methods. The study was a single-blinded, randomized controlled clinical trial with 2 balanced parallel arms. Thirty-six participants who had Kennedy Class I edentulous posterior areas bilaterally for at least 3 months and required maxillary immediate removable complete dentures were enrolled. Duplicates of the removable complete denture were made and converted into radiographic and surgical guides. Participants allocated to the test group received deproteinized bovine bone mineral blended with 10% porcine collagen (DBBM-C) in the extraction sockets, and participants in the control group received no grafting material. With a radiographic guide in place, cone beam computed tomography scans were made 10 days after tooth extraction, when the immediate removable complete denture was delivered (D10, baseline), after 3 months (D90), and after 1 year (D365). The scans were superimposed, and measurements were made on the cross-sectional plane of each extraction site. The influence of various prognosis factors associated with bone volume preservation, including the location of tooth extraction, smoking habits, periodontal disease, and operator team, were analyzed.

Results. Of 36 participants, 3 were lost to follow-up. The mean ±standard deviation loss of height of the buccal crest was 1.2 ±1.8 mm in the control group and 0.3 ±1.2 mm in the test group after 3 months of healing ($P<.001$) and 2.1 ±2.0 mm in the control group and 0.7 ±1.4 mm in the test group after 1 year of follow-up ($P<.001$). Mean ±standard deviation horizontal ridge width change was 1.3 ±1.4 mm in the control group and 0.5 ±0.8 mm in the test group after 3 months ($P<.001$) and 2.2 ±1.4 mm in the control group and 0.9 ±1.1 mm in the test group after 1 year of follow-up ($P<.001$). None of the other prognostic factors had a significant effect at either time period.

Conclusions. Grafting DBBM-C into the extraction socket after removing anterior teeth for immediate removable denture therapy resulted in significantly less vertical buccal crest and horizontal ridge resorption as compared with spontaneous socket healing after 1 year of follow-up. This procedure may be useful for preserving bone, especially when a fixed implant-supported prosthesis is planned. (J Prosthet Dent 2021;■:■-■)

Maxillary bone resorption after multiple extractions for complete dentures is a clinical problem, and its severity depends on systemic and genetic factors, the number of teeth removed, and the surgical trauma during extraction.[1-4] Resorption progresses with time, but the most significant loss of bone contour occurs during the first 3

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[a]Associate Professor, Prosthodontics Department, Université de Paris, Hôpital Charles Foix, Ivry-sur-Seine, France.
[b]Professor, Prosthodontics Department, Université de Paris, Hôpital Henri Mondor, Créteil, France.
[c]Biostatistician, Statistics Department, DenomX, Eaubonne, France.
[d]Associate Professor, Surgery Department, Université de Paris - AP-HP, Hôpital Henri Mondor, Créteil, France.
[e]Hospital Practitioner, Dentistry Department, Université de Paris - AP-HP, Hôpital Henri Mondor, Créteil, France.
[f]Assistant Professor, Prosthodontics Department, Université de Paris - AP-HP, Hôpital Henri Mondor, Créteil, France.
[g]Associate Professor, Prosthodontics Department, Université de Bordeaux - Bordeaux University Hospital, Bordeaux, France.

Clinical Implications

Socket grafting with DBBM-C after tooth extraction reduced bone loss for both buccal vertical bone height and horizontal alveolar ridge width in this clinical trial of participants receiving maxillary immediate dentures.

months after extraction.[5-7] The severity of the bone remodeling process may impact tooth replacement, as a large residual ridge enhances removable denture retention, stability, and support and therefore leads to improved comfort and well-being.[8] Large residual ridges are also favorable for implant placement.[9-14] Therefore, alveolar ridge preservation (ARP) at the time of tooth extraction may improve prosthetic success.

Systematic reviews have concluded that ARP strategies filling sockets with a bone grafting material minimize the ridge bone loss after anterior single tooth extractions.[13-17] However, information as to the best material or strategy for ARP is lacking.[9,11-13,18-24] More specifically, some randomized controlled trials (RCTs) have reported the benefit of using deproteinized bovine bone mineral blended with 10% porcine collagen (DBBM-C) as bone graft material to fill anterior maxilla sockets.[25-29]

Providing an immediate removable complete denture (IRCD) after extraction also helps reduce bone resorption and guide the structural remodeling of the ridge.[30-33] The prosthesis provides esthetics and oral function to help overcome the psychological impact associated with sudden edentulism.[33] The mean vertical and horizontal resorption have been reported to range from 1.3 to 3.7 mm and 1.8 to 2.2 mm, respectively.[30,34-37] Direct grafting of the extraction sockets with alloplastic materials has been evaluated before IRCD delivery.[35,38-41] However, the cephalometric or 2D radiographic methods used in these studies did not precisely investigate the extraction sites and did not allow for reproducible patient positioning.[42] The authors are aware of only a single IRCD study that reported the placement of bone substitute material after maxillary anterior tooth extractions.[35] These authors reported less bone resorption in the graft than in the control group at 1-year follow-up but with cephalometric radiograph measurements and a non-commercially available grafting material.

This RCT aimed to evaluate the efficacy of socket grafting in maxillary IRCD treatment in terms of bone volume preservation. The primary objective was to compare mean buccal bone ridge height loss at 1 year after maxillary IRCD placement with or without placing bone substitute material in maxillary anterior tooth sockets. The secondary objective was to compare changes in mean alveolar ridge width for each extraction site. The research hypothesis of the present study was that socket grafting would significantly decrease bone resorption in participants requiring IRCDs.

Table 1. Inclusion and exclusion criteria

Inclusion Criteria	Exclusion Criteria
Provision of informed consent	Medical conditions contraindicating oral surgery
At least 18 years old	Progressive cancer
Candidates for maxillary immediate denture with Kennedy Class 1 partial dentition	Major neurological disease
Healthy adherent gingiva	Anticoagulant treatment with international normalized ratio <2
Accepting to comply with study procedures	Valvulopathy, hematologic disease, or agranulocytosis
–	Immune deficiency or AIDS
–	Osteomalacia
–	Hepatic or renal insufficiency
–	Unregulated diabetes
–	Bisphosphonate treatment
–	Allergy to collagen
–	Pregnancy or nursing
–	Not affiliated with social security system

MATERIAL AND METHODS

The study was designed as a single-blinded, randomized controlled RCT with 2 balanced parallel arms. Participants were selected from patients requiring maxillary IRCDs visiting in the prosthodontic department of Henri Mondor Hospital (Assistance Publique-Hôpitaux de Paris [AP-HP], France).

The trial was approved by the local ethics committee (CPP registration no. 13-019) and the National Agency for Medicines and Health Products (ANSM, registration no. 2013-A00440-45). This study was registered at ClinicalTrials.gov (NCT02120053). Participants provided signed informed consent. Information about study participants with inclusion and exclusion criteria is presented in Table 1. The sample size was calculated to be 29 to achieve study objectives (α=.05, β=.01) but was increased to 34 to consider participants lost to follow-up and that 2 operator groups would be involved.[43] Two additional participants were included because the 4 last participants signed the consent form on the same inclusion day.

Thirty-six participants in need of a maxillary IRCD were enrolled in the study. Two different teams treated the participants. All participants had been without posterior teeth bilaterally for at least 3 months. The IRCD protocol was performed as described previously.[43] Briefly, 2 duplicates of the removable complete denture were fabricated for each participant. One was made of transparent resin and served as a surgical guide for the surgery stage, and the other was a radio-opaque duplicate containing barium sulfate powder (20 wt%), which was later

modified to act as a radiographic guide for bone resorption measurements.

For surgery, all participants were given 2 g antibiotics (amoxicilline 1000 mg; Sandoz) 1 hour before surgery in addition to an analgesic medication (Dafalgan codeine; Upsa) to be taken every 6 hours for 3 days after the surgery along with 0.2% chlorhexidine mouth wash (Eludril Gé; Pierre Fabre Oral Care) for 1 week after surgery. Local anesthesia of the anterior maxilla was performed with scandicaïne 3% without vasoconstrictor (Septodont). The surgical tooth extraction procedure has been previously described.[43] Osteoplasty was performed with rongeurs or a surgical bur and controlled by use of the transparent surgical guide. The surgical guide was used to adjust the bone contour by observing soft tissue whitening that indicated compression areas where bone correction was necessary. Bone correction was performed until homogeneous soft tissue whitening occurred under the surgical guide and the post dam area was well adapted.

After extraction and osteoplasty, participants were randomly assigned to the test group or control group with the use of a software program (Randoweb; AP-HP). For patients allocated to the test group, the fresh extraction sockets were filled with DBBM-C (Bio-Oss Collagen; Geistlich) that had been previously moistened with a saline solution. Participants allocated to the control group received no grafting material. In both groups, no sutures were needed. Postoperative care and maintenance appointments were scheduled at 48 hours, 96 hours, 1 week, and weekly thereafter to adjust the denture until comfortable.[43]

A standard radiography examination was performed at 10 days after tooth extraction and IRCD placement (baseline D10), 3 months (D90), and 1 year (D365) to compare ridge resorption in the 2 treatment arms. The radio-opaque radiographic guide was used as a reference index for reproducible measurements. To locate the extraction socket sites during the radiography examinations, 3-mm-wide pits were drilled in the radiographic guides to mark the positions of the extracted teeth and the center of the first maxillary molars. An independent radiology clinic collected the cone beam computed tomography (CBCT) data and performed the ridge measurements of each socket site (central incisors, lateral incisors, and canines). During the radiographic examination, the participant was asked to occlude on the radiographic guide.

CBCT scans were produced (NewTOm Vgi QR s.r.l) with an 8×12-cm field (acquisition: 60 seconds, voxel size: 0.3 mm, gray scale: 14 bits, focal spot: 1 mm, image acquisition: single 360-degree rotation). In the radiographic procedure, the horizontal plane corresponded to the palatal plane. To check the correct positioning of the radiographic guide during the various CBCT examinations, the reproducibility of the distance between the basal surface of the radiographic guide and the anterior/posterior nasal spine bone landmarks on the sagittal cross section was assessed. The panoramic section was performed by linking the middle of the pits from the index right maxillary molar (start slot) to the index left maxillary molar (stop slot). Buccal-palatal reconstructions were performed with a slice thickness of 1 mm and a space of 1 mm. The radiolucent pits of the socket sites served as landmarks for the choice of cross-section plane for each extraction site. In addition, to ensure the superimposition of cross-sections during the examinations, the number of calibrated cross-sections on the panoramic curves passing through the middle of the pits between the start slot and the stop slot was checked. The selected CBCT cross-sections were analyzed at the longitudinal midpoint of the socket. The number of the cross-sections became the reference section for measuring bone resorption at each site. Measurements were performed with a software program (NNT v.8.0; NewTOm Vgi QR s.r.l). The vertical distance (h) represented the height, and the horizontal dimension (l) of the bone ridge width was measured as described in Figure 1. Dimensions were measured for each extraction site during the 3 evaluation times (D10, D90, D365) by using the same landmarks and lines. Two independent calibrated oral radiologists (T.H.N., G.P.), who were unaware of the treatment arm, performed all measurements.

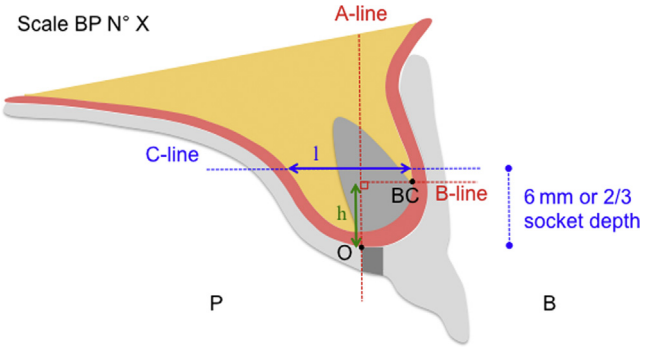

Figure 1. Schematic of measurements and landmarks used for CT scans. Landmarks: BC=top of the buccal crest; O=apical palatal pit end. Lines: vertical A-line=apical extension of point O; horizontal B-line=palatal extension of point BC; horizontal C-line=horizontal buccal-palatal line drawn apically at 6 mm from point O. In some sites, C-line chosen=2/3 of the socket depth. B-line perpendicular to A-line. C-line parallel to B-line. h=height measurement between point O and intersection of lines A and B. l=length measurement.

The randomization was designed to ensure balanced distribution between test and control treatments. Main factors such as team, smoking habits (<or ≥10 cigarettes/day), and periodontal disease (marginal bone loss < or ≥half radicular height) were considered for allocation.

The data were analyzed by an independent statistician with the use of a software program (R; The R Foundation).[44] Missing measurements were considered

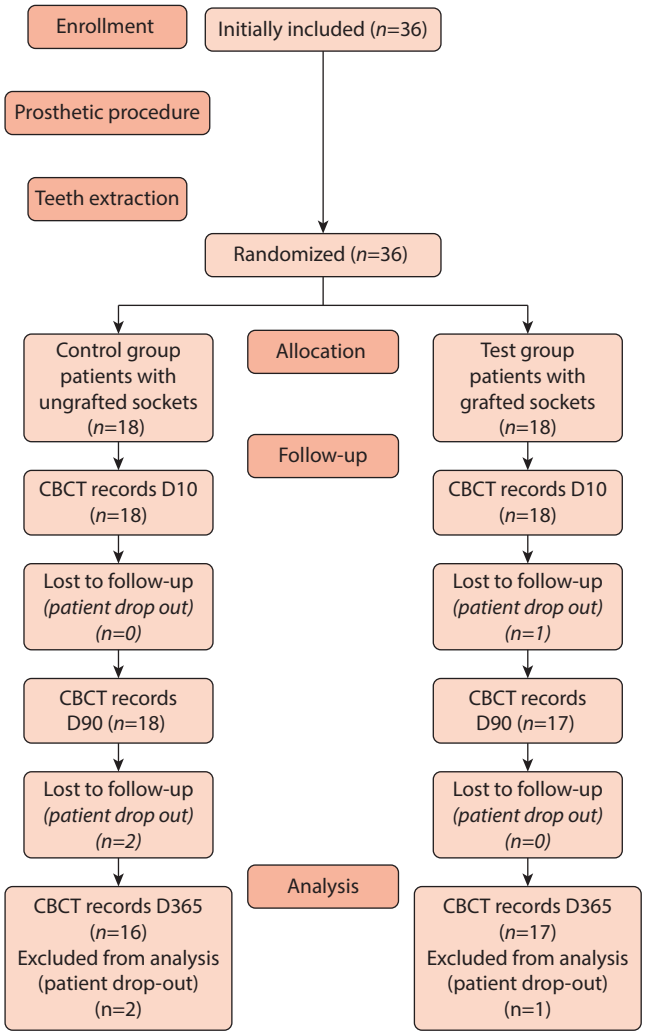

Figure 2. Flowchart of participant enrollment. CBCT, cone beam computed tomography; D10, day 10 after treatment; D90, day 90 after treatment; D365, day 365 after treatment.

missing at random and were discarded. Differences in bone ridge changes (height and width) at D10-D90, D90-D365, and D10-D365 were computed for each tooth location. For each group, these 3 differences were compared according to operator team, smoking habit, periodontal disease evolution, age, and sex by using *t* tests (α=.05) and were adjusted for multiple testing.[45] These differences were then modeled by using linear mixed statistical models, with patient and tooth location included as random-effects factors and treatment group, operator team, smoking habit, periodontal disease evolution, age, and sex as fixed-effects factors.[46] Likelihood ratio tests were used to identify the best-fit models, and parameter estimates were given with 95% confidence intervals.

RESULTS

The Consolidated Standards of Reporting Trials (CONSORT) guidelines were used to report the results of this study. A total of 36 participants (19 men; mean ±standard deviation age 57 ±13.1 years; range 33 to 77) requiring maxillary IRCD were enrolled in this RCT, which started in October 2013 and ended in December 2018 (Fig. 2). Three participants were lost to follow-up. Randomization allowed participants to be equally distributed into 2 homogenous groups. Demographic data are presented in Table 2. All participants received a maxillary IRCD at the end of the surgical stage. Denture adjustments were consistent with the usual prosthodontic follow-up.

Table 2. Participant demographic data

Participants	Control Group n=18	Test Group n=18
Sex (male/female)	9/9	8/10
Age, mean (years)	56.8 ±10.8	57.1 ±15.0
Smokers	3	2
Periodontal disease	11	8
Treatment team 1/2	12/6	13/5

Data presented as number or mean ±standard deviation.

Buccal crest height and width ridge radiologic measurements were performed in 174 extraction sites at D10, D90, and D165. The overall sample comprised 60 central incisors, 59 lateral incisors, and 55 canines, and tooth location distribution is illustrated in Table 3.

The dimensional change in buccal bone-crest height between the test and control groups at 1-year follow-up is reported in Table 4. The mean ±standard deviation height bone loss of the buccal crest was 2.1 ±2 mm in the control group and 0.7 ±1.4 mm in the test group, for a significant mean difference of 1.4 mm (P<.001) favoring DBBM-C for buccal crest dimensional change. Moreover, after 3 months of healing, the mean ±standard deviation height loss of the buccal crest was 1.2 ±1.8 mm in the control group and 0.3 ±1.2 mm in the test group, for a significant mean difference of 0.9 mm (P<.001) favoring DBBM-C. The dimensional change in horizontal ridge width between the test and control groups at 1 year is presented in Table 5. Mean ±standard deviation change in horizontal ridge width at 1 year was 2.2 ±1.4 mm in the control group and 0.9 ±1.1 mm in the test group, for a significant mean difference of 1.4 mm (P<.001) favoring DBBM-C. In addition, the mean alveolar width ridge resorption during the first 3 months after tooth extraction was 1.3 ±1.4 mm in the control group and 0.5 ±0.8 mm in the test group, for a significant mean difference of 0.8 mm (P<.001) favoring DBBM-C.

In the first 3 months following tooth extraction, the control and test groups showed 57.1% and 41.1% of the total height ridge resorption over 1 year (Fig. 3) and 58.6% and 52.9% of the total width ridge resorption within the first 3 months (Fig. 4). These results suggest that dimensional ridge changes were greater in the first 3 months than in the following months.

The potential variability of "participant" and "tooth location" were considered to confirm the first results. For

Table 3. Distribution of extraction sites

Tooth Location	Grafted Sockets, n	Ungrafted Sockets, n
Right central incisor	14	16
Left central incisor	15	15
Right lateral incisor	14	15
Left lateral incisor	13	17
Right canine	13	14
Left canine	14	14
Total	83	91

Table 5. Horizontal ridge bone loss at 1-year follow-up

Category	Control Group, mm	Test Group, mm	Difference Test −Control, mm	P*
Global	2.22 ±1.40	0.87 ±1.12	-1.35	<.001
Team	—	—	—	—
A	2.20 ±1.20	1.02 ±1.11	-1.18	<.001
B	2.26 ±1.71	0.28 ±0.95	- 1.98	<.001
Sex	—	—	—	—
Female	2.53 ±1.29	0.87 ±1.15	-1.66	<.001
Male	1.97 ±1.45	0.83 ±1.07	-1.14	<.001
Age (years)	—	—	—	—
<60	2.19 ±1.50	0.82 ±1.11	-1.37	<.001
≥60	2.30 ±1.16	0.90 ±1.13	-1.40	<.001
Smoker status	—	—	—	—
Nonsmoker	2.27 ±1.47	0.80 ±1.11	-1.47	<.001
Smoker	1.87 ±0.67	1.62 ±1.00	-0.25	.589
Periodontal disease	—	—	—	—
Yes	2.59 ±1.57	0.68 ±0.93	-1.91	<.001
No	1.98 ±1.24	1.02 ±1.25	-0.96	<.001

Data presented as mean ±standard deviation. *t test P value corrected for multiple testing (α=.05).

Table 4. Vertical buccal crest bone loss at 1-year follow-up

Category	Control Group, mm	Test Group, mm	Difference Test −Control, mm	P*
Global	2.05±1.96	0.67±1.38	-1.38	<.001
Team	—	—	—	—
A	1.76 ±1.43	0.56 ±1.38	-1.20	<.001
B	2.52 ±2.57	1.06 ±1.35	- 1.46	.04
Sex	—	—	—	—
Female	2.30 ±2.18	0.55 ±1.48	-1.75	<.001
Male	1.84 ±1.76	0.82 ±1.23	-1.02	.009
Age (years)	—	—	—	—
<60	2.29 ±1.96	0.66 ±1.52	-1.63	<.001
≥60	1.49 ±1.89	0.67 ±1.31	-0.82	.04
Smoker status	—	—	—	—
Nonsmoker	2.13 ±2.04	0.69 ±1.41	-1.44	<.001
Smoker	1.44 ±1.06	0.80 ±1.04	-0.64	.068
Periodontal disease	—	—	—	—
Yes	1.84 ±2.01	0.69 ±1.23	-1.15	.01
No	2.19 ±1.94	0.65 ±1.52	-1.54	<.001

Data presented as mean ±standard deviation. *t test P value corrected for multiple testing (α=.05).

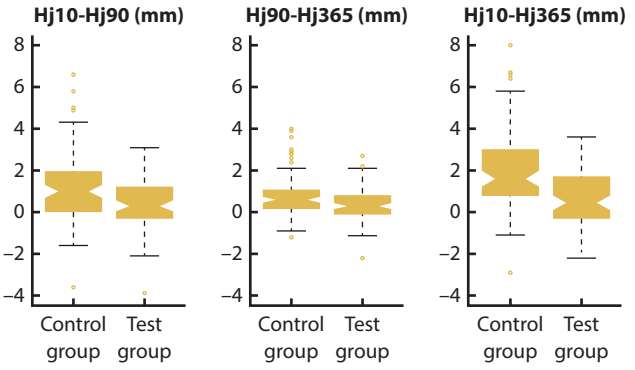

Figure 3. Boxplot of vertical buccal-crest bone loss over 3 months (left part), between 3 months and 1 year (middle part), and over 1 year (right part) (mm). Median=horizontal indents; range=box edges; interquartile range=whiskers.

the buccal-crest height loss comparing D365 with D10, the model M_1 with a "tooth location" random effect did not provide significant information (P=.91) in addition to the null model M_0 including the "participant" random effect only (Table 6). However, model M_2, with the "participant" random effect and "ARP treatment" fixed effect provided significant information in addition to the null model (P<.001). For this response variable, no more fixed effects, such as team, age, sex, tobacco use, or periodontal disease, provided significant additional information. Thus, the only significant effect explaining a significant difference in the reduced resorption favoring the test group was ARP treatment. In a similar way, for D365-D10 ridge width bone loss, model M_2 with the participant random effect and ARP treatment fixed effect provided significant information to the null model (P<.001) (Table 7). For the ridge-width bone loss, no other prognostic variables provided a significant effect. Considering intermediate bone loss (D90-D10) with linear mixed models also gave significant ARP treatment effects−0.9 mm for buccal-crest height loss (P=.05) and 0.9 mm for width ridge loss (P<.001)−which suggests a significant ARP treatment effect from 3 months. These results remained stable even at the participant level. Indeed, modeling the mean bone ridge loss in the 36 patients over the year and using simple linear models and a stepwise selection based on Akaike information criteria[47] provided significant treatment effects of -1.27 mm for height loss (P=.002) and -1.46 mm for width loss (P<.001) over 1 year (Table 8).

DISCUSSION

The research hypothesis that socket grafting would significantly decrease bone resorption in participants requiring IRCDs was confirmed by the study. Grafting DBBM-C into extraction sockets after removing anterior teeth for an IRCD resulted in significantly less vertical buccal-crest and horizontal ridge resorption as compared

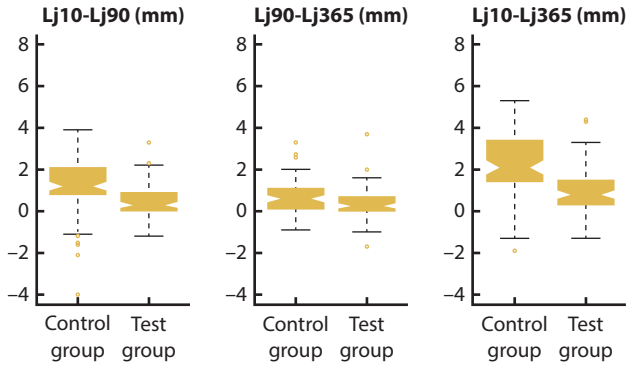

Figure 4. Boxplot of horizontal ridge bone loss over 3 months (left part), between 2 months and 1 year (middle part), and over 1 year (right part) (mm). Median=horizontal indents; range=box edges; interquartile range=whiskers.

Table 7. Linear mixed model of horizontal ridge width bone loss at 1-year follow-up (mm)

Model	Random Effects		Fixed Effects Estimates [95% CI]		LR Test*
M_0	Participant	–	–	–	-
M_1	Participant	Teeth location	–	–	0.07
M_2	Participant	–	ARP treatment -1.40 [-1.91;-0.91]	–	<.001
M_3	Participant	–	ARP treatment -1.45 [-1.96;-0.96]	Team -0.29 [-0.83; 0.25]	.07
M_4	Participant	–	ARP treatment -1.42 [-1.92;-0.94]	Age 0.01 [-0.01; 0.03]	.23
M_5	Participant	–	ARP treatment -1.44 [-1.94;-0.95]	Sex -0.28 [-0.77; 0.22]	.07
M_6	Participant	–	ARP treatment -1.41 [-1.92;-0.91]	Tobacco 0.10 [-0.78; 0.98]	.07
M_7	Participant	–	ARP treatment -1.44 [-1.95;-0.94]	Periodontal disease -0.18 [-0.69; 0.32]	.07

ARP, alveolar ridge preservation; LR, linear regression; 95% CI, 95% confidence interval.
*LR test *P* value corrected for multiple testing (α=.05).

Table 6. Linear mixed model of vertical buccal crest bone loss at 1-year follow-up (mm)

Model	Random Effects		Fixed Effects Estimates [95% CI]		LR Test*
M_0	Participant	–	–	–	-
M_1	Participant	Tooth location	–	–	0.91
M_2	Participant	–	ARP treatment -1.31 [-2.04;-0.58]	–	0.007
M_3	Participant	–	ARP treatment -1.25 [-1.95;-0.54]	Team 0.60 [-0.17; 1.35]	0.427
M_4	Participant	–	ARP treatment -1.30 [-2.03;-0.56]	Age -0.01 [-0.03; 0.02]	0.91
M_5	Participant	–	ARP treatment -1.31 [-2.04;-0.58]	Sex -0.02 [-0.75; 0.71]	0.91
M_6	Participant	–	ARP treatment -1.34 [-2.07;-0.61]	Tobacco -0.53 [-1.79; 0.74]	0.91
M_7	Participant	–	ARP treatment -1.29 [-2.02;-0.55]	Periodontal disease 0.16 [-0.58; 0.90]	0.91

ARP, alveolar ridge preservation; LR, linear regression; 95% CI, 95% confidence interval
*LR test *P* value corrected for multiple testing (α=.05).

Table 8. Results of simple linear models at 3 months and 1-year follow-up (mm)

Variables Included in the Full Model:	Best Linear Models of Bone Ridge Loss With Stepwise AIC Selection			
	Dependent Variables	Best Model Included Variables:	Parameter Estimates	*P*
Age	Height loss	–	–	–
Sex	H_{j10}-H_{j365}	Treatment	-1.27 [-1.98; -0.55]	.002
Tobacco	H_{j10}-H_{j90}	Treatment	-0.81 [-1.40; -0.23]	.009
Periodontal disease	Width loss	–	–	–
Team	W_{j10}-W_{j365}	Treatment	-1.46 [-1.97; -0.94]	<.001
Treatment	W_{j10}-W_{j90}	Treatment	-0.96 [-1.34; -0.59]	<.001
		Sex	-0.35 [-0.73; 0.04]	.087
		Periodontal disease	-0.31 [-0.70; 0.08]	.128

AIC, Akaike information criterion.

with spontaneous socket healing after 1 year of follow-up.

The present results were consistent with those of systematic reviews and meta-analyses that demonstrated the efficacy of ARP procedures in reducing bone resorption after single tooth extraction as compared with unassisted socket healing.[12-14,16,19-23] These studies included RCTs and controlled clinical trials with heterogeneous ARP procedures or location of the extracted teeth. However, some reviews presenting strong similarities with the present study exhibited comparable values of vertical and horizontal dimensional changes in the ARP group, including socket filling with a bone substitute material.[19,20,23] Bassir et al[13] included studies evaluating the extraction of premolars and anterior teeth but by using several different ARP procedures. The authors reported an overall statistically significant difference between the test and control site in ridge width change, with a magnitude of 1.86 mm, favoring ARP. This meta-analysis included a separate analysis of CBCT scans and for bone dimensional height, a favored change for ARP of 1.36 mm was detected. These results are consistent with the findings of the present study of a vertical gain of 1.4 mm, favoring the grafted group. Finally, the Avila-Ortiz et al[14] meta-analysis reported specific radiologic

outcomes comparing ARP with DBBM-C and untreated socket extraction, the authors reported insufficient evidence favoring ARP. However, the same meta-analysis concluded that ARP was an effective strategy to minimize dimensional reduction of the alveolar ridge after tooth extraction as compared with unassisted sockets.[14]

For IRCDs, some studies reported the use of alloplastic biomaterials to fill extraction sockets, mainly in the mandible, with conflicting results.[38-41] In a randomized study, Bergested et al[35] evaluated the use of grafting spongy bovine bone in alveolar sockets after removing the maxillary anterior teeth and maxillary IRCD placement. At 1-year follow-up, mean vertical bone loss measured by using radiographic cephalometric images was 2.73 ±1.13 mm in the test group and 3.29 ±1.95 mm in the unassisted socket group control. The mean horizontal ridge resorption was 1.81 ±0.74 mm in the test group and 2.24 ±1.28 mm in the control group. These differences were not statistically significant.

Although several bone graft materials and bone substitutes have been developed for ARP techniques to preserve the alveolar ridge, evidence to support the superiority of one material over others is lacking.[11-14,16,17,19,22] However, the present findings were consistent with those of previous CBCT studies using DBBM-C as a bone substitute and reporting similar clinical outcomes for maxillary teeth at 4 to 6 months of follow-up.[25-29]

One of the strengths of the present study was the use of a linear mixed statistical model to analyze the effects of various prognostic factors such as the location of the tooth extraction, smoking, presence of periodontal disease, and effect of different teams. The only significant effect was the "treatment effect" with ARP procedures for minimizing alveolar ridge resorption under IRCD. This finding is consistent with those of other studies reporting prognostic factors that may affect dimensional bone loss after tooth extraction such as tooth location,[13] smoking,[14] and untreated periodontal disease.[12]

Limitations of the present study include the radiographic measurements. In single extraction studies, maxillary CBCT scans are precisely superimposed by using adjacent teeth, anatomic landmarks,[27,29] or custom-made templates.[24] In maxillary complete edentulism, the accuracy of the superimposition relies on the correct positioning of the guide on a large and stable bearing surface, assuming that this is stable over time. Additionally, the baseline measurements were made 10 days after removing the teeth (in order to allow edema to resolve so the guide could be seated), but radiographic studies assessing the efficacy of an ARP procedure for single extraction used baseline bone socket measurement before removing the teeth. A third limitation was the imbalance in data collection between groups. Data collected from smokers, for example, were probably underpowered and should be interpreted with caution. The additional costs of the ARP procedure using DBBM-C should be considered, because one block of bone substitute was used to fill each extraction socket. Further investigation is needed to compare the benefit of this extra treatment with the conventional ungrafted protocol.

CONCLUSIONS

Based on the findings of this randomized controlled trial, the following conclusions were drawn:

1. Grafting DBBM-C into extraction sockets after removing anterior teeth for IRCD treatment resulted in significantly less vertical buccal-crest and horizontal ridge resorption as compared with spontaneous socket healing after 1 year.
2. This procedure may be useful for preserving bone and improve prosthetic treatment for edentulous jaw therapy.

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Corresponding author:
Dr Christophe Rignon-Bret
Faculty of Dentistry
1 rue Maurice Arnoux
92120 Montrouge
FRANCE
Email: rignon-bret@wanadoo.fr

CRediT authorship contribution statement

Christophe Rignon-Bret: Conceptualization, Methodology, Investigation, Writing - original draft, Project administration. **Claudine Wulfman:** Investigation, Writing - review & editing. **Fabien Valet:** Formal analysis, Writing - review & editing. **Alain Hadida:** Investigation. **Thien-Huong Nguyen:** Methodology, Validation. **Alexis Aidan:** Validation, Data curation. **Adrien Naveau:** Visualization, Writing - original draft, Writing - review & editing.

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