

RIDGE PRESERVATION USING OPEN BARRIER MEMBRANE TECHNIQUES AND FREE GINGIVAL GRAFTS: A RANDOMIZED CONTROLLED TRIAL

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ABSTRACT

Background: Tooth extraction leads to a cascade of processes causing alveolar bone resorption and difficulties in subsequent dental rehabilitation. Ridge preservation (RP) involves different strategies, such as atraumatic extraction, immediate implants, and guided tissue regeneration. **Aim of the study:** This study aims to compare the influence of three different RP methods (with a dense polytetrafluoroethylene membrane (d-PTFE), with a d-PTFE membrane and platelet-rich plasma (PRP), and socket sealing with a free gingival graft (FGG)). **Materials and methods:** This randomized controlled trial was conducted at the Medical-Dental Centre at the Medical University of Varna, Bulgaria for the period 06/27/2022 – 04/20/2023. Eighty patients were randomly allocated (1:1:1:1) to one of the experimental groups or a control group without ARP. **Results:** The ARP methods observed in this trial successfully reduced the vertical post-extraction resorption, with the open barrier techniques being superior to the socket sealing with FGGs. **Conclusion:** The vertical loss of the buccal wall depended on its width and the type of socket management, with the latter being the determining factor. The three methods significantly compensated for the vertical loss of the thin socket walls but did not completely neutralize the influence of the wall width.

Key words: alveolar ridge preservation; dense polytetrafluoroethylene membrane; free gingival graft; platelet-rich plasma; post-extraction resorption; socket sealing

INTRODUCTION

Tooth extraction leads to a cascade of processes causing alveolar bone resorption, which can result in difficulties during implant and prosthetic treatment. Tissue deficit is a major challenge for successful dentition rehabilitation. Therefore, surgical methods for tissue preservation after tooth loss and tissue augmentation before or during implant placement have gained extreme popularity (1-3). Ridge preservation (RP) involves different strategies: minimally invasive procedures (atraumatic tooth extraction, surgeries without or with minimal flap retraction), immediate implantation, guided regeneration, and so on.

The most common RP techniques utilize bone grafting materials and barrier membranes. The barrier membrane covers and isolates the graft from undesired tissue

ingrowth. Absorbable membranes have been widely used in regenerative dentistry (4). However, they need to be fully covered by soft tissues which limits their application in the RP procedures. Clinicians must know the indications and limitations of different materials and select the most appropriate for each individual (5,6).

Dense polytetrafluoroethylene (d-PTFE) membranes have recently been demonstrated to have promising properties and eliminate some major limitations of other absorbable and non-absorbable membranes. Due to their microporosity, d-PTFE barriers can be left exposed to the oral environment (open barrier membrane technique) and bacteria cannot penetrate through them. In addition, they can be removed without additional surgical interventions (7,8). These barriers allow for

efficient bone regeneration while preserving the level of the surrounding soft tissues (9).

Autologous platelet concentrates (APCs) have been successfully used in various medical and dental fields (10-13). They are blood products that promote tissue healing and regeneration due to the release of numerous biologically active molecules (growth factors). They can be used as socket fillers alone or with bone grafting materials to stimulate bone deposition. Some of the most commonly used APCs in oral surgery and implant dentistry are platelet-rich plasma (PRP) and platelet-rich fibrin (PRF).

Free gingival grafts (FGGs) have recently gained popularity as a method for RP due to their advantage of preserving and even augmenting the keratinized gingiva (14-17). Common donor areas include the hard palate and maxillary tuberosity (18-20).

This study aims to compare the effect of three different RP techniques on the vertical post-extraction ridge resorption.

MATERIALS AND METHODS

Study Design and Setting

This randomized controlled clinical trial was carried out at the Faculty of Dental Medicine and University Medical and Dental Centre, Medical University of Varna, Bulgaria for 11 months (June 2022 - April 2023) after approval (№ 118/ 23/06/22) from the Research Ethics Committee and following the

Declaration of Helsinki. The protocol was registered on ClinicalTrials.gov (registration protocol - NCT06621498).

Study Subjects

Eighty participants were enrolled in the study and equally and randomly divided into 4 groups: Group 1 – RP with a d-PTFE membrane; Group 2 - RP with a d-PTFE membrane and PRP; Group 3 – RP with an FGG; and Group 4 – control (unassisted socket healing). The patients were Bulgarian citizens – 42 women (52%) and 38 men (48%), aged between 26 and 65 years.

The sample size was determined using the following formula for interventional studies (21):

$$\text{Sample size} = \frac{2SD^2(Z_{\alpha/2} + Z_{\beta})^2}{d^2}$$

SD – standard deviation reported in previous studies (22); $Z_{\alpha/2}$ – critical value for level of significance at 5% error (1.96); Z_{β} – critical value for 8% power (0.84); d – effect size (d=0.8 – a large effect size).

$$\text{Sample size} = 2(0.77)^2(1.96+0.84)^2/0.8^2 = 14.5$$

Simple randomization (lottery method) was used. A statistician who had no direct contact with the participants picked envelopes containing their names and the type of socket management (research groups). The flow chart of participants' enrolment is displayed in Figure 1.

CONSORT 2010 Flow Diagram

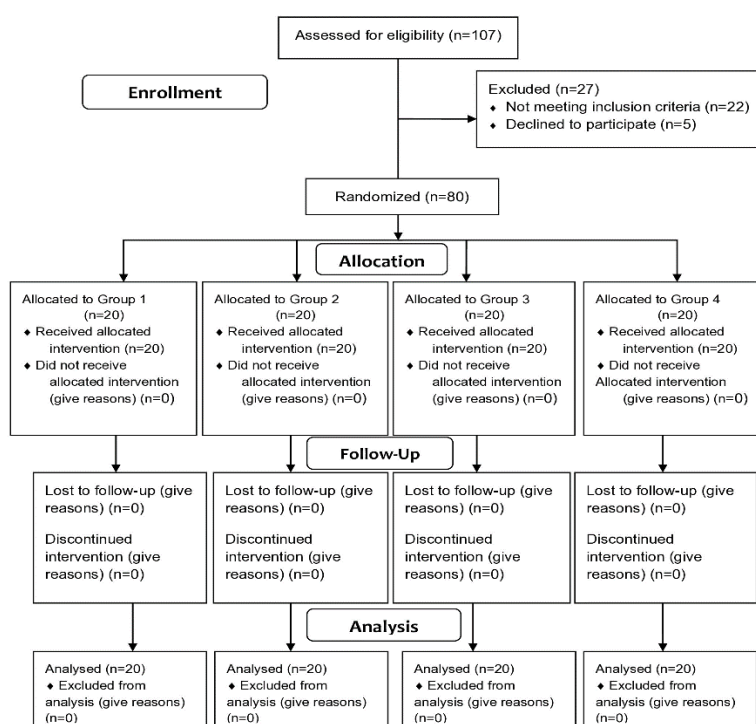


Figure 1. Flow Diagram of the Participants

Patient recruitment

Patient recruitment was performed after a careful analysis of the inclusion and exclusion criteria. The inclusion criteria were: patients at the age of 18-65 and in good general health; a premolar/molar requiring surgical removal; written informed consent. The exclusion criteria were general and local contraindications to surgical interventions and patients with no motivation to cooperate during treatment.

Radiological examination

Cone-beam computed tomography (CBCT) images were used to measure the height and width of the socket walls immediately after the surgery (BWH – buccal wall height; OWH – oral wall height; BWW – buccal wall width; OWW – oral wall width) and the wall heights after 90 days (BWH2 and OWH2 – buccal and oral wall heights on the second CBCT).

Measurements were taken using a paraxial section in the middle of the socket. The reference points for height measurements were the uppermost point of the socket wall and the highest point of the mandibular canal or the lowest point of the maxillary sinus, respectively. Measurements of BWW and OWW were made 3 mm downwards from the highest points of the socket walls (Figure 2).

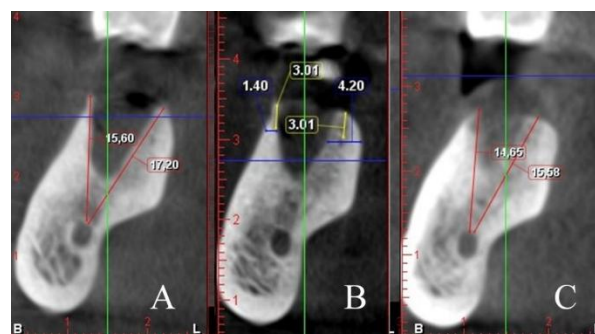


Figure 2. Measurements using cone-beam computed tomography. (A) Heights of the

socket walls on the day of extraction. (B) Widths of the socket walls on the day of extraction. (C) Heights of the socket walls 3 months after the extraction.

Molar sockets with a preserved bony septum provided two measurement sites – mesial and distal. Therefore, the number of measurements was greater than the extracted teeth. In addition, patients from all groups were divided into two subgroups with BWH of less than 2 mm and more than 2 mm. The rationale for that will be further analyzed in the Discussion section.

Surgical Technique

The surgical technique for all 4 groups started with atraumatic tooth extraction under local infiltration anesthesia using Articaine 4%, 1.8 ml. The sockets in Group 1 were covered with d-PTFE barriers inserted under the periosteum around the socket orifice and left partially exposed. Similarly, d-PTFE membranes were used to cover the sockets in Group 2 but the sockets were first filled with autologous PRP. The RP method in Group 3 was socket sealing with free gingival grafts harvested from the hard palate or the maxillary

tuberosity. Sockets in Group 4 were left on secondary healing without RP (control group). Sockets were sutured with 5/0 polyamide material (except from group 3 where 6/0 polyamide was used for suturing the graft) (Figure 3).

Postoperative instructions for appropriate diet and strict oral hygiene were given and antibiotics (amoxicillin with clavulanic acid), analgesics, and 0.12% chlorhexidine mouthwash were prescribed. Suture removal was after 7-10 days for groups 3 and 4, and after 14 days for groups 1 and 2. The d-PTFE barriers were removed after 28 days.

Statistical Analysis

The statistical analysis in this research was performed using IBM SPSS v.25.0, Jamovi Statistical Software, and MS Office Excel 2016. Measures of descriptive statistics were used for the presentation of the results. Parametric (the t-test, the Pearson correlation) and non-parametric tests (the Mann-Whitney U test, the Kruskal-Wallis test, the Pearson's chi-squared test, the Spearman correlation, Wilcoxon signed rank test, Fisher's exact test). The level of significance of the null hypothesis is $P=0.05$.

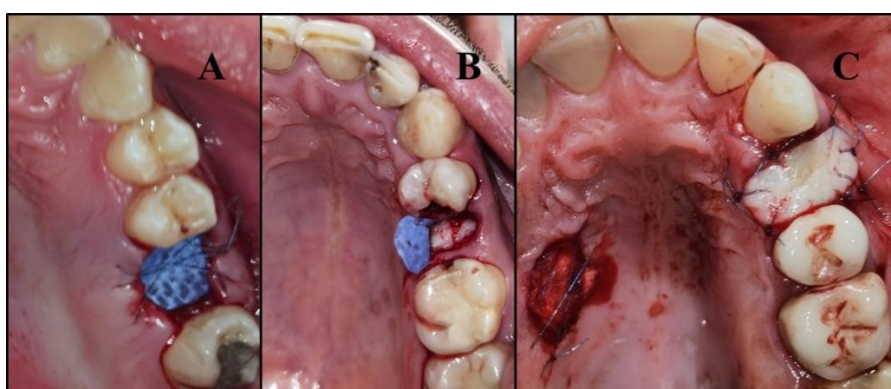


Figure 3. The ridge preservation methods presented in the study. (A) Using a d-PTFE barrier (Group 1); (B) using a d-PTFE barrier and PRP (Group 2); (C) with an FGG (Group 3)

RESULTS

The comparison of the vertical resorption of the buccal walls among the RP groups

demonstrated a significant difference (Table 1, Figure 4).

The difference in the buccal resorption between Group 1 and Group 2 was statistically insignificant (Mann-Whitney U test =

281.000, $p=0.417$). In contrast, it was statistically significant between Group 1 and Group 3 ($t=-2.49$, $p=0.018$) and between Group 2 and Group 3 (Mann-Whitney U test = 413.500, $p=0.007$).

There was a significant difference in the

vertical buccal resorption between the groups with RP (Groups 1, 2, and 3) and the control (Group 4) (Mann-Whitney = 235.500, $p<0.0001$) (Table 2, Figure 5).

Table 1. Comparison of vertical buccal wall resorption among the ridge preservation groups

BWH-BWH2 ^{a)} , mm	N	Mean±SD	Median (IQR)	Kruskal-Wallis test	P-value
Group 1	24	1.05 ± 0.62	1.03 (0.69)	8.933	0.011
Group 2	27	1.18 ± 1.28	0.82 (0.87)		
Group 3	21	1.65 ± 0.92	1.60 (0.85)		

^{a)}BWH-BWH2 – vertical buccal wall resorption.

Table 2. Vertical resorption of the buccal wall in the ridge preservation and control groups

BWH-BWH2 ^{a)} , mm	N	Mean±SD	Median (IQR)	Range (Min-Max)	Mann-Whitney U test	P-value
Groups 1, 2, 3 (RP)	72	1.27±1.01	1.05 (0.90)	5.19 (0.08-5.27)	235.500	<0.0001
Group 4 (control)	24	3.47±1.96	3.30 (2.40)	7.85 (0.55-8.40)		

^{a)}BWH-BWH2 – vertical buccal wall resorption.

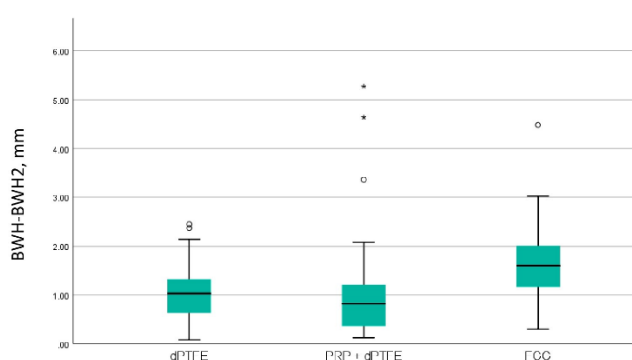


Figure 4. Buccal wall resorption in the RP groups. dPTFE: dense polytetrafluoroethylene membrane (Group 1); PRP+dPTFE: platelet-rich plasma and dense polytetrafluoroethylene membrane (Group 2); FGG: free gingival graft (Group 3).

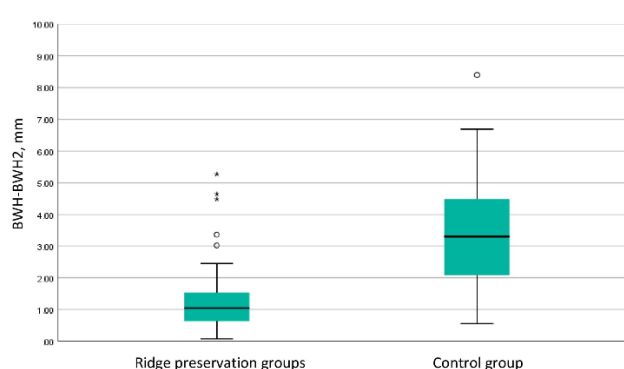


Figure 5. Boxplots presenting the vertical resorption of the buccal wall in the ridge preservation and control groups. BWH-BWH2: vertical buccal wall resorption.

Data analysis demonstrated a statistically significant (χ^2 , $p<0.0001$) and strong (Cramer's

V = 0.53, $p < 0.0001$) correlation between post-extraction behavior (with or without RP) and vertical loss of the buccal socket wall. The risk of more than 2 mm reduction in the buccal height significantly decreased with RP (OR = 0.073, CI – 0.024-0.221).

The mean vertical buccal loss in the RP

groups for 3 months was 1.27 ± 1.01 mm. If the value above 2 mm was considered a significant vertical loss, the wall widths in 12 out of 13 cases with such a loss were found to be ≤ 2 mm (Table 3).

Table 3. Cases with vertical loss of the buccal wall ≥ 2 mm according to the wall width

Vertical resorption of the buccal wall ≥ 2 mm															Total
Buccal wall width	in the experimental groups														
		2.01	2.05	2.08	2.10	2.14	2.37	2.42	2.45	3.02	3.36	4.48	4.64	5.27	
	.63					1									1
	.80										1	1	1		3
	.82						1								1
	.89									1					1
	1.02							1							1
	1.26								1						1
	1.40			1											1
	1.41													1	1
	1.46	1													1
	1.55		1												1
	3.25				1										1
Total		1	1	1	1	1	1	1	1	1	1	1	1	1	13

The comparison in the vertical buccal resorption in cases with buccal wall width ≤ 2 mm on one side and > 2 mm on the other side

between the ridge preservation and control groups demonstrated statistically significant differences (Tables 4, 5).

Table 4. Comparison in the vertical buccal resorption in cases with buccal wall width ≤ 2 mm between the ridge preservation and control groups

BWH-BWH2 ^a , mm (when BWW ^b ≤ 2 mm)	N	Mean $\pm$ SD	Median (IQR)	Range (Min-Max)	Mann-Whitney U test	P-value
Group 1 (d-PTFE ^c)	5	1.79 ± 0.78	2.14 (1.02)	1.81 (0.64 – 2.45)	65.500	0.032
Group 4 (control)	16	3.84 ± 2.09	3.46 (3.09)	7.22 (1.18 – 8.40)		
Group 2 (d-PTFE ^c + ^d PRP)	13	1.75 ± 1.66	1.23 (1.49)	5.15 (0.12 – 5.27)	172.000	0.002
Group 4 (control)	16	3.84 ± 2.09	3.46 (3.09)	7.22 (1.18 – 8.40)		
Group 3 (FGG ^e)	11	2.10 ± 0.98	1.97 (0.82)	3.72 (0.76 – 4.48)	137.500	0.013
Group 4 (control)	16	3.84 ± 2.09	3.46 (3.09)	7.22 (1.18 – 8.40)		

^aBWH-BWH2 – vertical buccal wall resorption, ^bBWW – buccal wall width; ^cd-PTFE – dense polytetrafluoroethylene, ^dPRP – platelet-rich plasma, ^eFGG – free gingival graft.

Table 5. Comparison in the vertical buccal resorption in cases with buccal wall width > 2 mm between the ridge preservation and control groups

BWH-BWH2 ^{a)} , mm (when BWW ^{b)} > 2 mm)	N	Mean ± SD	Mean diff.	95% CI		t	P-value
				Lower	Upper		
Group 1 (d-PTFE ^{c)}) Group 4 (control)	19 8	0.86 ± 0.40 2.73 ± 1.53	-1,87	-3.14	-0.59	- 3.41	0.010
Group 2 (d-PTFE ^{c)} + PRP ^{d)}) Group 4 (control)	14 8	0.65 ± 0.33 2.73 ± 1.53	-2.08	-3.36	-0.80	-3.80	0.006
Group 3 (FGG ^{e)}) Group 4 (control)	10 8	1.15 ± 0.54 2.73 ± 1.53	-1.58	-2.87	-0.28	-2.79	0.023

^{a)}BWH-BWH2 – vertical buccal wall resorption, ^{b)}BWW – buccal wall width; ^{c)}d-PTFE – dense polytetrafluoroethylene, ^{d)}PRP – platelet-rich plasma, ^{e)}FGG – free gingival graft.

Linear regression was performed in the control group to exclude the role of the ridge preservation method. Data analysis demonstrated a medium and statistically insignificant ($r = 0.358$, $p > 0.05$) correlation between the buccal wall width and vertical resorption. Only 12.8% of the variations in the vertical loss in the group can be attributed to the wall width ($r^2 = 0.128$).

Multiple linear regression was used to determine the influence of both factors – post-extraction behavior and buccal wall width.

Data analysis demonstrated that both factors are individual predictors for vertical resorption with a statistical significance ($p < 0.0001$). However, the determining factor is the post-extraction behavior (RP versus unassisted socket healing) ($\beta = -1.88$, 95% CI = -2.47 – 1.29).

No statistically significant difference in the vertical resorption of the oral (palatal and lingual) socket walls among the RP groups was found (Table 6, Figure 6)

Table 6. Comparison of vertical oral wall resorption among the ridge preservation groups

OWH-OWH2 ^{a)} , mm	N	Mean ± SD	Median (IQR)	Kruskal-Wallis test	P-value
Group 1	24	1.08 ± 0.59	1.27 (0.97)	4.971	0.083
Group 2	27	1.88 ± 0.56	0.74 (0.72)		
Group 3	21	1.27 ± 0.57	1.12 (1.00)		

^{a)}OWH-OWH2 – vertical oral wall resorption.

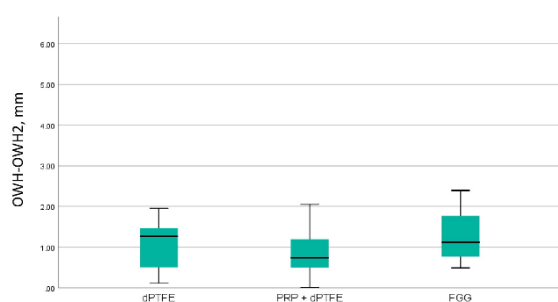


Figure 6. Oral wall resorption in the RP groups. dPTFE: dense polytetrafluoroethylene membrane (Group 1); PRP+dPTFE: platelet-rich plasma and dense polytetrafluoroethylene membrane (Group 2); FGG: free gingival graft

(Group 3).

The difference in the resorption of the oral socket wall between Group 1 and Group 2 (Mann-Whitney = 261.500, $p = 0.238$) and between Group 1 and Group 3 (Mann-Whitney = 297.000, $p = 0.306$) was statistically insignificant. In contrast, it was statistically significant between Group 2 and Group 3 ($t = -2.33$, $p = 0.024$).

There was a significant difference in the vertical resorption of the oral wall between the RP and the control groups (Mann-Whitney = 361.500, $p < 0.0001$) (Table 7, Figure 7).

Table 7. Vertical resorption of the oral wall in the ridge preservation and control groups

OWH-OWH2 ^a , mm	N	Mean±SD	Median (IQR)	Range (Min-Max)	Mann-Whitney U test	P-value
Groups 1, 2, 3 (RP)	72	1.06±0.59	0.99 (0.95)	2.38 (0.01-2.39)	361.500	<0.0001
Group 4 (control)	24	2.08±1.10	1.93 (1.33)	4.52 (0.10-4.62)		

^aOWH-OWH2 – vertical oral wall resorption.

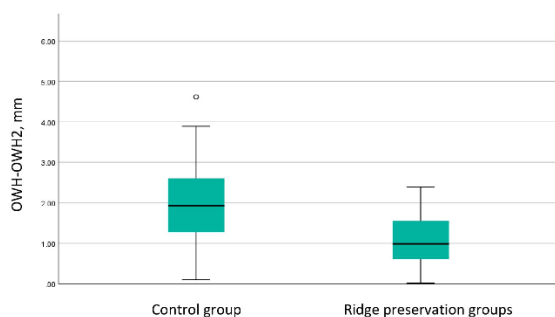


Figure 7. Boxplots present the oral wall's vertical resorption in the ridge preservation and control groups. OWH-OWH2: Vertical oral wall resorption.

Data analysis demonstrated a statistically significant (Fisher's exact test, $p < 0.0001$) and strong (Cramer's $V = 0.51$, $p = 0.000007$) correlation between post-extraction behavior (with or without RP) and vertical loss of the oral socket wall. The risk of losing more than 2 mm of oral height significantly decreased

when RP was applied (OR = 0.051, CI – 0.013-0.210).

A comparison between the groups in this study regarding the vertical oral wall loss at width values ≤ 2 mm and >2 mm was impossible due to the limited number (only three) of walls ≤ 2 mm in the control group.

Linear regression was performed in the control group to exclude the role of the ridge preservation method. Data analysis demonstrated a weak and statistically insignificant ($r = 0.287$, $p > 0.05$) correlation between the oral wall width and vertical resorption. Only 8.2% of the variations in the vertical loss in the group can be attributed to the wall width ($r^2 = 0.082$).

Multiple linear regression was used to determine the influence of both post-extraction behavior and oral wall width. Data analysis demonstrated that both factors are individual predictors for vertical resorption with a

statistical significance ($p < 0.05$). However, the determining factor is the post-extraction behavior (RP versus unassisted socket healing) ($\beta = -1.005$, 95% CI = -1.34- -0.67).

DISCUSSION

Tooth extraction initiates a cascade of processes that lead to horizontal and vertical resorption of the alveolar ridge in the post-extraction site. The extent and severity of resorption varies between individuals and depends on different local and systemic factors. The greatest loss is expected in the first 3 months and the horizontal resorption can reach up to 50% in the first year (23, 24). Ridge preservation is a method for limiting the post-extraction remodeling processes and preserving tissue volume. It involves different techniques and materials. Most studies in the field are aimed at evaluating and comparing the effects of different RP methods.

This randomized controlled trial included 4 study groups – 3 experimental and 1 control. In the experimental groups, 3 different methods for RP were evaluated (with d-PTFE-membranes, d-PTFE membranes in combination with PRP, and FGGs). The sockets in the experimental group were left on spontaneous healing.

When comparing vertical resorption of the buccal wall for 3 months between each RP group and the control one, a significant difference was found – between 1.82 mm and 2.41 mm. It was demonstrated that each RP method in this study gave better results than the control without a significant difference between the methods. The results indicated that the application of PRP did not improve the results obtained with d-PTFE membranes.

The RP methods successfully preserved the vertical dimension of the buccal socket walls. However, it should be noted that the buccal walls in the control group were thinner than those in the experimental groups (16 out of 24

measured sites in the control group had widths of ≤ 2 mm).

Data analysis demonstrated that RP reduced the risk of vertical buccal loss of more than 2 mm. A moderate or significant negative and statistically significant correlation was found between the buccal wall width and vertical resorption in the RP groups. These results correlate with the statement that the amount of resorption depends on the width of the socket walls (25), but diverge from those reported by Cardaropoli et al. (26). They found no correlation between buccal bone thickness and bone resorption in the RP group, while in the control group, a strong negative correlation was registered. The authors conclude that RP compensated for post-extraction resorption regardless of the buccal wall width. It should be noted, however, that they used bovine xenograft and collagen membranes in the RP group.

A moderate, negative, and statistically insignificant correlation was found between the buccal wall width and vertical resorption in the control group. The vertical resorption was significant in both thin and thick walls, but since the mean width in the group was 1.73 ± 1.19 mm (i.e., < 2 mm), the "width" factor is to be further discussed.

The greater bone loss in some cases can be associated with the thinner socket walls composed mainly of alveolar bone proper – a structure that disappears after tooth extraction (24, 25). There is some study heterogeneity regarding the "critical wall width", below which the resorption is much more pronounced. Some studies report 2 mm (27, 28), while others state 1 mm (28, 29). Furthermore, post-extraction behavior might influence this threshold (RP or unassisted socket healing). It has been suggested that using bone grafting materials can compensate for the resorption of the thin socket walls (30, 31).

A significant vertical buccal resorption with a mean value between 1 and 2 mm was found in all RP groups. In 12 out of 13 sites with vertical loss of more than 2 mm, the wall width was less than 2 mm. Data analysis indicated that the vertical loss in the control group was significantly greater than the RP groups for both thin (≤ 2 mm) and thick buccal walls (> 2 mm). Therefore, RP can be regarded as a determining factor for vertical resorption. This statement was confirmed by the regression analysis performed in this study. In addition, it was found that the “wall width” is a weak predictor in sockets with unassisted healing. However, the width can be a valuable prognostic marker for predicting bone resorption before tooth extraction when RP is planned.

These results demonstrated that the RP methods used in this study are effective and can significantly compensate for the influence of the thin bone walls but not completely neutralize it. These findings are in contrast to the statement that RP is unnecessary when socket wall widths are more than 1 mm (29).

When comparing vertical resorption of the oral wall for 3 months between each RP group and the control one, a significant difference, ranging between 0.9 mm and 1.3 mm, was found. It was demonstrated that each RP method in this study gave better results than the control. In addition, the RP methods significantly reduced the risk of vertical bone loss greater than 2 mm. The results also demonstrated that the application of PRP did not improve the results obtained with d-PTFE membranes for both socket walls.

It has been suggested that vertical bone loss is more pronounced in the buccal than the oral wall, which can be attributed to the smaller ratio of alveolar bone proper to supporting bone (32).

The performed regression analysis demonstrated that the post-extraction behavior was the determining factor for the vertical resorption of the oral wall. The importance of the wall width as a factor for the resorption increases when RP is performed.

Limitations

The major limitation of this research is the short follow-up period of 3 months, which is insufficient for the planning of delayed and late implantation. Furthermore, the 2 mm threshold was used instead of using and comparing both possible “critical” values of 1 mm and 2 mm. This was due to the small number of buccal walls with widths of less than 1 mm in all groups.

Future directions

Further long-term randomized clinical trials should evaluate the success of the RP methods used in this study and define the critical plate width associated with more pronounced vertical loss.

CONCLUSIONS

The RP procedures used in this study (with d-PTFE membranes, d-PTFE membranes with PRP, and FGGs) can reduce the risk of vertical post-extraction resorption. They gave similar results, but the first two methods were superior to the third one concerning the vertical dimensions of the socket walls. The results demonstrated that PRP did not improve the results achieved with d-PTFE membranes. It was found that the vertical loss of the buccal wall depended on its width and the socket management with the latter being a more significant determining factor. The three methods can significantly compensate for the vertical loss of the thin socket walls, but not completely neutralize the influence of the wall width.

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