Comparative Effects of Different Materials on Alveolar Preservation

Moacyr Tadeu Vicente Rodrigues, DDS, MSc, [*] *Gabriel Albuquerque Guillen, DDS, MSc,* [*] *Felipe Germóglio Cardoso Macêdo, DDS,* [†] *Douglas Rangel Goulart, DDS, MSc, PhD,* [‡] *and Cláudio Ferreira Nóia, DDS, MSc, PhD* [§]

Objective: The purpose of this study was to compare different materials' effects on alveolar ridge preservation of postextraction sockets in anterior maxilla.

Materials and Method: In this prospective, single center, randomized, controlled clinical trial, healthy patients who needed one single anterior maxillary tooth extraction (including bicuspids) were selected. After a minimally traumatic extraction without complications, 44 patients were randomly allocated into 4 groups: *1)* natural socket healing (blood clot), *2)* xenograft and gingival free graft, *3)* dense polytetrafluoroethylene membrane, and *4)* platelet rich fibrin plugs. Alveolar ridge height and width loss were evaluated in cone beam computed tomography (CBCT) and in dental casts at 3 moments: *1)* preoperative (T1), *2)* 7 days postoperative (T2), and *3)* 120 days postoperative (T3). Height and width alveolar ridge loss detected in CBCT and in dental casts were compared among the groups (two-way analysis of variance [ANOVA]; $P < .05$).

Results: Forty patients (24 women and 16 men) ranging from 25 to 70 years old (mean of 42 years old) participated in this study. Group 2 showed the least alveolar ridge height loss results in CBCT ($9.8 \pm 1.9\%$ at T3) and dental cast analysis (1.0 ± 0.2 mm). Groups 2 ($12.7 \pm 4.7\%$ at T3) and 3 ($15.4 \pm 2.7\%$ at T3) showed the least alveolar ridge width loss measured in CBCT compared with groups 1 and 4, but the difference between groups 2 and 3 were not statistically significant ($P = .968$). Group 3 (0.9 ± 0.2 mm) and group 2 (1.0 ± 0.2 mm) showed the least width loss compared with groups 1 and 4 in dental cast analysis. Again, the difference between groups 3 and 2 was not statistically significant ($P = 1.000$).

Conclusion: In postextraction sockets of the anterior maxilla and bicuspid region, group 2 (xenogenous bone graft with free gingival graft) and group 3 (dense polytetrafluoroethylene) obtained the best results in alveolar preservation, with group 2 being more indicated when the vertical alveolar ridge preservation is mandatory.

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[*]PhD student in Oral and Maxillofacial Surgery, Piracicaba School of Dentistry, University of Campinas- UNICAMP, Piracicaba, São Paulo, Brazil.

[†]MSc student in Oral and Maxillofacial Surgery, Piracicaba School of Dentistry, University of Campinas- UNICAMP, Piracicaba, São Paulo, Brazil.

[‡]Professor of Oral and Maxillofacial Surgery, Federal University of Goiás- UFG, Goiânia, Goiás, Brazil.

[§]Professor of Oral and Maxillofacial Surgery, Piracicaba School of Dentistry, University of Campinas- UNICAMP, Piracicaba, São Paulo, Brazil.

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Address correspondence and reprint requests to Dr Rodrigues: PhD Student - Oral and Maxillofacial Surgery Department, University of Campinas- Piracicaba Dental School, Av. Limeira, 901, CEP 13.414-903, Piracicaba, São Paulo, Brazil; e-mail: mtadeuvr@gmail.com

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Alveolar bone loss following removal of teeth can compromise implant placement. Alveolar ridges can decline 62% in width and 22% in height in the first 3 months after tooth extraction.[1-13]

Immediate placement of implants after tooth extraction is reported in the literature as the best option for treatment and preservation of the postextraction alveolar ridge. However, this technique is not indicated for all cases, thus, an alveolar ridge preservation (ARP) procedure is essential to allow future implantation.[14]

Autogenous bone is still considered to be the gold standard for bone regeneration, although some limitations, such as extra surgical site, prolonged time of surgery, unpredictable resorption, surgical complications, and limited availability from intraoral bone graft harvesting techniques motivate the search for alternatives in bone regeneration.[15-21]

A systematic review that solely included randomized controlled trials revealed that ARP via socket grafting using a xenograft or an allograft is an effective therapy for minimizing the dimensional reduction of the alveolar ridge that occurs after tooth extraction.[22]

Soft tissue grafts are also an alternative in ARP. The free gingival graft has been used for alveolar ridge preservation in human studies. This soft tissue graft is preferred as it eliminates the need to elevate a full thickness mucoperiosteal flap and compensates for soft tissue deficiencies when an alveolar ridge preservation or augmentation procedure is required, preserving mainly the heights of the buccal and lingual crestal bones.[23]

Another interesting option in ARP is guided bone regeneration by means of membranes. They eliminate the problem of soft tissue and epithelial migration into bone defects resulting in enhanced regeneration of bone by selective cell repopulation.[9,24]

The first nonresorbable membrane available for this finality was made of expanded polytetrafluoroethylene (PTFE). The disadvantage of that membrane is that it should not be exposed during healing due to its permeability to oral bacteria incorporation and the need for a second surgical procedure to remove it.[9,25]

The nonexpanded PTFE membrane, also called dense PTFE (d-PTFE) has different properties. It is considered very simple to use and it can be left intentionally exposed because its porosity resists the incorporation of bacteria, thus, large flaps and vertical incisions are not necessary to achieve primary closure.[26] These features assure soft tissue architecture maintenance with mucogingival junction alignment and preservation of the attached gingiva width.[27] Also, it can be easily removed 3 to 6 weeks after placement. Studies with intentionally exposed PTFE membrane application in sockets have demonstrated successful clinical and histological results with regenerated bone and soft tissue under the membrane without infection, thus being a simple and low-cost alternative in ARP.[9,28]

Other autologous material proposed for the use of ARP include the growth factors derived from the blood in the form of second-generation leukocyte- and platelet-rich fibrin (L-PRF) with a high concentration of platelets, leukocytes, and lymphocytes. PRF is obtained by the centrifugation of blood alone and comprises high amounts of platelets and leukocytes. It is stable, elastic, adhesive, flexible, and releases growth factors and mediators involved in cell proliferation and differentiation for wound healing.[29-31]

PRF can be cut or adapted to various anatomical defects and used in combination with bone graft materials, as a sole graft material (plugs), or in the form of fibrin membranes.[32]

Some study protocols suggest the use of 2 to 5 L-PRF plugs inserted into the alveolar socket as an effective method for its volumetric preservation compared with the blood clot. Rapid healing has been observed in the soft tissues surrounding the extraction site and with a greater percentage of newly formed bone.[29,31,33-37]

Therefore, it is very important to preserve as much alveolar bone as possible at the time of tooth extraction, reducing the postextraction alveolar bone resorption and remodeling rate with a high-quality bone regeneration. It can eliminate the need for a bone augmentation procedure during implant therapy. It also reduces the risk of complications, and the cost and time of the treatment. Considering the favorable features, such as simple execution techniques, low cost, and low risk of complications, this clinical trial proposed to analyze the effectiveness of these different materials on socket dimensions preservation.

Materials and Methods

STUDY DESIGN, PARTICIPANTS, ELIGIBILITY CRITERIA, AND STUDY VARIABLES

To address the research purpose, the investigators designed and implemented a single-center, prospective, randomized, controlled clinical trial performed in accordance with the declaration of Helsinki, as revised in 2016 and with the Consolidated Standard of Reporting Trials statement guidelines for clinical trials. The Consolidated Standard of Reporting Trials flowchart illustrating the timeline and study design is depicted in Figure 1. Ethical approval was obtained from the Research Ethics Committee of the Piracicaba Dental School of the University of Campinas before patient enrollment (protocol CAAE 82625418.4.000.5418). Written informed consent was obtained from each patient as well as pertinent explanations about the study, randomization, and expected results.

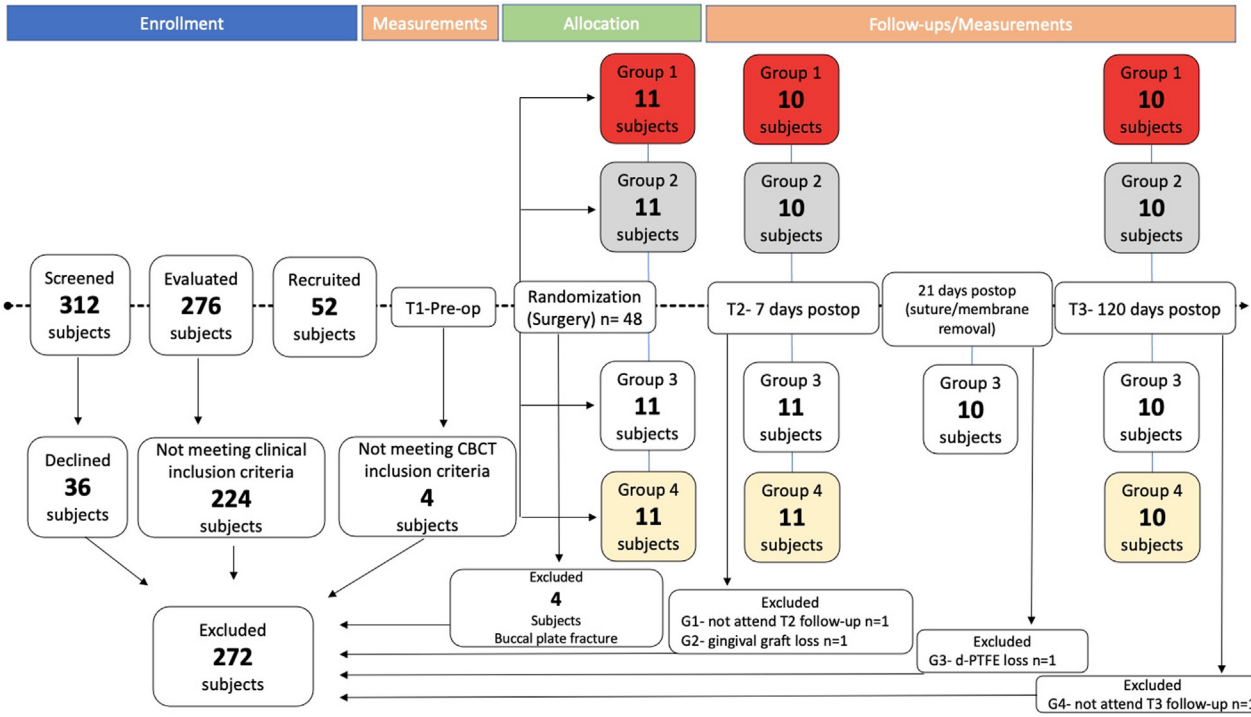

FIGURE 1. Consolidated Standard of Reporting Trials flowchart. d-PTFE, dense polytetrafluoroethylene; Pre-op, preoperative.

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The study population was composed of patients seeking dental treatment at the Department of Oral Diagnosis, Piracicaba Dental School, University of Campinas, Brazil with an indication for a unique dental extraction in the anterior maxillary region (incisors, canines and bicuspids) aiming to undergo later dental implant placement were recruited between February and March of 2019. Reasons for extraction included gross decay, root fractures, cracked teeth, and root resorption. After a panoramic radiography selection, 312 subjects were selected. Then, they were consecutively recruited by general health evaluation. At that moment 36 subjects declined to participate. In the sequence, 276 patients were clinically examined. Smokers, those who presented impaired systemic conditions for tooth extraction and/or alveolar healing (eg, diabetes, uncontrolled hypertension, medical history of head or neck radiation treatment, recent myocardial infarction) were excluded from the study. Subjects presenting local impairments such as inadequate oral hygiene, or clinically acute oral infections were also excluded from the study. A total of 224 subjects presented some general and/or local exclusion criteria as mentioned above. Thus, 52 patients were recruited for the next step, in which a preoperative CBCT image (OP300 Maxio unit set at 90kVp, 8 mA, 5 × 5cm field of view and 0.2 mm voxel size; Instrumentarium Dental Tuusula, Finland) and a type 4 stone dental cast (Durone IV-Dentsply-Sirona, York, PA, USA) were obtained (T1). Of 52 subjects, 4 patients did not meet an obligatory CBCT inclusion criterion which was buccal and lingual alveolar plates' integrity. Forty-eight patients met all the clinical and imaginological inclusion criteria and agreed to participate.

Alveolar ridge height and width measurements on CBCT and dental casts were obtained at 3 different moments: *1)* preoperative (T1); *2)* 7 days postoperative (T2); and *3)* 120 days postoperative (T3), to evaluate the effectiveness of different materials on alveolar ridge preservation.

RANDOMIZATION AND SURGICAL PROCEDURES

Group allocation was performed immediately after tooth extraction. A trained examiner (GAG) randomly selected an envelope containing the information about the material/surgical technique (group) that was to be applied. Forty-eight patients had a single tooth extracted but, in 4 patients, an accidental buccal bony plate fracture occurred. Those patients were properly treated and excluded from the study. Forty-four patients had uneventful atraumatic surgeries and were divided into 4 different groups (11 subjects in each): *1)* group 1 (control) – natural healing of postextraction socket (blood clot); *2)* group 2- socket filled with porous particulate protein-free bovine bone substitute, chemically treated to eliminate the organic matrix (Lumina Porous particle size of 1000-2000 μm,

Critéria Biomateriais, São Carlos-Brazil) associated with a free gingival graft removed from the palate used to seal the socket; *3)* group 3- socket covered by a dense polytetrafluoroethylene membrane (d-PTFE) (Lumina-PTFE, Critéria Biomateriais) without any other graft material inside the alveolus; and *4)* group 4- Socket filled with 3 PRF plugs centrifuged at 400g for 12 minutes–Choukron protocol.

One-hour before surgery, 8 mg of dexamethasone (Hypofarma, Ribeirão das Neves–Brazil) was orally administered to all patients, as well as rinsing with a 0.12% chlorhexidine digluconate mouthwash (Riohex Gard 0,12%-Rioquímica, São José do Rio Preto, Brazil). A trained surgeon (CFN) performed all surgical procedures.

The surgical procedure began with an anesthetic infusion of 2% lidocaine with 1:100,000 epinephrine (DFL, Rio de Janeiro-Brasil) applying buccal and lingual infiltrative techniques, followed by a sulcular incision made with a number 15 scalpel blade (Solidor, Rio de Janeiro-Brazil). To minimize soft tissue reflection and bone damage, a periotome was introduced into the periodontal ligament space to luxate the tooth and facilitate its extraction. The socket was irrigated with 0.9% physiological saline solution (JP, Ribeirão Preto-Brazil). Sockets were treated according to the parameters of the group to which each patient was randomized.

After randomized socket treatment, a cross suture with 4-0 nylon suture thread (Shalon, Goiania-Brazil) was applied to each surgical site. The patients received written instructions regarding postoperative care as well as a non-steroidal, anti-inflammatory drug prescription (Nimesulide, 100 mg every 12 hours-Biosintética, São Paulo-Brazil) and an analgesic (Metamizole, 500 mg every 6 hours-Biosintética, São Paulo-Brazil), both for 3 days. Chlorhexidine mouthwash (0.12%) was also prescribed every 12 hours from the second day after extraction through to the tenth day.

FOLLOW-UPS AND ASSESSMENTS

On the seventh postoperative day, sutures were removed for patients in groups 1, 2, and 4. In the case of group 3 the suture was maintained for 21 days and removed at the same time as the d-PTFE membrane removal.

The trained surgeon (CFN) was responsible for clinical follow-ups and suture removal and the trained examiner (GAG) was responsible for all CBCT and dental cast measurements.

CBCT Evaluation

Patients were received a CBCT exam before the surgical procedure (T1), 7 days postoperative (T2) and 120 days after the surgical procedure (T3). All the tomographic examinations were carried out by the same radiologist using the same tomograph and the same settings.

Tomographic measurements of alveolar ridge dimensions were made by the trained examiner (GAG) using the Dolphin Imaging 11.5 software (Dolphin Imaging and Management Solutions, Chatsworth, Los Angeles, CA), according to the following parameter specifications:

1. CBCT Height: from the most apical point of the socket to the most occlusal bony point of the socket (red line) according to the central axis of the alveolus from a line tangential to the buccal and lingual plates (yellow line) (Fig 2).
2. CBCT Width: from the buccal bony plate to the lingual plate (yellow line), perpendicular to the midpoint of the central height axis of the alveolus (red line) (Fig 3).

After the establishment of height and width measurement planes at T1, a line continuing via central height axis superiorly, going from the most apical point of the socket at T1 to an anatomical reference of the anterior maxilla, such as nasal floor, maxillary sinus floor, or Y line of Ennis was defined and measured (Fig 4). This measurement was applied in each subsequent CBCT for better standardization of height measurements. The same strategy was applied for width

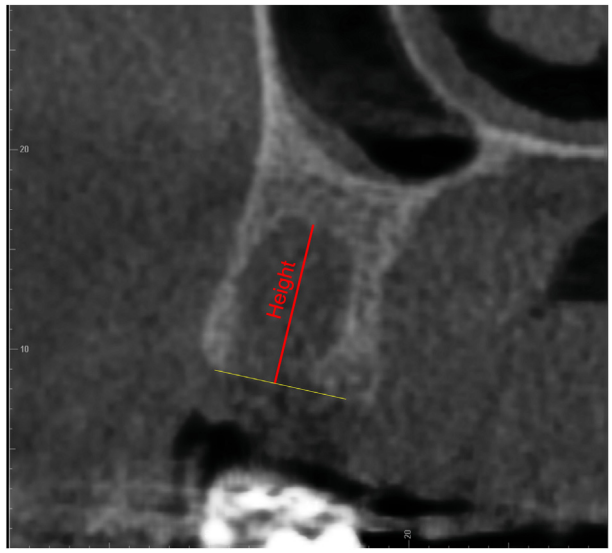

FIGURE 2. Measurement of the height of the alveolus in the cone beam computed tomography (CBCT) images. The *red line* corresponds to the height measurement from the most apical point of the socket to the most occlusal bony point of the socket (*yellow line* tangential to the buccal and lingual plates).

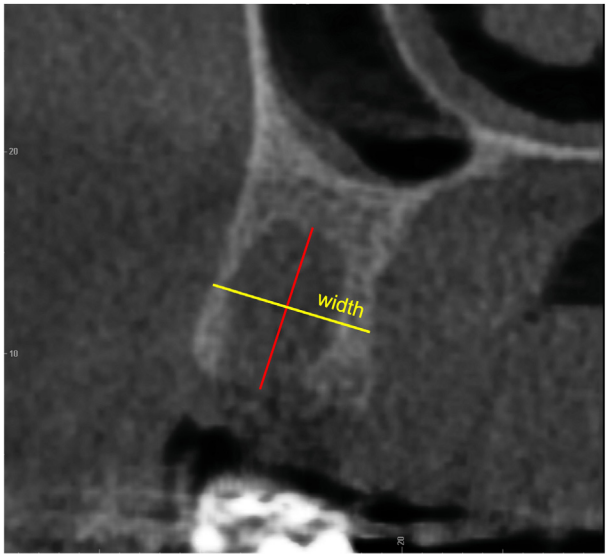

FIGURE 3. Measurement of the thickness of the alveolus in the CBCT images. The *red line* is the vertical central line of reference to define the horizontal yellow line (width) from the buccal bony plate to the lingual plate, passing through the midpoint of vertical line (*red*).

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FIGURE 4. T1 vertical reference for posterior height measurements of the alveolus in the CBCT images. After the establishment of height measurement plane at T1 (*red line*), from the oclusal horizontal plane of the socket (*yellow line*) to the most apical point of the socket, a new line continuing upward the *red line* (via central height axis superiorly), going from the most apical point of the socket at T1 to an anatomical reference of the anterior maxilla, such as nasal floor, maxillary sinus floor, or Y line of Ennis was defined and measured (*blue line*). This measurement (*blue line*) was applied in each subsequent CBCT for better standardization of height measurements.

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reference (Fig 5). All measurements were made by a trained examiner (GAG).

After establishing the measurements based on the CBCT exams, the percentage of bone loss at T2 and T3 was calculated using as a reference the measurements found at T1 according to the following equations:

$$\%BL = \frac{(T1 - T2)}{T1} \times 100 \quad \%BL = \frac{(T1 - T3)}{T1} \times 100$$

Dental Cast Evaluation

Type 4 dental stone casts obtained before the surgical procedure (T1), 7 days postoperative (T2) and 120 days postoperative (T3) were cut across in a buccal–lingual direction through the center axis of the extraction socket. An acrylic guide resting on the occlusal surface of the adjacent teeth was prepared based on the T1 model and used to evaluate height and width losses at T2 and T3 (Fig 6). If necessary, the coronal tooth structure of the tooth to be extracted was removed from the models. All dental impressions, model confections, and model measurements were made by the trained examiner (GAG).

Patients who failed to return for clinical/CBCT assessments, and those who abandoned the treatment were also excluded from the study.

DATA ANALYSIS

For the sample size calculation, an algorithm based on 4 groups, 4 measurements, 1 of effect size, 5% error probability, and 80% of statistical power was adopted. The minimum of 8 participants in each group was established (G*Power software-version 3.1.9.6- Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany).

Descriptive and comparative statistical analyses were conducted using the IBM SPSS Statistics for Windows, Version 22.0.[38] The intraexaminer reproducibility for the CBCT and dental cast evaluation, the Kappa coefficient (κ) was calculated in 20% of the sample, 1 week apart from each evaluation. The Shapiro–Wilk and Levene tests were used to test for variance distribution and homogeneity. The sample presented normal distribution and homogeneity of the variances, so the two-way analysis of variance (two-way ANOVA) suitable for repeated measurements was applied, followed by Bonferroni's *post hoc* test. To verify the equivalence between the groups in the baseline and age measures, one-way ANOVA was used. For the gender, the chi-square (χ^2) test was used. Data were statistically significant for P values < .05.

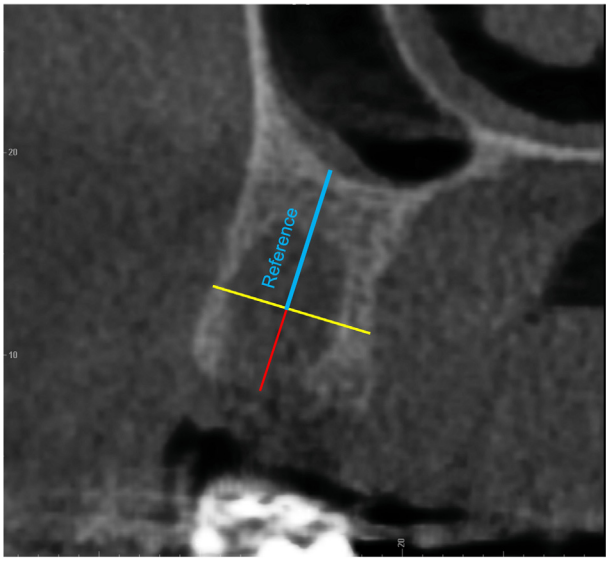

FIGURE 5. T1 vertical reference for posterior width measurements of the alveolus in the CBCT images. The *blue line* goes from the anatomical reference of the anterior maxilla, such as nasal floor, maxillary sinus floor, or Y line of Ennis previously defined to the width reference line (*yellow line*). This measurement (*blue line*) was applied in each subsequent CBCT for better standardization of width measurements.

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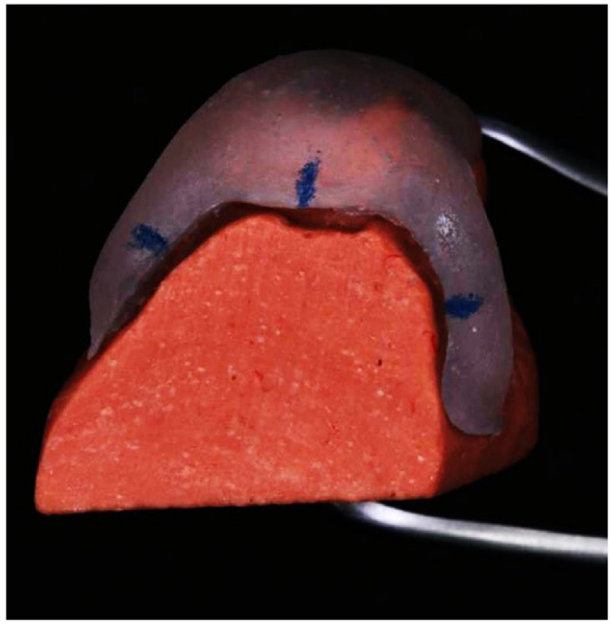

FIGURE 6. Acrylic guide based on the T1 model positioned on the T3 model showing the height and thickness losses.

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Results

Forty-four patients had uneventful, atraumatic tooth extraction, and were allocated into the 4 different study groups. One patient of Group 1 did not attend T2 assessments; one patient of Group 2 lost the gingival graft, exposing the xenograft at T2 assessment; one patient of Group 3 lost the d-PTFE membrane in the 21-day clinical follow-up, and one patient of Group 4 did not attend T3 assessment.

A total of 40 patients (10 patients per group) attended all clinical follow-ups, CBCT, and dental cast assessment (Fig 1). The age of the participants ranged between 25 and 70 years (mean = 41.87 ± 11.48 years old) and no statistically significant difference was found in the comparison of age between the groups (F (3.36) = 0.179; P = .910). Most of the sample was composed of women (60.0%; n = 24). When comparing the groups, no statistically significant difference was found regarding gender ($\chi^2(3) = 0.833$; P = .84). For CBCT baseline measurements, there were no statistically significant differences for height

Table 1. COMPARISON BETWEEN GROUPS FOR PROFILE AND BASELINE MEASUREMENTS (N = 40)

	Group				
	Blood Clot (n = 10)	Xenograft + FGG (n = 10)	d-PTFE (n = 10)	PRF (n = 10)	
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	*P* Value
Age (yr)	40.4 ± 8.9	44.1 ± 13.9	41.2 ± 12.5	41.9 ± 11.5	.910*
Height (mm)	10.7 ± 1.3	11.0 ± 1.0	10.8 ± 1.5	10.9 ± 1.0	.945*
Width (mm)	9.2 ± 1.3	8.8 ± 1.2	8.8 ± 1.3	9.0 ± 1.2	.920*
Gender	*f* (%)	*f* (%)	*f* (%)	*f* (%)	
Male	4 (40.0)	3 (30.0)	4 (40.0)	5 (50.0)	.841†
Female	6 (60.0)	7 (70.0)	6 (60.0)	5 (50.0)	

Abbreviations: d-PTFE, dense polytetrafluoroethylene; FGG, gingival free graft; PRF, platelet rich fibrin; SD, standard deviation.
* ONE-WAY ANOVA test.
† χ^2 test; mm–millimeters.

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Table 2. BONFERRONI'S MULTIPLE COMPARISONS TEST

	% of Bone Loss (CBCT Height)			
	7 Days	120 Days		
Group	Mean ± SD	Mean ± SD	*d'*	*P* Value
Blood Clot	2.6 ± 1.6	25.2 ± 4.7	6.400	.001
Xenograft + FGG	1.7 ± 0.7	9.8 ± 1.9*,‡	5.627	.001
d-PTFE	1.7 ± 0.8	15.9 ± 3.8*,†	5.121	.001
PRF	1.7 ± 0.5	19.1 ± 3.1*,†	7.895	.001
Time	$F_{(1,36)}$ = 771.514; *P* < .001			
Group	$F_{(1,36)}$ = 31.952; *P* < .001			
time * Group	$F_{(1,36)}$ = 29.526; *P* < .001			

Abbreviations: CBCT, cone beam computed tomography; d-PTFE, dense polytetrafluoroethylene; FGG, gingival free graft; PRF, platelet rich fibrin; SD, standard deviation.

* Statistically significant difference (*P* < .001) with the Blood Clot group.

† Statistically significant difference (*P* < .001) with the Xenograft + FGG.

‡ Statistically significant difference (*P* < .01) with the d-PTFE group.

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measurement (F (3.36) = 0.124; *P* = .945) and thickness (F (3.36) = 0.163; *P* = .920) (Table 1). Thus, it was not necessary to use those variables as covariates for statistical control.

The κ indicated good intraexaminer agreement both for the CBCT measurements (κ = 0.99) and for the dental cast evaluation measurements (κ = 0.89).

CBCT EVALUATION

The best CBCT bone height preservation was found in group 2, which presented the least bone loss percentage (9.8 ± 1.9%) at T3. The worst result obtained was for group 1, in which height bone loss percentage was 25.2 ± 4.7% at T3. The difference between those 2 groups was statistically significant (*P* < .001). CBCT height bone loss percentage for group 3 was 15.9 ± 3.8% at T3 and, for group 4 the percentage of height bone loss was 19.1 ± 3.1% at T3.

Statistically significant difference was observed between groups 1 and 2, 1 and 3, 1 and 4 (*P* < .001); 2 and 3, 2 and 4 (*P* < .001). Table 2 displays these results.

In the case of CBCT width loss, the worst results were obtained in group 4, in which the alveolar ridge thickness loss was 29.8 ± 5.2% at T3 followed by group 1, which was 29.5 ± 3.5% at T3. The best result was observed in group 2, where width loss was of

Table 3. BONFERRONI'S MULTIPLE COMPARISONS TEST

	% of Bone Loss (CBCT Width)			
	7 Days	120 Days		
Group	Mean ± SD	Mean ± SD	*d'*	*P* Value
Blood Clot	4.0 ± 1.5	29.5 ± 3.5	9.422	.001
Xenograft + FGG	3.0 ± 0.9	12.7 ± 4.7*	2.871	.001
d-PTFE	3.9 ± 1.0	15.4 ± 2.7*	5.674	.001
PRF	3.3 ± 0.9	29.8 ± 5.2†,‡	7.132	.001
Time	$F_{(1,36)}$ = 815.663; *P* < .001			
Group	$F_{(1,36)}$ = 42.388; *P* < .001			
time * Group	$F_{(1,36)}$ = 48.770; *P* < .001			

Abbreviations: CBCT, cone beam computed tomography; d-PTFE, dense polytetrafluoroethylene; FGG, gingival free graft; PRF, platelet rich fibrin; SD, standard deviation.

* Statistically significant difference (*P* < .001) with the Blood Clot group.

† Statistically significant difference (*P* < .001) with the Xenograft + FGG.

‡ Statistically significant difference (*P* < .001) with the d-PTFE group.

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Table 4. BONFERRONI'S MULTIPLE COMPARISONS TEST

	Model Height Loss (mm)			
	7 Days	120 Days		
Group	Mean ± SD	Mean ± SD	*d'*	*P* Value
Blood Clot	0.3 ± 0.1	2.8 ± 0.3	12.718	.001
Xenograft + FGG	0.3 ± 0.1	1.0 ± 0.2*	4.947	.001
d-PTFE	0.3 ± 0.1	1.7 ± 0.2*,†	11.723	.001
PRF	0.3 ± 0.1	2.7 ± 0.3†,‡	10.101	.001
Time	$F_{(1,36)}$ = 1886.181; *P* < .001			
Group	$F_{(1,36)}$ = 117.460; *P* < .001			
time * Group	$F_{(1,36)}$ = 115.785; *P* < .001			

Abbreviations: d-PTFE, dense polytetrafluoroethylene; FGG, gingival free graft; PRF, platelet rich fibrin; SD, standard deviation.
* Statistically significant difference (*P* < .001) with the Blood Clot group.
† Statistically significant difference (*P* < .001) with the Xenograft + FGG.
‡ Statistically significant difference (*P* < .001) with the d-PTFE group.

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12.7 ± 4.7% at T3 and in group 3, where it was 15.4 ± 2.7%, but the difference between these 2 groups was not statistically significant (*P* = .968). Statistically significant difference was observed between groups 1 and 2, 1 and 3 (*P* < .001); 2 and 4 (*P* < .001); 3 and 4 (*P* < .001). Table 3 displays those results.

DENTAL CAST EVALUATION

Dental cast height loss analysis revealed that Group 1 (2.8 ± 0.3 mm) and group 4 (2.7 ± 0.3 mm) showed the worst results at T3. The best dimensional preservation measured at T3 was observed in group 2 (1.0 ± 0.2 mm) and group 3 (1.7 ± 0.2 mm). The statistical analysis revealed a statistically significant difference between groups 1 and 2, 1 and 3 (*P* < .001); 2 and 3, 2 and 4 (*P* < .001), and 3 and 4 (*P* < .001). Table 4 displays those results.

Regarding dental cast width loss, group 1 (3.0 ± 0.2 mm) and group 4 (2.9 ± 0.1 mm) exhibited the worst dimensional preservation at T3. Once more, group 3 (0.9 ± 0.2 mm) and group 2 (1.0 ± 0.2 mm) presented better alveolar ridge horizontal preservation results at T3, but the difference was not statistically significant (*P* = 1.000). A statistically significant

Table 5. BONFERRONI'S MULTIPLE COMPARISONS TEST

	Model Width Loss (mm)			
	7 Days	120 Days		
Group	Mean ± SD	Mean ± SD	*d'*	*P* Value
Blood Clot	0.3 ± 0.1	3.0 ± 0.2	19.197	.001
Xenograft + FGG	0.3 ± 0.1	1.0 ± 0.2*	5.946	.001
d-PTFE	0.3 ± 0.1	0.9 ± 0.2*	5.638	.001
PRF	0.3 ± 0.1	2.9 ± 0.1†,‡	30.002	.001
Time	$F_{(1,36)}$ = 3413.355; *P* < .001			
Group	$F_{(1,36)}$ = 601.588; *P* < .001			
time * Group	$F_{(1,36)}$ = 403.096; *P* < .001			

Abbreviations: d-PTFE, dense polytetrafluoroethylene; FGG, gingival free graft; PRF, platelet rich fibrin; SD, standard deviation.
* Statistically significant difference (*P* < .001) with the Blood Clot group.
† Statistically significant difference (*P* < .001) with the Xenograft + FGG.
‡ Statistically significant difference (*P* < .001) with the d-PTFE group.

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result between groups 1 and 2 ($P < .001$), 1 and 3 ($P < .001$), 2 and 4 ($P < .001$), and 3 and 4 ($P < .001$) was found. Table 5 displays those results.

Discussion

This study compared vertical and horizontal alveolar preservation after application of 3 different materials (xenograft + gingival free graft, d-PTFE, and PRF plugs) to naturally healed sites (blood clot), assisting the clinician in decision making regarding the choice of materials to achieve predictable, simple and low-cost socket preservation therapies.

PRF used for alveolar preservation is controversial regarding its real benefit, which is mainly in hard tissue volume preservation. Indeed, while some authors report significant results stemming from PRF use,[36,39,40] others report no such advantages in alveolar ridge preservation, except for soft tissue healing and bone quality.[16,19,34,41]

These findings are confirmed by Miron et al[42] who published a far-reaching systematic review, indicating that PRF is efficient in fostering soft tissue regeneration but there is still a lack of studies to convincingly demonstrate its role in the regeneration of the hard tissues. Areewong et al[43] compared the new bone formation ratio between using PRF as a socket preservation material and normal wound healing, by means of histomorphometric analysis. They concluded that the use of PRF in ARP does not statistically significantly enhance new bone formation after tooth extraction compared to normal wound healing. Aravena et al[31] concluded that L-PRF socket filling showed the same dimensional and volumetric behavior as normal blood clot healing in the ARP of postextraction tooth sockets, similarly to the present study results. Ivanova et al[44] observed that PRF isolated is suitable for the filling of postextraction sockets without bone defects, revealing a significantly higher percentage of vital bone formation compared to the control group (blood clot), but the authors did not evaluate height and width losses of alveolar bone.

The best results of this study were observed when the sockets were filled with xenograft material (group 2), particularly in height preservation. Similar results to this study can be found when using xenograft material compared to unassisted healing (blood clot) and/or with the use of PRF in postextraction sockets.[7,17,42] In fact, only autologous bone has the best biological properties for bone augmentation procedures. Nevertheless, extra site of operation, prolonged time of surgery, donor side morbidity, high cost, limited autologous bone availability, and postoperative discomfort lead to the use of alternative bone substitutes for bone regeneration. Bone graft materials are chosen based on their ability to serve as a scaffold, and to maintain space for new bone ingrowth with osteoconductive activity.[45] The use of lyophilized demineralized bovine bone granules in socket preservation to fill in the extraction socket is effective in preserving the alveolar bone dimension with excellent soft and hard tissue healing.[18]

It must be underscored that during implant installation 4 months later, a considerable amount of xenograft particles could still be seen in the alveolar space. It is also important to highlight that the removal of the free gingival graft to seal the socket increases the morbidity of the procedure and greater postoperative discomfort.

The results obtained with the use of the d-PTFE membrane (group 3) were similar to xenograft + free gingival graft group (group 2) in width loss as measured both tomographically and on dental casts. These results are similar to a recent systematic review and meta-analysis study, which revealed no statistically significant alterations after extraction when d-PTFE membrane was used alone or in combination with other biomaterials for clinical changes in the horizontal and vertical alveolar bone dimensions, although the meta-analysis revealed that sites treated with d-PTFE + allograft resulted in statistically significant reduced radiographic vertical bone loss compared with d-PTFE alone.[46]

The authors also consider that the statistically significant difference between groups 2 and 3 in CBCT height evaluation may not be relevant clinically in absolute numbers to the point of not encouraging the use of d-PTFE membrane for alveolar height preservation. Furthermore, d-PTFE was the simplest technique and less time consuming compared to the other experimental groups, with good clinical alveolar bone preservation results.

Comparing alveolar preservation studies are especially difficult because preservation techniques are analyzed in different locations of the jaws as well as using different evaluation/investigation methods.[46]

The present study has several limitations, such as the use of conventional impressions and conventional dental casts instead of intraoral scanning and models obtained from 3D printing or other clinical bone measurements for correlation with CBCT measurements, in addition to the lack of histomorphometric analysis to evaluate bone quality of the different groups. Furthermore, eventual fibrosis under soft tissues in the d-PTFE group could interfere with the results of width measurements.

Therefore, considering all the limitations of this clinical trial, in postextraction sockets of the anterior maxilla and bicuspid region, group 2 (xenogenous bone graft with free gingival graft) and group 3 (d-PTFE) obtained the best results in alveolar preservation, with group 2 indicated when the vertical alveolar ridge preservation is mandatory.

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