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Cone-beam computed tomographic evaluation of dimensional hard tissue changes following alveolar ridge preservation with leucocyte and platelet-rich fibrin techniques: a pilot study

Avaliação tomográfica computadorizada de feixe cônico das alterações dimensionais de tecido duro após preservação de crista alveolar com técnicas de fibrina rica em leucócitos e plaquetas: um estudo piloto

Natalia Passos da SILVA[1,2], João Carlos Costa da SILVA[1,2], André FREITAS[2], Iêda Margarida Cruzoé REBELLO[2], Ruijia YANG[3], Tao WANG[3], Rusin ZHAO[3], Getulio NOGUEIRA[1,3]

1 - Centro de Implantodontia e Reabilitacao Oral de Salvador, Private Practice. Salvador, BA, Brazil.
2 - Universidade Federal da Bahia, School of Dentistry. Salvador, BA, Brazil.
3 - University of Otago, Faculty of Dentistry. Dunedin, New Zealand.

ABSTRACT

Objective: This study evaluated the effect of leucocyte and platelet-rich fibrin (L-PRF) techniques used in alveolar ridge preservation on dimensional hard tissue changes of the alveolar ridge assessed using cone-beam computed tomography (CBCT) scans. **Material and Methods:** Elective alveolar ridge preservation surgeries were performed on seven systemically healthy patients who underwent single posterior tooth extraction. Patients were randomly treated with PRF mixed with a commercial bone xenograft (n = 3) or PRF plug (n = 4). CBCT scans were taken immediately after tooth extraction and then four months later, just before implant surgery. Dimensional alterations in socket height (SH), socket area (SA) and socket volume (SV) were evaluated on CBCT scans by percentage differences before and after treatments. **Results:** Sockets treated with PRF plus bone xenograft had a tendency to maintain alveolar bone dimensions over time (SH= 11.22% to 82.74%, SA= 1.84% to 48.91% and SV= 9.11% to 203.62%), while sockets treated only with PRF plug technique presented only a modest increase in height (SH= 1.47% to 11.11%) but greater alveolar ridge resorption confirmed by a decrease in socket area and volume dimensions (SA= 0.21% to -24.09% SV= 8.53% to -54.12%). **Conclusion:** Within the limitations of this study, the maintenance of alveolar socket dimensions was observed when PRF was associated with a xenograft. However, the loss of alveolar ridge dimensions was not entirely prevented by PRF treatment alone.

KEYWORDS

Alveolar bone loss; Bone substitutes; Cone-beam computed tomography; Platelet-rich fibrin; Tooth socket.

RESUMO

Objetivo: Este estudo avaliou o efeito das técnicas de fibrina rica em leucócitos e plaquetas (L-PRF) usadas na preservação da crista alveolar em alterações dimensionais de tecido duro da crista alveolar avaliadas por tomografia computadorizada de feixe cônico (CBCT). **Material e Métodos:** Foram realizadas cirurgias eletivas de preservação da crista alveolar em sete pacientes sistemicamente saudáveis que foram submetidos a uma única extração dentária posterior. Os doentes foram tratados aleatoriamente com PRF misturado com um xenoenxerto ósseo comercial (n = 3) ou com PRF plug (n = 4). CBCT foi realizada imediatamente após a extração dentária e quatro meses depois, imediatamente antes da cirurgia de implante. Alterações dimensionais na altura do alvéolo (SH), área do alvéolo (SA) e volume do alvéolo (SV) foram avaliadas em exames CBCT por diferenças percentuais antes e depois dos tratamentos. **Resultados:** Os alvéolos tratados com PRF mais xenoenxerto ósseo apresentaram tendência a manter as dimensões ósseas alveolares ao longo do tempo (SH= 11.22% a 82.74%, SA= 1.84% a 48.91% e SV= 9.11% a 203.62%), enquanto alvéolos tratados apenas com a técnica de PRF plug apresentaram apenas um aumento modesto na altura (SH= 1.47% a 11.11%), mas uma maior reabsorção alveolar confirmada pela redução das dimensões de área e volume do alvéolo (SA= 0.21% a -24.09% SV= 8.53% a -54.12%). **Conclusão:** Dentro das limitações deste estudo, a manutenção das dimensões alveolares foi observada quando o PRF foi associado ao xenoenxerto. No entanto, a perda das dimensões alveolares não foi totalmente evitada pelo tratamento apenas com PRF.

PALAVRAS-CHAVE

Perda óssea alveolar; Substitutos ósseos; Tomografia computadorizada de feixe cônico; Fibrina rica em plaquetas; Alvéolo dental.

INTRODUCTION

Adequate alveolar ridge dimensions create the foundation for optimal function, stability, and aesthetic outcomes and dictate implant treatment success [1,2]. Alveolar bone ridge changes following tooth extraction can compromise the use of dental implants for prosthodontic rehabilitation. Maintaining socket dimensions is considered biologically challenging [3] as the buccal-lingual dimension of the alveolar ridge can be reduced by at least 50% during the first year after tooth extraction, and 30% of the initial ridge width can be lost during the first three months [4].

For this reason, elective alveolar ridge preservation (ARP) has been utilized before implant placement to minimize the loss of ridge dimensions after tooth extraction and avoid more demanding surgical bone augmentation procedures [5]. Even though the loss of alveolar ridge dimensions cannot be entirely prevented by any graft material [1], various ARP techniques have been published to treat healing socket sites by preserving the post-extraction bone structures [6-12]. Animal and clinical studies [13,14] have shown significant preservation of the post-extraction socket dimensions using a bovine bone xenograft without preventing the resorption of the buccal-lingual alveolar ridge. Cone-beam computed tomography (CBCT) has also been used in non-inferiority clinical trials showing minimal differences among bone graft substitutes in maintaining bone volume after tooth extraction [1,15].

Leukocyte-platelet-rich fibrin (L-PRF) is a second-generation platelet concentrate that forms a natural fibrin matrix obtained from the centrifuged blood without anticoagulants [16,17]. This fibrin clot consists of a concentration of cytokines, growth factors, glycemic chains and structural glycoproteins entangled within a fibrin network that can be used in oral surgeries. L-PRF improves tissue healing since it progressively releases cytokines and growth factors during the remodeling of the fibrin matrix. It promotes rapid and effective angiogenesis and neovascularization of tissues, including directly stimulating cell migration and proliferation, such as osteoblast, fibroblasts and dental pulp cells, which improve healing and regeneration [18,19]. Due to the mentioned reasons, L-PRF became a viable option for ridge preservation [20-23]. Classic studies from Choukroun et al. [24] and Dohan et al. [25] describe the original techniques to obtain platelet-rich fibrin from blood with applications in implant dentistry.

The use of xenografts in alveolar ridge preservation techniques following tooth extraction seems to reduce vertical dimensional changes in crest height compared with allografts. Compared to non-grafted controls, L-PRF can reduce horizontal ridge resorption up to 3 mm below the alveolar crest and reduce vertical resorption of the buccal bone wall, improving the total bone volume after three months [21]. Also, a higher percentage of new bone formation was noted when L-PRF was used as the sole socket filling material after tooth extraction. The efficacy of PRF compared to bone substitutes in alveolar ridge preservation and sites left to heal spontaneously has been investigated after three months of tooth extraction [26]. The beneficial effects of using a collagen membrane, freeze-dried bone allograft, and PRF alone in reducing horizontal and vertical bone changes were observed. However, none of the evaluated methods could completely prevent alveolar bone dimensional changes after tooth extraction.

Although the use of PRF for alveolar ridge preservation following a tooth extraction is widespread in clinical practice throughout the world, there remain limited studies in the literature that have managed to make a definitive conclusion on the impact of PRF on bone volume changes. Additionally, the literature investigating the use of PRF alone or combined with other bone substitutes such as xenografts for ridge preservation in posterior teeth is also very limited. Thus, this study evaluated CBCT scans aiming to observe the possible influence of platelet-rich fibrin alone or when associated with a commercial xenograft on the maintenance of bone dimensions in post-extraction healing sockets.

MATERIAL AND METHODS

Patient selection

Seven systemically healthy patients attending dental clinics at the Federal University of Bahia (UFBA, Bahia, Brazil) assigned for dental implant placement were invited to participate in the study. Patients between 18 and 70 years of age needing an extraction of a posterior tooth due to deep caries, root fracture, or prosthetic reasons were included in the study (Table I). Patients presenting uncontrolled diabetes, smoking habits, autoimmune diseases, periodontitis, or undergoing chemotherapy/radiotherapy treatment in the past five years were excluded.

Study design

A randomized, parallel-design pilot study evaluated the effect of alveolar ridge preservation techniques in seven patients assigned by lottery into two treatment groups: a mix of commercial bovine xenograft with L-PRF (Group 1, n=3) and L-PRF alone (Group 2, n=4). All patients received instructions for oral hygiene and carried out CBCT before the exodontia (T1) and at least four months after socket preservation surgery (T2). The patients were fully aware of the procedures and signed informed consent of research. This study was approved by the Ethics and Research Committee of the Federal University of Bahia, School of Dentistry (CAAE: 86436418.7.0000.5024).

Table I - Patient demographics, extraction site characteristics and group distribution

Patient	Sex	Age	Site	Reason for extraction
1	M	46	25	Deep caries
2	F	70	25	Prosthetic reasons
3	F	55	26	Deep caries
4	M	31	16	Deep caries
5	F	59	45	Prosthetic reasons
6	F	59	37	Prosthetic reasons
7	F	36	36	Deep caries

M: Male; F: female.

Clinical procedures

For all patients, blood samples were initially collected and centrifuged at 3000 rpm for 10 minutes according to the L-PRF protocol [25]. The alveolar ridge augmentation surgery consisted of atraumatic exodontia using periotomes to preserve socket bone walls. After extraction and alveolus curettage, the three assigned sites received a mixture of L-PRF with a commercial bovine xenograft (BioOss®, Geistlich Pharma, Wouhusen, Switzerland) carefully prepared and inserted in the sockets until the entire alveolus was filled and sutured (Figure 1). For the other four L-PRF assigned sites, the fibrin clot was initially placed in a cylindrical sterile container under compression with a piston for plug formation and posteriorly placed into the sockets and sutured for second intention healing (Figure 2). An L-PRF membrane was also placed on all seven grafted sites to promote better graft protection. Post-operative recommendations consisted of 0.12% chlorhexidine rinse for two weeks, sodium dipyrone monohydrate (1g) and 875 mg amoxicillin (875 mg, b.i.d.) for seven days. The sutures were removed after two weeks.

Tomographic (CBCT) evaluation

CBCT images were obtained with a tomograph (Sirona Orthophos CXG5, Germany) on the extraction day and after four months of graft placement from all participants. Three-dimensional digital sections were performed to carry out the volumetric measurements. CBCT images were digitally analyzed (OsiriX DICOM software, Pixmeo, Switzerland) by an experienced radiologist (JCS). The following measures were defined to assess the alveolar ridge dimensions before and after tooth extraction: *Socket height (SH)*- refers to the measurement (mm) of a vertical reference line positioned in the center of the socket, which runs from the bone crest level edge of the socket until a horizontal reference line in the socket bottom (Figure 3); *Socket area (SA)*- comprises the measurement (mm^2) of the central socket area (Figure 4); *Socket volume (SV)*- comprises the measurement (mm^3) of socket volume (Figure 5). SA and SV measures followed the same anatomical landmarks defined for SH.

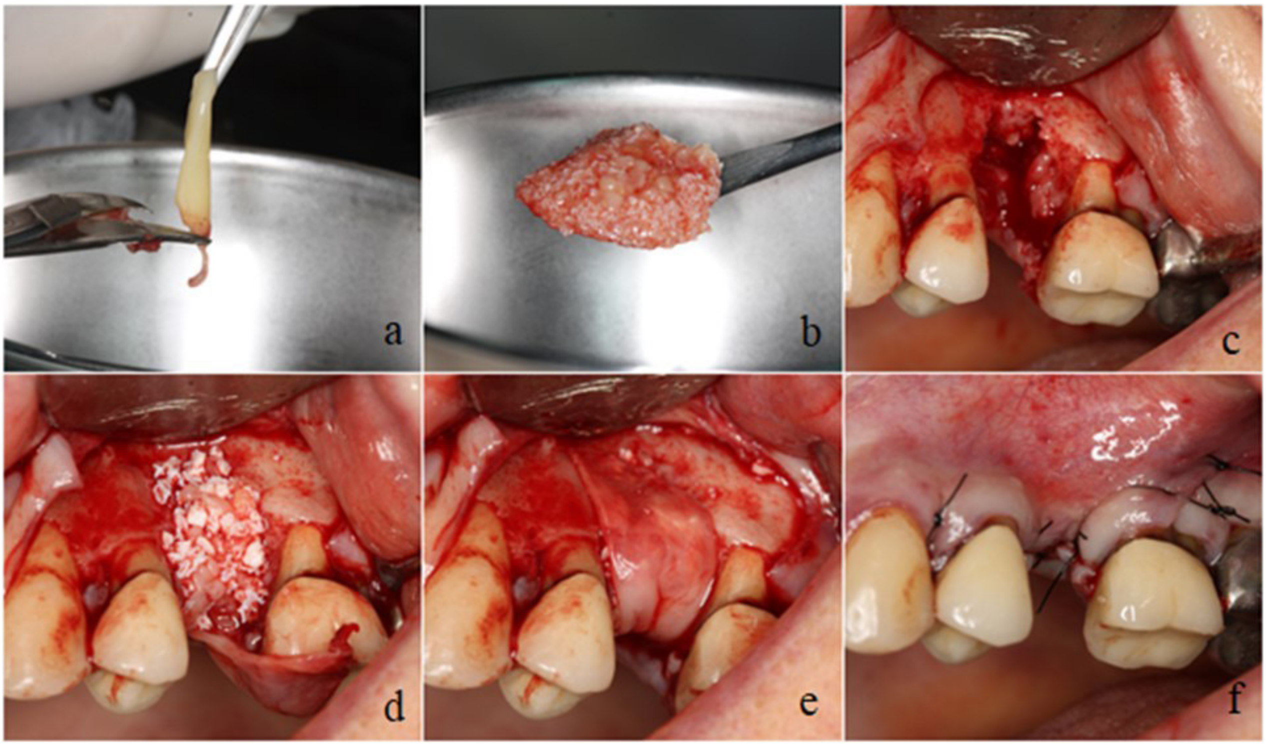

Figure 1 - Preparation of graft mixture used for L-PRF/xenograft sites: fragmentation of L-PRF (a), combination of PRF with xenograft (b), extraction socket (c), insertion of the mixture into the socket (d), placement of L-PRF membrane over the graft (e), placement of sutures (f).

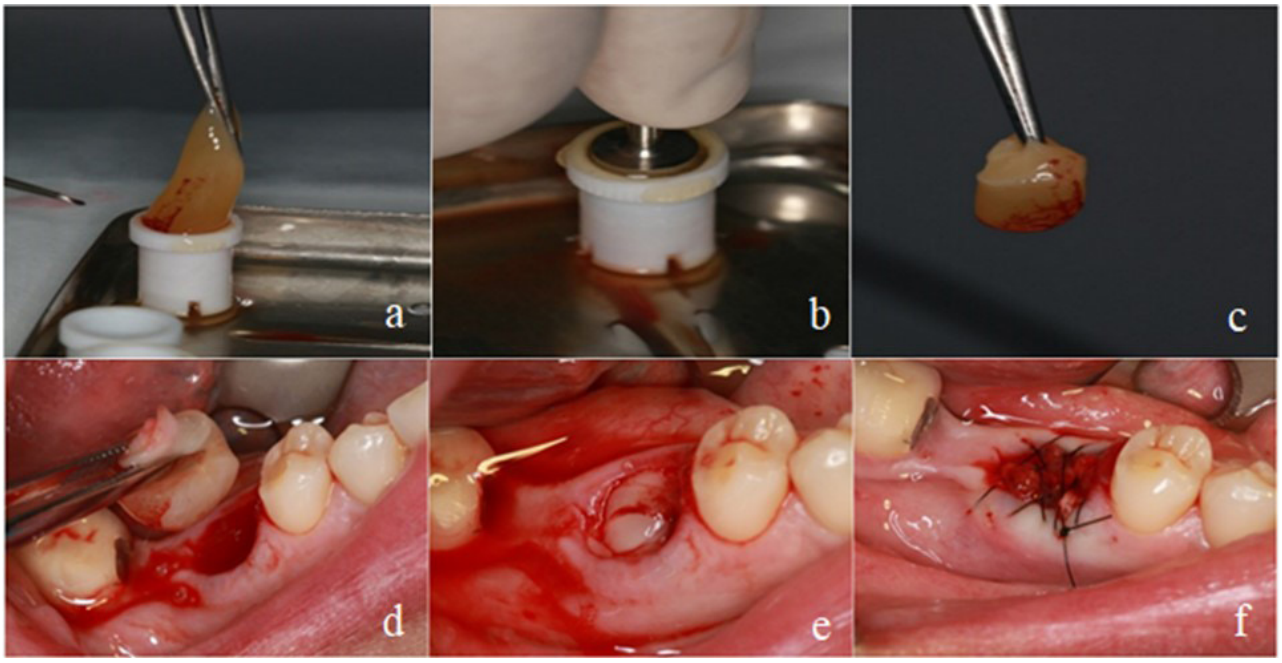

Figure 2 - Preparation of L-PRF sites: L-PRF membrane inserted on cylinder (a), L-PRF membrane compression (b), L-PRF plug prepared (c), insertion of L-PRF plug into socket (d), placement of L-PRF membrane over the socket (e), placement of sutures (f).

RESULTS

A descriptive analysis of all tomographic parameters is presented as percentage difference means by comparing CBCT scans before and after treatments from all treated sites (Tables II-IV).

Socket height (SH) measurements

The sites treated with PRF/xenograft showed a consistently increased % difference in height dimension (Table II), with the highest increase in socket height observed on patient 2 (82.74%),

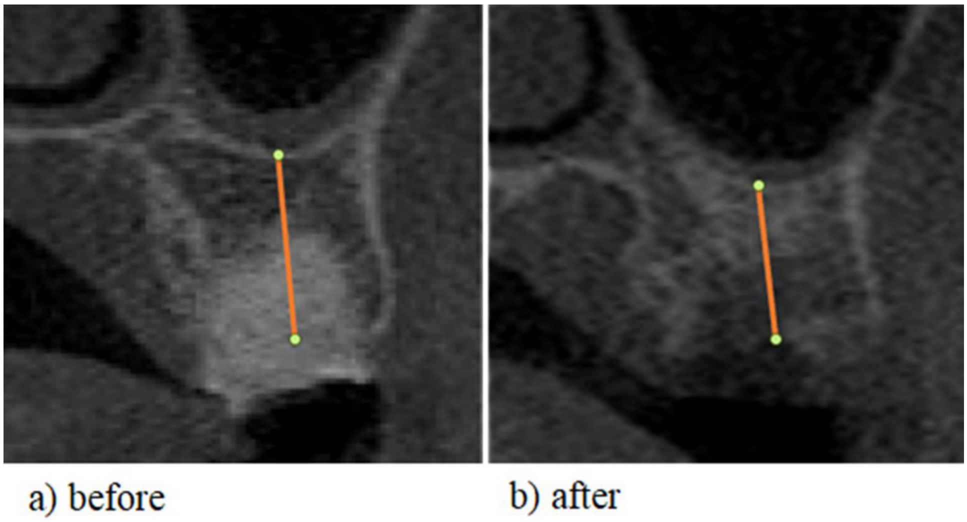

Figure 3 - Illustration of socket height measurements (mm) before (a) and after (b) PRF treatments using coronal views of CBCT scans.

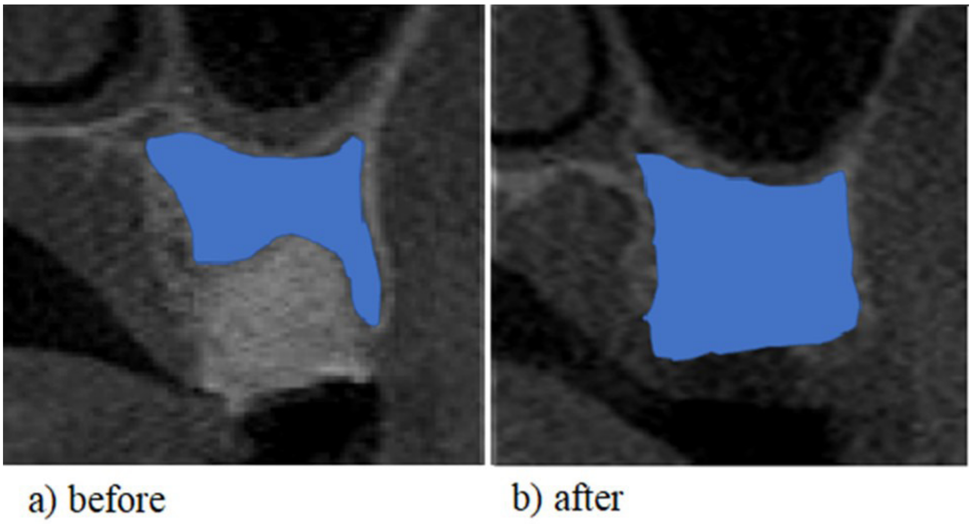

Figure 4 - Illustration of socket area measurements (mm^2) before (a) and after (b) PRF treatments using coronal views of CBCT scans.

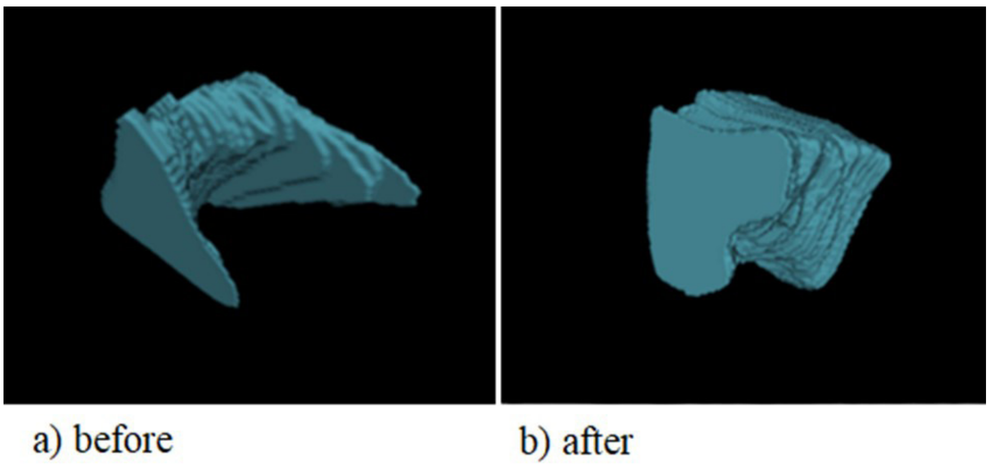

Figure 5 - Illustration of socket volume measurements (mm^3) before (a) and after (b) PRF treatments using 3D modelling.

who did not present a preserved buccal bone wall. Comparatively, the sites treated with L-PRF alone showed height dimensions ranging from -24.65% to 11.11%, with a reduction in socket height

Table II - Comparison of CBCT socket heights (mm) measurements before (T1) and after (T2) treatments

Patient	Treatment Group	SH at T1 (mm)	SH at T2 (mm)	% difference in socket height	Residual bone walls
1	PRF/xenograft	9.26	10.70	15.55%	Yes
2	PRF/xenograft	3.42	6.25	82.74%	No buccal
3	PRF/xenograft	9.88	11.00	11.22%	No palatal
4	PRF	4.38	3.30	-24.65%	No buccal
5	PRF	13.20	14.10	6.81%	Yes
6	PRF	13.60	13.40	-1.47%	No buccal
7	PRF	15.30	17.00	11.11%	Yes

SH: socket height; T1: before treatment; T2: after treatment; PRF: platelet rich fibrin.

Table III - Comparison of CBCT socket area (mm^2) measurements before (T1) and after (T2) treatments

Patient	Treatment Group	Area at T1 (mm^2)	Area at T2 (mm^2)	% difference in socket area	Residual bone walls
1	PRF/xenograft	103.10	105.00	1.84%	Yes
2	PRF/xenograft	32.27	48.06	48.91%	No buccal
3	PRF/xenograft	128.20	134.90	5.22%	No palatal
4	PRF	67.02	42.43	-36.68%	No buccal
5	PRF	136.50	136.20	-0.21%	Yes
6	PRF	144.90	110.00	-24.09%	No buccal
7	PRF	121.10	122.70	1.32%	Yes

T1: before treatment; T2: after treatment; PRF: platelet rich fibrin.

Table IV - Comparison of socket volume (mm3) measurements before (T1) and after (T2) treatments

Patient	Treatment Group	Volume at T1 (mm^3)	Volume at T2 (mm^3)	% difference in socket volume	Residual bone walls
1	25	691.2	628.2	-9.11%	Yes
2	25	124.1	376.8	203.62%	No buccal
3	26	619.2	939.8	51.77%	No palatal
4	16	690.1	316.6	-54.12%	No buccal
5	45	1493.7	1122.6	-24.84%	Yes
6	37	1344.7	920.4	-31.55%	No buccal
7	36	788.8	721.5	-8.53%	Yes

T1: before treatment; T2: after treatment; PRF: platelet rich fibrin.

observed in patient 4 (-24.65%) and patient 6 (-1.47%) who did not present preserved buccal bone walls before treatment.

Socket area (SA) measurements

The sites treated with PRF/xenograft showed consistently increased % difference in area dimension (Table III), with the highest increase observed in patient 2 (48.91%), who did not present a preserved buccal bone wall and the lowest increase in patient 1 (1.84%) who presented preserved socket walls. Comparatively, sites treated with L-PRF alone showed area dimensions ranging from -36.68% to 1.32%, with a higher reduction in socket area, observed in patient 4 (-36.68%) and patient 6 (-24.09%) who did not present preserved buccal bone walls before treatment.

Socket volume (SV) measurements

The sites treated with L-PRF/xenograft showed a range in the % difference in volume dimension (Table IV), with the highest increase observed in patient 2 (203.62%), who did not present a preserved buccal bone wall and a volume reduction on patient 1 (-9.11%) who presented preserved socket walls. Comparatively, sites treated with PRF alone showed a consistent decrease in socket volume, with the highest volume loss observed in patients 4 (-54.12%) and 6 (-31.55%) who did not present preserved buccal bone walls before treatment.

DISCUSSION

The comparative findings of this pilot study showed that the alveolar socket preservation technique utilizing leucocyte- and platelet-rich fibrin (L-PRF) as a single treatment was insufficient to preserve tooth extraction dimensions sockets in the posterior region of the mouth. L-PRF alone was not efficient in maintaining the volume of post-extraction sockets, with all patients showing a volume loss of up to 54.12% (Table IV). In contrast, adding a xenograft bone substitute with the fibrin clot improved socket dimensions upon evaluating percentage differences of tomographic measurements before and after treatments. Interestingly, in both treatment groups, the absence of the buccal bone wall seemed to impact changes in socket volume (Table IV).

Although PRF has been extensively used for ARP since its introduction in the early 2000s by Dohan et al. [16,25]due to its reported superiority to platelet-rich plasma (PRP) in promoting soft tissue healing and bone formation, there remains controversy in the literature surrounding the efficacy of PRF in enhancing bone formation [27,28]. Studies have reported a wide range of results, finding the effect of PRF on ridge preservation to range from no impact to markedly positive. Studies have shown successful outcomes with L-PRF alone to regenerate bone and soft tissue. Anwandter et al. [9] evaluated the dimensional changes in post-extraction sockets treated with L-PRF independently and found that L-PRF achieved similar outcomes in ridge preservation when compared with other bone substitutes such as xenografts and allografts. In another study, Temmerman et al. [22] concluded in a sample of 12 patients that using L-PRF as a single material to fill the sockets is beneficial during a three-month follow-up period and displayed similar effectiveness in ridge preservation compared to that of other bone substitutes.

Furthermore, the same study claimed that using L-PRF also helps avoid the disadvantages of traditional bone substitutes, such as high cost and graft particles that remain in the socket. Canellas et al. [21]. have shown that non-molar extraction sockets treated with L-PRF decreased vertical resorption of the vestibular socket wall and improved the total socket bone volume after three months of follow-up with CBCT scans when compared to a control group of spontaneous healing with no treatment. The authors also performed a histomorphometric analysis that revealed a higher percentage of new bone formation when L-PRF was used as the sole socket filling material after tooth extraction. This is also supported by Castro et al. [29]. They reported greater bone formation in sockets treated with PRF as a sole filling material relative to unfilled sockets in patients undergoing multiple extractions in the anterior maxilla. However, the same group found that PRF alone could not preserve ridge dimensions three months after extraction [29]. Several other recent studies reported positive effects of PRF in socket preservation although the clinical outcomes were not significantly different from control group outcomes [27,30-32]. Despite the apparent lack of consensus in the literature, it appears to be generally accepted, evident through the widespread use of PRF in ARP techniques to this day, that the use of PRF does indeed have a degree of positive impact on the preservation of bone volume post-extractions.

Several recent publications evaluated the combination of L-PRF with bone substitutes for alveolar ridge preservation after tooth extraction [31-42]. A review from Liu et al. [43] indicates that despite PRF presenting a promising treatment option for oral and maxillofacial bone regeneration by improving proliferation, differentiation, migration, and mineralization of cells during bone formation, it has an unstable effect on osteogenesis when utilized as a single treatment [43]. However, PRF combined with other materials can optimize its effectiveness and improve bone quality. Indeed, PRF can improve the plasticity of the material and its biological properties by providing cytokines, platelets, leukocytes, and circulating stem cells. PRF can also work as a delivery system for graft particles as the fibrin clot helps prevent dispersion of the Bio-Oss® particles [35,44-46].

A case report written by Araujo & Castro-Silva [47] reported positive results with Geistlich Bio-Oss® spongious bone xenograft substitute associated with L-PRF clot (Dohan technique) in achieving bone and soft tissue regeneration in broad circumferential apical defects. Oliveira et al. [48] demonstrated that the combination of xenograft and fibrin clot in mouse calvary defects showed greater new bone formation than all other experimental groups. It has been shown in various other experimental studies that the combination of PRF and Bio-Oss® can enhance bone healing and new bone volume more than when either PRF or Bio-Oss® is used alone [30,49,50]. This is because a combination of the two materials can utilize the benefits of both materials, with Bio-Oss providing a structural scaffold for new bone to form upon; whilst PRF stimulates migration and proliferation of bone-forming cells and releases healing cytokines to promote new bone growth [19,51,52]. This effect is demonstrated well through the results of the present study, where an up to 203.62% increase in bone volume was observed at four months of follow-up in sockets treated with a combination of PRF and Bio-Oss®, compared to up to 54.12% bone volume loss in sockets treated with PRF alone at the same period (Table IV).

Interestingly, as mentioned previously, the absence of the buccal wall appeared to affect the potential for socket volume regeneration. In patients treated with a combination of PRF and Bio-Oss®, the lack of the buccal wall resulted in the greatest percentage increase in socket volume at four months post-treatment (+203.62%); whereas in patients treated with PRF only, the absence of the buccal wall resulted in the greatest percentage decrease in socket volume at the same period of observation (-54.12% and -31.55%). This observation alludes to the importance of the presence of a structural scaffold in the formation & maintenance of new bone. In this combination, BioOss provides structural and mechanical support through osteoconduction. Its highly porous structure allows blood vessels infiltration into the newly formed bone via angiogenesis to further stimulate the bone regeneration [52]. This is enhanced further by the sustained release of a vast array of growth factors by L-PRF, which help stimulate osteoblastic growth and differentiation, restoring vascular integrity and optimising wound healing, thus resulting in a marked volume increase of the post-extraction socket [53].

The absence of the buccal wall meant a greater capacity for new bone formation. Thus, an immense volume increase was observed in patient 2, in the mechanical support provided by the BioOss material (+203.62%). Conversely, in the absence of a structural scaffold, as in Group 2 patients treated with PRF only, any newly formed bone is unable to be maintained at the site due to a lack of mechanical support, therefore resulting in unfavorable three-dimensional ridge preservation and the subsequent loss of socket volume over time. The absence of the buccal wall in these cases means that there is a lack of support buccally that would have been provided by the alveolar buccal wall where it is preserved, resulting in a larger volume loss observed in patients 4 and 6 (buccal wall absent) in the present study when compared with patients 5 and 7 (buccal wall intact) [54] (Table IV).

Recently, Stumbras et al. [26] evaluated the alveolar ridge dimensional changes of different alveolar ridge preservation techniques after three months of tooth extraction and compared the efficacy of autologous plasma rich in growth factor (PRGF) to the bone substitutes in alveolar ridge preservation and sites left to heal spontaneously in the aesthetic zone. They demonstrated that none of the socket preservation techniques evaluated could completely prevent alveolar bone dimensional changes after tooth extraction; however, all methods, including using a fibrin clot, were beneficial in reducing horizontal and vertical bone changes.

A limitation of the present study is the lack of a Bio-Oss® treatment group and a no-treatment control group, which makes evaluating the actual effect of the combination of the Bio-Oss® and PRF materials rather challenging. However, a systematic review conducted by Aludden et al. [55] reported new bone formation rates of between 22% to 42%, and a study conducted by Nevins et al. [56] reported new bone formation rates of between 24% to 50% when Bio-Oss® was used alone with a collagen membrane. Compared to the new bone formation rates of up to 203.62% in the present study, this reveals the potential of the combination of PRF and Bio-Oss® to significantly increase new bone formation rates in osseous defects (Table IV). It is worth noting that the sample size in the present study is relatively small and thus prone to higher variability and reduced reliability.

CONCLUSION

Within the limitations of this study, the use of PRF associated with a bone xenograft appears beneficial in alveolar ridge preservation following tooth extraction. However, the tomographic analysis carried out in this clinical study has shown that the isolated use of a fibrin clot did not maintain the bone volume of sockets post-extraction. Our results also found that the presence of either the buccal wall or an osteoconductive graft material is beneficial in preserving ridge volume after extractions. It is worth pointing out that randomized clinical studies with larger sample size and appropriate controls are necessary for elucidating the real clinical advantages of using fibrin clots for ridge preservation before implant placement. Therefore, further studies are needed to clarify the healing mechanisms during alveolar ridge preservation with autologous fibrin clots.

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Author's Contributions

NPS: Conceptualization, Methodology, Formal Analysis, Investigation, Writing – Original Draft Preparation. JCCS: Conceptualization, Methodology, Formal Analysis, Writing – Original Draft Preparation, Supervision. AF: Conceptualization, Methodology, Formal Analysis, Writing – Original Draft Preparation, Supervision. IMCR: Conceptualization, Methodology, Formal Analysis, Writing – Original Draft Preparation, Supervision. RY: Formal Analysis, Writing – Original Draft Preparation, Writing – Review & Editing. TW: Formal Analysis, Writing – Original Draft Preparation, Writing – Review & Editing. RZ: Formal Analysis, Writing – Original Draft Preparation, Writing – Review & Editing, Project Administration. GN: Conceptualization, Methodology, Formal Analysis, Writing – Original Draft Preparation, Writing – Review & Editing, Supervision, Project Administration.

Conflict of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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Regulatory Statement

This study was conducted following all the provisions of the local human subject's oversight committee guidelines and policies of the Declaration of Helsinki. The approval code of this study is 86436418.7.0000.5024.

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Getulio Nogueira
(Corresponding address)
University of Otago, Faculty of Dentistry, Department of Oral Sciences, Dunedin, New Zealand.
Email: getulio.nogueira@otago.ac.nz

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