ORIGINAL ARTICLE / ARTICLE ORIGINAL

***Surgery** / Chirurgie*

EFFICACY OF AUTOLOGOUS PLATELET RICH FIBRIN(PRF) IN PROMOTING SOFT TISSUE HEALING AND BONE REGENERATION FOLLOWING EXTRACTION IN THE ANTERIOR MAXILLA: A DIGITAL AND RADIOLOGICAL STUDY

Anthony El Rai[1] | Abdallah Menhall[1] | Joseph Zaarour[1] | Robin Jalkh[1] | Joseph Bassil[1]

Objectives: The main objective of this study was to evaluate the effectiveness of PRF in promoting soft tissue healing and bone regeneration after extraction in the anterior maxillary region. A secondary objective was to correlate soft tissue change with underlying bone structure variation. Finally, the study also aimed to compare soft and hard tissue alteration based on different types of extracted teeth.

Methods: The sample included five adult patients requiring the extraction of at least two symmetrical teeth in the anterior maxilla, totaling fourteen teeth. Participants underwent CBCT scans and digital impressions before extraction. Concerned teeth were then extracted, and extraction sites were randomly assigned either to the experimental group (PRF) or the control group (without PRF). Ten weeks after extraction, follow-up CBCT scans and digital impressions were performed. The evaluation of soft and hard tissue changes was carried out by superimposing and aligning preoperative and postoperative CBCT scans and STL files.

Results: After ten weeks of healing, the study revealed an increase in soft tissue thickness of 38% and 34% at 2 mm and 4 mm, respectively, for the control group. As for the experimental group, soft tissue thickness increased 18% and 22%. Regarding hard tissues, the control group showed a resorption of 33% and 25% at 2 mm and 4 mm respectively, while the experimental group showed a resorption rate of 23% and 22%. The central incisor exhibited the highest hard tissue resorption, followed by the canine, while the first premolar showed the least resorption.

Conclusions: Within the limitations of this study, we observed better dimensional changes in hard tissue and soft tissue healing after extraction in the group where PRF was
Keywords: Tooth Extraction, Platelet-Rich Plasma, Bone Remodeling, Clinical Trial, Wound Healing, Maxilla Imaging, Three-Dimensional Tomography, X-Ray Computed, Soft Tissue Injuries.

Keywords: Tooth Extraction, Platelet-Rich Plasma, Bone Remodeling, Clinical Trial, Wound Healing, Maxilla, Imaging Three-Dimensional Tomography, X-Ray Computed, Soft Tissue Injuries.

Corresponding author:
Anthony El Rai, e-mail: anthony.rahi@net.usj.edu.lb

Conflicts of interest:
The authors declare no conflicts of interest.

1. Department of Oral Surgery, Faculty of Dental Medicine, Saint Joseph University of Beirut, Beirut, Lebanon.

EFFICACITÉ DU CONCENTRÉ DE PLAQUETTES AUTOLOGUES RICHE EN FIBRINE (PRF) DANS LA CICATRISATION DES TISSUS MOUS ET LA RÉGÉNÉRATION OSSEUSE APRÈS EXTRACTION DANS LA RÉGION ANTÉRIEURE DU MAXILLAIRE : UNE ÉTUDE NUMÉRIQUE ET RADIOLOGIQUE

Objectifs: L'objectif principal de cette étude est d'évaluer l'efficacité du PRF dans la promotion de la cicatrisation des tissus mous et de la régénération osseuse après une extraction dans la région antérieure du maxillaire. Le second objectif est de corréler les changements des tissus mous avec les modifications des structures osseuses sous-jacentes. Enfin, l'étude vise à comparer les altérations des tissus mous et durs en fonction des différents types de dents extraites.

Méthodes: L'échantillon comprenait cinq patients adultes nécessitant l'extraction d'au moins deux dents symétriques dans le maxillaire antérieur, totalisant quatorze dents. Des CBCT et des empreintes numériques ont été réalisés pour tous les participants avant l'extraction. Les dents ont ensuite été extraites, et les sites assignés aléatoirement aux groupes expérimental (PRF) ou témoin (sans PRF). Après extraction, des CBCT et des empreintes numériques de suivi ont été effectués après dix semaines. L'évaluation des changements des tissus mous et durs a été réalisée par superposition et alignement des CBCT préopératoires et postopératoires et des STLS.

Résultats: Après dix semaines de cicatrisation, l'étude a révélé une augmentation de l'épaisseur des tissus mous de 38 % et 34 % à 2 mm et 4 mm respectivement pour le groupe témoin. En revanche, le groupe expérimental a montré une augmentation de l'épaisseur des tissus mous de 18 % et 22 %. Concernant les tissus durs, le groupe témoin a présenté une résorption de 33 % et 25 % à 2 mm et 4 mm, tandis que le groupe expérimental a montré des taux de résorption inférieurs de 23 % et 22 %. Par ailleurs, l'incisive centrale a montré la plus grande résorption des tissus durs, suivie de la canine, tandis que la première prémolaire a montré la plus faible résorption.

Conclusion: Dans les limites de cette étude, nous avons observé un meilleur résultat dans le changement dimensionnel des tissus durs et la cicatrisation des tissus mous après l'extraction dans le groupe où le PRF a été appliqué.

Mots-clés: Extraction dentaire, Plasma riche en plaquettes, Remodelage osseux, Essai clinique, Cicatrisation des plaies, Imagerie tridimensionnelle, Maxillaire, Tomographie tridimensionnelle, Tomodensitométrie, Lésions des tissus mous.

Introduction

In recent years, regenerative medicine has witnessed significant advancements, particularly within dental and maxillofacial applications. This multidisciplinary field focuses on leveraging the body's intrinsic healing mechanisms to repair, replace, or regenerate damaged tissues and organs. The challenges posed by tooth extraction in the anterior maxilla where both aesthetic outcomes and functional restoration are critical have highlighted the need for innovative solutions to optimize soft tissue healing and bone regeneration [1].

Among the regenerative techniques introduced, Platelet-Rich Fibrin (PRF) has emerged as a promising autologous material. Rich in platelets and growth factors, PRF stimulates wound healing, enhances soft tissue repair, and promotes bone regeneration [2]. Its application in dental and oral surgery has shown potential to accelerate healing and improve the quality of regenerated tissues, especially in extraction sockets where future implant placement is planned [3].

Soft tissue healing is pivotal for achieving optimal aesthetic outcomes and functional restoration after tooth extraction. PRF has demonstrated promising results in promoting soft tissue healing [4,5], making it an appealing choice for enhancing wound healing in the anterior maxilla, where aesthetics is crucial.

Bone regeneration is another critical aspect addressed in this study. Extraction sites in the anterior maxilla often experience bone resorption, which can compromise support for future dental implants or prosthetic restorations [6]. PRF has shown the ability to stimulate osteoblastic activity and enhance bone formation, potentially aiding bone regeneration [3,7].

Beyond biological materials, digital technology has increasingly transformed modern surgical protocols in dentistry. Digital tools such as Cone-Beam Computed Tomography (CBCT) and intraoral scanners allow clinicians to precisely assess and quantify both hard and soft tissue healing, offering reproducible and highly accurate diagnostic data for monitoring post-surgical outcomes. Their application enables three-dimensional evaluation, early detection of healing discrepancies, and improved planning for implant placement or additional regenerative procedures [8,9]. Digital workflows have also enhanced long-term follow-up and communication between clinicians and patients by providing visual and volumetric comparisons over time [10, 11].

The present study aims to investigate the effectiveness of PRF in enhancing soft tissue healing and bone regeneration after tooth extraction in the anterior maxilla using a digital evaluation approach. Specifically, this research seeks to determine whether the application of PRF leads to measurable improvements in healing outcomes, as assessed by CBCT and intraoral scan data, compared to extraction sites left to heal without PRF.

The main objective is to quantitatively evaluate PRF's impact on soft and hard tissue healing. Secondary objectives include comparing the healing rates of extraction sockets with and without PRF application and analyzing differences among various anterior teeth (central incisors, lateral incisors, canines, and first premolars). The null hypothesis states that there will be no significant difference in soft tissue healing and bone regeneration between PRF-treated and non-treated extraction sites.

Materials and Methods

This prospective clinical trial was approved by the Ethics Committee of Saint Joseph University (approval number: Tfemd/2024/51). All participants were thoroughly informed about the study objectives and signed a written consent form before enrollment.

Study Sample

The study was conducted on a group of adult patients who required the simple extraction of at least two symmetrical teeth in the maxilla. Initially, five subjects were included; however, three teeth were excluded from the final analysis due to buccal bone fractures that occurred during extraction. The final sample consisted of 14 teeth, distributed as follows: 4 central incisors, 5 lateral incisors, 2 canines, and 3 first premolars. All patients were referred to the Oral Surgery Department at Saint-Joseph University for extractions limited to the maxillary region between the first premolars.

Inclusion Criteria:

Adults aged 18 to 80 years, regardless of gender.

Ability to read, understand, and sign informed consent in Arabic.

Availability for routine follow-up visits throughout the study period.

Systemically healthy individuals, as determined by medical history and clinical examination.

Exclusion Criteria:

Presence of systemic diseases or medical conditions known to impair wound healing or bone regeneration, such as uncontrolled diabetes mellitus, immunosuppressive disorders, osteoporosis, or ongoing chemotherapy/radiotherapy.

Inability to comply with study requirements or follow-up appointments.

History of significant trauma or fractures in the maxilla.

Previous bone augmentation procedures in the anterior maxilla.

Pregnancy or breastfeeding, due to hormonal influences on healing.

Severe periodontal disease or active oral infection.

History of heavy smoking (>20 cigarettes/day for at least 5 years).

History of bisphosphonate use.

Known coagulation disorders or use of anticoagulant medications.

Procedures:

1. Pre-operative Phase:

Each subject underwent a comprehensive dental examination and medical history review.

Prior to extraction, a CBCT scan was performed along with a digital impression captured using the 3Shape Trios 3 intraoral scanner, focusing on the anterior maxillary region.

Blood samples for PRF preparation were collected at the Department of Laboratory Technicians and Analysts at Saint-Joseph University.

2. Surgical Phase:

Patients rinsed with 0.12% chlorhexidine before surgery.

Local anesthesia was administered using 4% articaine with 1:100,000 epinephrine.

Teeth were extracted using a flapless, minimally traumatic technique involving controlled luxation and slow movements to protect surrounding bone and soft tissue. The study targeted anterior maxillary teeth, from the first premolar to its contralateral counterpart.

Following tooth extraction, each socket was randomly assigned to either the experimental group (receiving PRF application) or the control group (no PRF application)

In the experimental group, PRF was prepared from venous blood using the A-PRF 12 centrifuge (Figure1) following standard protocol

Figure 1. A-PRF Centrifuge machine.

(centrifugation: 8 minutes at 1300 rpm). The PRF was processed using a sterile A-PRF kit and immediately placed into the extraction socket. To stabilize the PRF, a surgical "X" suture was applied (Figure 2).

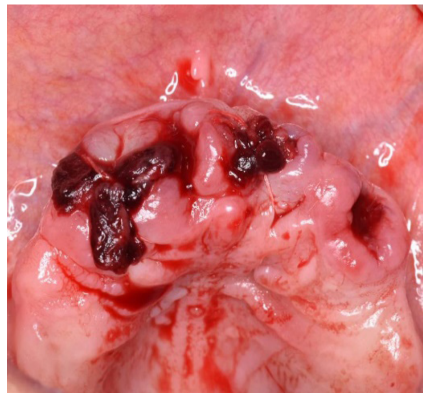

Figure 2. Post extraction picture for one of the subjects.

In the control group, extraction was performed without PRF placement or suturing.

3. Post-operative Phase:

Analgesics were prescribed immediately after extraction, and patients started using chlorhexidine mouthwash 24 hours later.

After 10 weeks, a second CBCT scan and digital impression were recorded for each patient.

The collected datasets were processed using imaging software for segmentation, mesh model creation, and superimposition for comparative analysis.

Comparison of the hard tissue dimensions pre-extraction and ten weeks post-extraction:

CBCT scans were acquired before extraction and 10 weeks post-extraction. Alignment and superimposition were based on three stable anatomical landmarks: the anterior nasal spine, the posterior nasal spine, and the medial pterygoid plate. This alignment was performed using 3D Slicer software.

Bone thickness was measured at two vertical levels: 2 mm and 4 mm from the pre-extraction buccal bone crest. Bone height was recorded from the buccal bone crest to the basal bone border line.

In this study, hard tissue measurements are represented dimensionally (Thickness x height). For clarity, preoperative hard tissue dimensions were denoted as T^2 (W^2 x H) and T^4 (W^4 x H) at 2mm and 4mm from the buccal bone crest, respectively. Similarly, postoperative hard tissue dimensions were labeled as $T^{2'}$ ($W^{2'}$ x H') and $T^{4'}$ ($W^{4'}$ x H') correspondingly (Figure 3).

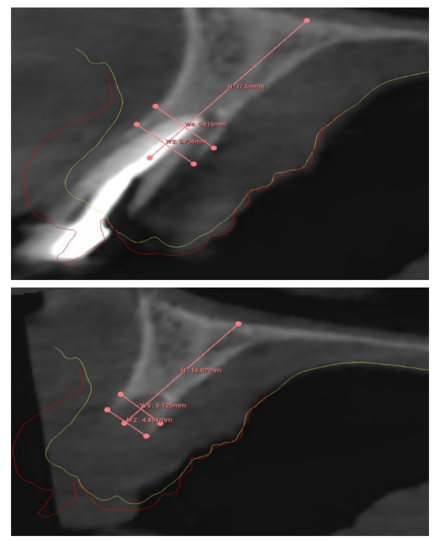

Figure 3. 3D Slicer Software Analysis of Bone Dimension Changes in Pre and Postoperative CBCT Scans.

Comparison of the facial soft tissue thickness pre-extraction and ten weeks post extraction:

Two intraoral scans were taken per patient: one prior to extraction and another at 10 weeks post-extraction. The DICOM datasets were segmented using 3D Slicer and imported into Medit Link for superimposition and alignment. For patients with remaining upper arch teeth, automatic alignment was performed. For edentulous cases, anatomical landmarks on the hard palate were manually identified for alignment. Following this, the aligned DICOM datasets were transferred to 3D Slicer and matched with patient CBCT scan using anatomical landmarks. The resulting output involved the overlay and alignment of pre- and post-operative intra oral scans along with DICOM datasets. (Figure 4). Simultaneously, soft tissue thickness was measured at two specific distances: 2 mm and 4 mm from the pre-extraction buccal bone crest. These values were recorded as S2 (at 2 mm) and S4 (at 4 mm) preoperatively. After 10 weeks, the same measurements were repeated on the post-extraction scans and labeled as S2′ and S4′(Figure 5).

Statistical Analysis

All statistical analyses were conducted using SPSS software while data visualization was performed using Python-based scientific modules, including Plotly and NumPy. The level of statistical significance was set at a 5% margin of error (p-value $\leq$ 0.05).

The analysis aimed to assess dimensional changes in both hard and soft tissues at two measurement levels: 2 mm and 4 mm from the preoperative buccal bone crest, before and 10 weeks after tooth extraction. These measurements were used to determine whether the application of PRF reduced tissue dimensional variations compared to extraction sites without PRF, thereby evaluating the validity of the study's null hypothesis.

The following tests were applied:

The Kolmogorov-Smirnov Test was used to assess the normality of data distribution.

The paired sample t-test was used to compare preoperative and postoperative hard and soft tissue measurements (at 2 mm and 4 mm levels) for both the experimental (PRF) and control groups.

Descriptive statistics were calculated to summarize the data, while inferential statistics were applied to identify significant differences between the groups. Additionally, tissue dimensional changes were analyzed according to tooth type to assess variability in soft and hard tissue healing.

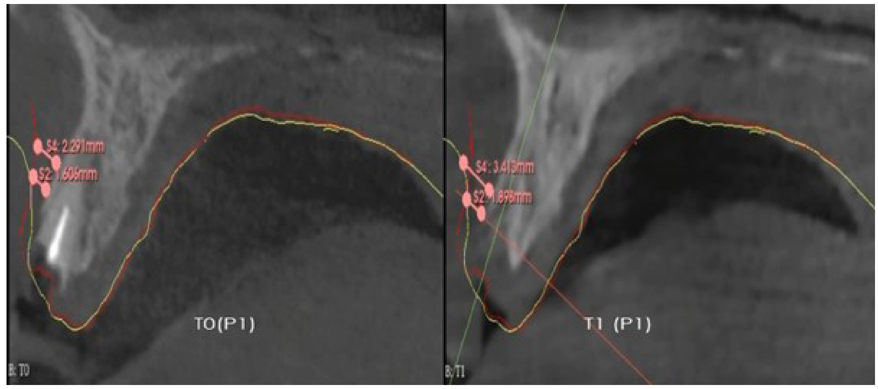

Figure 4. Visualizing 3D Superimposition and Alignment of Two DICOMs on Preoperative Cone Beam CT scan: Soft Tissue Boundary Representation. The red line represents the preoperative soft tissue limits while the yellow line represents the postoperative soft tissue limits.

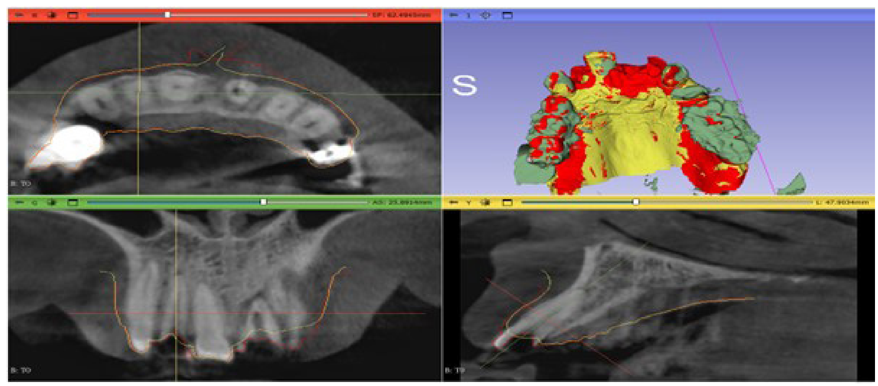

Figure 5. 3D Slicer Software Analysis of Soft Tissue Dimension Changes in Pre and Postoperative CBCT Scans.

Results

Soft Tissue Thickness Alterations:

In the absence of PRF application, the average soft tissue thickness increased following tooth extraction at both measurement levels (2 mm and 4 mm). Similarly, in cases where PRF was applied, an increase in average soft tissue thickness was also observed at both levels.

At the 2 mm level, the increase in soft tissue thickness was greater in the absence of PRF (from 2.06 mm to 2.76 mm, a difference of 0.7 mm) compared to cases where PRF was used (from 2.44 mm to 2.96 mm, a difference of 0.52 mm) (Figure 6).

A similar trend was observed at the 4 mm level: soft tissue thickness increased more in the absence of PRF (from 2.22 mm to 2.91 mm, a difference of 0.69 mm) than in cases with PRF application (from 2.98 mm to 3.52 mm, a difference of 0.54 mm) (Figure 6).

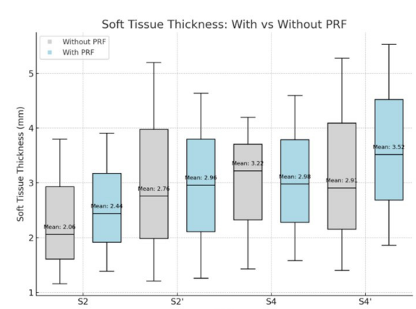

Figure 6. Box Plot for Soft Tissue Thickness pre and post extraction

Hard tissue dimension alterations:

In cases without PRF application, both the height and width of the hard tissue decreased after extraction at both the 2 mm and 4 mm measurement levels. Consequently, the overall hard tissue dimensions were reduced.

Similarly, in cases where PRF was applied, both height and width showed a decrease at both measurement sites post-extraction.

To compare the decrease in measurements between cases with and without PRF, a table presenting the mean differences is provided (Figure 7). It can be noted that hard tissue resorption was higher in cases where PRF was not used in comparison to cases where PRF was applied.

	Without PRF	With PRF
H/H'	1.39	1.31
W2/W2'	2.45	1.59
W4/W4'	1.80	1.51
T2/T2'	54.72	38.88
T4/T4'	44.71	35.78

Figure 7. Table showing Hard Tissue Height, Weight, and Dimensional Mean Difference pre and post extraction in both group.

Soft Tissue Alteration in Correlation with dimensional Hard Tissue changes at 2mm:

The relationship between hard tissue resorption and soft tissue thickness at 2 mm was assessed. Patients were categorized based on whether PRF was applied or not. In the absence of PRF, all cases exhibited a negative variation in hard tissue dimensions, indicating a consistent decrease in bone volume post-extraction. In parallel, soft tissue thickness measurements showed either an increase or little to no change across cases. When PRF was applied, a decrease in hard tissue dimensions was also observed in all cases. However, soft tissue thickness increased in the majority of subjects.

On average, cases without PRF showed a 33% reduction in hard tissue, accompanied by a 38% increase in soft tissue thickness. In contrast, cases treated with PRF displayed a 23% reduction in hard tissue and an 18% increase in soft tissue thickness. These findings suggest a potential compensatory relationship between bone resorption and soft tissue expansion. Notably, the application of PRF was associated with a lower percentage of bone resorption (Figure 8).

Soft Tissue Alteration in Correlation with the dimensional hard tissue changes at 4mm:

The relationship between hard tissue resorption and soft tissue thickness was also assessed at 4mm. In all control cases a decrease in hard tissue volume was observed post-extraction. However, unlike the 2 mm measurements, the majority of cases also demonstrated an increase in soft tissue thickness at this level.

Similarly, in the experimental group, hard tissue volume decreased in all cases, while soft tissue thickness increased in most cases.

For the control group, a 25% decrease in hard tissue volume corresponded to a 34% increase in soft tissue thickness. In the experimental group, a 22% decrease in hard tissue was associated with a proportional 22% increase in soft tissue thickness (Figure 9).

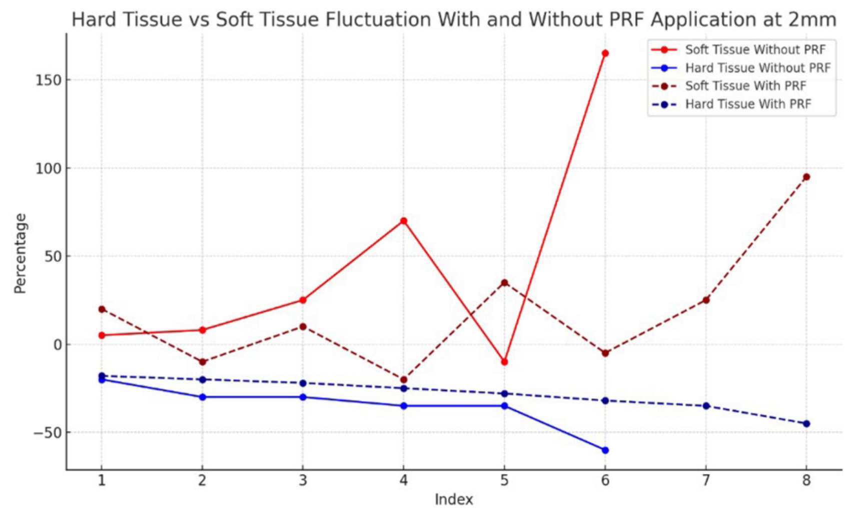

Figure 8. Graph representing the hard tissue fluctuation vs the soft tissue fluctuation with and without PRF application at 2 mm.

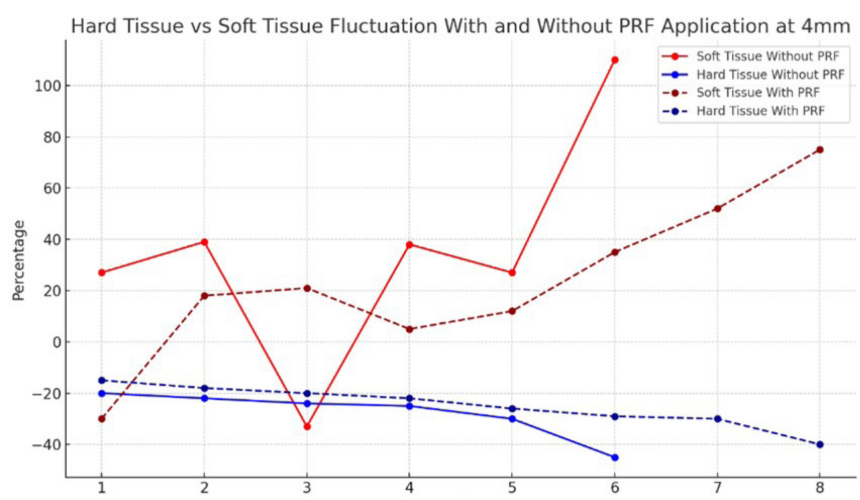

Figure 9. Graph representing the hard tissue fluctuation vs the soft tissue fluctuation with and without PRF application at 4 mm.

These results further highlight a potential inverse relationship between hard tissue resorption and soft tissue expansion. The application of PRF appeared to limit both bone resorption and soft tissue dimensional changes after extraction.

A paired sample t-test was conducted to evaluate whether there was a statistically significant difference between the pre- and post-extraction tissue measurements. The null hypothesis stated that the mean difference between the paired observations would be zero, meaning no statistically significant change in tissue dimensions would occur after extraction, regardless of whether PRF was applied or not.

Soft Tissue Comparison Before and After Extraction:

The null hypothesis was rejected when the p-value was less than 0.05. However, for soft tissue measurements, the p-values were greater than 0.05 in all cases. This indicates that there was insufficient evidence to reject the null hypothesis. Therefore, no statistically significant difference was found between pre- and post-extraction soft tissue measurements, regardless of whether PRF was applied or not.

Hard Tissue Comparison Before and After Extraction:

A paired sample t-test was also performed to compare hard tissue measurements before and after extraction. In contrast to the soft tissue results, the p-values were less than 0.05 across all cases. This indicates sufficient evidence to reject the null hypothesis. As a result, hard tissue measurements showed a statistically significant difference between pre- and post-extraction values.

Soft and Hard Tissue Alterations Between Different Teeth (Central, Lateral, Canine, Premolar):

Hard Tissue:

The mean reduction in hard tissue height was recorded as 1.18 mm for canines, 1.13 mm for central incisors, 1.58 mm for lateral incisors, and 1.34 mm for premolars (Figure 10). The greatest loss in bone height was observed at the lateral incisors (1.58 mm), indicating the most significant post-extraction dimensional change for this tooth type.

For bone thickness measured 2 mm from the facial bone crest, the reductions were 1.66 mm for canines, 3.58 mm for central incisors, 1.38 mm for lateral incisors, and 1.46 mm for premolars. The central incisors showed the highest decrease in thickness (3.58 mm) compared to the other tooth types.

At the 4 mm measurement level, the greatest reduction in bone thickness was observed at canine sites, with a mean value of 2.17 mm (Figure 10).

Soft Tissue:

Mean soft tissue thickness changes at 2 mm were 0.39 mm, 1.8 mm, 0.06 mm and 0.04 mm for canines, central incisors, lateral incisors and premolars respectively (Figure 11).

Similarly, at the 4 mm level, soft tissue alterations were 1.14 mm, 1.38 mm, 0.36 mm, and 0.37 mm for canines, central incisors, lateral incisors and premolars respectively.

At both measurement levels (2 mm and 4 mm), the central incisors showed the greatest increase in soft tissue thickness following tooth extraction (Figure 11).

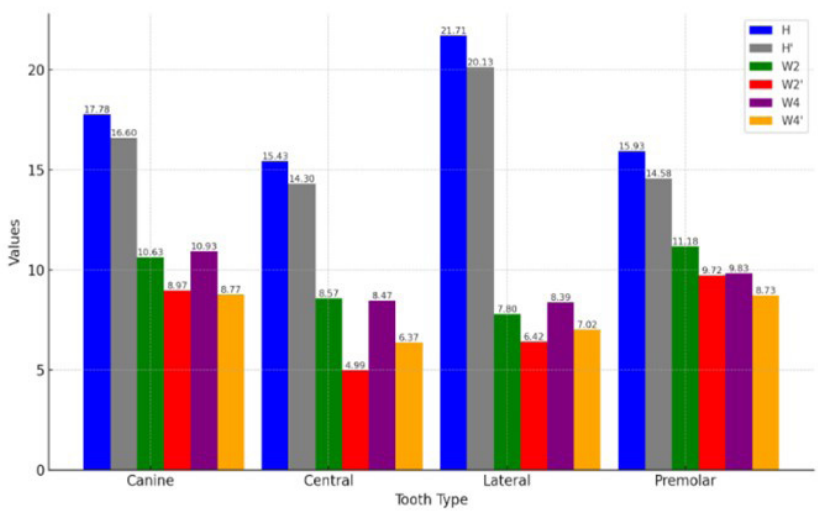

Figure 10. Hard Tissue Alteration Between Different Teeth: Pre- and Post-Extraction

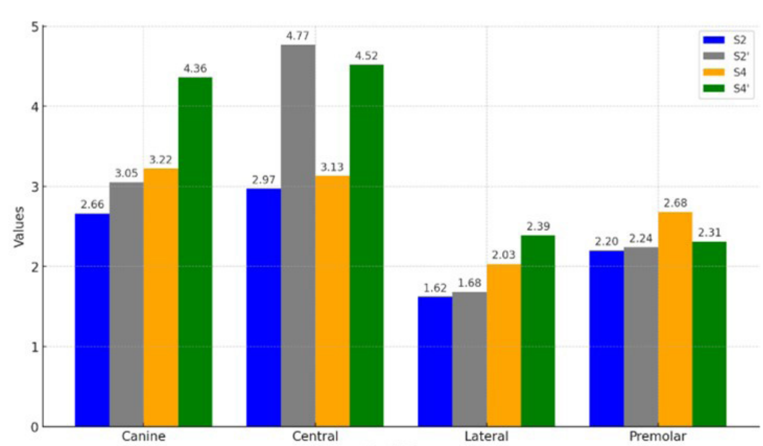

Figure 11. Soft Tissue Alteration Between Different Teeth: Pre- and Post-Extraction

Discussion

The present study aimed to evaluate the efficacy of platelet-rich fibrin (PRF) in promoting soft tissue healing and bone regeneration following extraction in the anterior maxilla.

The present study assessed the diverse changes in both hard tissue dimensions and soft tissue buccal thickness following tooth extraction in the anterior maxilla over a 10-week period, encompassing both experimental and control groups. Each parameter was analyzed separately, leading to the identification of correlations between these parameters through analytical comparisons. Furthermore, these alterations were examined and compared between various tooth types, including central incisors, laterals, canines, and first premolars.

The findings of bone resorption following tooth extraction in this study align with previous preclinical research conducted in this field [12-13]. In fact, regardless of whether the participants were in the experimental or control group, there was a noticeable resorption of hard tissue at both 2- and 4-mm post-extraction. This is consistent with existing literature documenting bone remodeling and resorption following extractions. According to studies, approximately 66% of the hard tissue volume is lost within the first three months post-extraction [14]. The majority of bone loss occurs during the initial six months. After this period, bone resorption continues at a slower, more gradual rate, estimated at about 0.5 to 1% per year [15].

However, the main goal of this study was to examine hard tissue decrease percentage with and without PRF application. For the group without PRF application, mean hard tissue decrease was 33% at 2 mm and 25% at 4 mm. As for the experimental group, it was 23% and 22% respectively. Moreover, in addition to the descriptive statistics, an analytical test for hard tissue showed that measurements taken before and after the extraction procedure showed a statistically significant difference between the two groups. This finding is consistent with previous studies by Dohan et al. [16] and Choukroun et al. [17], where bone resorption was less pronounced in cases where PRF was used, suggesting a potential positive effect on bone remodeling. This is further supported by recent clinical findings demonstrating PRF's osteogenic potential in preserving alveolar ridge dimensions in early healing phases [18].

Preserving peri-implant soft tissue thickness is critical for achieving optimal aesthetic outcomes in dental implant therapy within the aesthetic zone. Soft tissue thickness influences various aspects such as final emergence profile, extent of gingival recession, and implant crown margin visibility, all of which contribute to implant aesthetics [19]. Therefore, maintaining adequate soft tissue thickness is essential [20]. Throughout this research, the control group showed a 38% post-extraction buccal soft tissue thickness increase at 2mm and 34% at 4mm. As for the experimental group where PRF was applied, buccal thickness increase was 18% at 2mm and 22% at 4mm. As for analytical statistics, due to the small sample, we were unable to find significant statistical differences in post-extraction soft tissue alterations following between the two groups. However, new histological data have shown PRF's potential in modulating fibroblast activity and vascularity, contributing to more organized soft tissue maturation and healing [21].

The increase in soft tissue thickness after tooth extraction has been previously explained as a result of the bone resorption process. When the underlying bone undergoes post-extractive resorption post-extraction, the resulting space is gradually filled with soft tissue, potentially as a compensatory response to tissue trauma. This phenomenon has been studied by Miron et al. [22] and Ghanaati et al. [23-24], who suggested that soft tissue expansion occurs in response to the loss of hard tissue. Furthermore, our findings align with this concept, as we observed a greater increase in soft tissue thickness in the control group, where hard tissue resorption was more pronounced, compared to the experimental group. This highlights a complex interplay between soft and hard tissue changes, emphasizing the need for further investigation. While our results appear to follow the same trend as those reported by Miron et al. [25], which demonstrated parallel healing patterns in both hard and soft tissues, emerging evidence continues to support this interrelationship. Notably, a 2022 review by Safi et al. further reinforces the concept that soft tissue remodeling frequently occurs as a compensatory response to volumetric bone loss, particularly within the anterior maxilla [26]. However, further research is needed to better understand the biological mechanisms behind these interactions.

Before examining tissue alterations across different tooth types, it is important to note patient-reported outcomes regarding postoperative discomfort. In this study, 3 out of 5 participants reported reduced discomfort and diminished sensitivity to direct pressure at the site where PRF was applied, compared to the control site. In contrast, the remaining two subjects did not perceive any significant difference between the two sites. These findings are consistent with those of Masuki et al. [27], who demonstrated that PRF contributes to enhanced healing and modulation of the inflammatory response through the sustained release of growth factors. Supporting this, a 2024 meta-analysis also reported improved postoperative comfort and reduced inflammation in PRF-treated sites, attributing these effects to elevated local concentrations of TGF-β and VEGF [28]. These promising outcomes underscore the need for further investigation with a larger sample size to validate and expand upon these preliminary findings.

Regarding the differences in alterations between different types of teeth, it is important to note that this variable was analyzed regardless of PRF application. However, due to the small sample size, we could not identify a single tooth type that consistently exhibited the highest bone resorption across all levels. Nevertheless, a notable finding in this clinical trial was that central incisors exhibited the greatest overall dimensional hard tissue resorption, considering all measurements (height and width at all levels), while canines ranked second with less resorption, followed by lateral incisors, and finally premolars with the least resorption. Interestingly, there is a scarcity of studies directly comparing the variance in bone resorption among anterior teeth, highlighting the need for research with larger sample sizes. Araujo et al. reported a 43% width reduction for central incisors compared to 38% for lateral incisors within two to three months post-single tooth extraction [29]. A more recent review by Udeabor et al. also supported these findings, emphasizing that anatomical differences among tooth types significantly influence the extent of bone resorption [30]. The observed discrepancy in bone resorption following tooth extraction can be attributed to these anatomical differences. Central incisor extraction is particularly susceptible to tissue collapse due to the large size of the extraction socket and the thin surrounding bone, which increases the risk of significant resorption. On the other hand, lateral incisors, being smaller and positioned adjacent to central incisors, tend to have smaller extraction sockets and denser bone, which may contribute to less hard tissue loss. The canines, with their more prominent root structure, result in larger extraction sockets compared to lateral incisors, though smaller than those of central incisors, potentially leading to moderate bone resorption and ranking second in terms of resorption. Lastly, the first premolars exhibited the least bone resorption, which may be due to their root morphology and structural characteristics, as supported by prior studies [31]. The clinical findings regarding the tooth type with the highest soft tissue thickness increase align with the bone loss results, as central incisors, which experienced the most bone loss post-extraction, also showed the greatest increase in soft tissue thickness at both 2 and 4 mm.

Overall, the results of our study contribute to the growing body of evidence supporting the use of PRF in dental extractions. However, further research is warranted to elucidate the underlying mechanisms and optimize treatment protocols for enhanced clinical outcomes. Additionally, comparative studies with larger sample sizes and longer follow-up periods are needed to validate our findings and provide more strong evidence for the efficacy of PRF in promoting soft tissue healing and bone regeneration.

Limitations:

- The main challenge in using PRF in routine dental extractions is the complicated process of obtaining it, which includes technical and psychological difficulties that this study did not address, even though they were experienced firsthand.

- A major constraint of this study is the small sample size, which increases the chance of random errors and limits the generalizability of the findings to a broader population.

- Utilization of superimposition software in dental CBCT scans or STL files comparison and analysis, aimed at assessing changes in dental structures over time or between different patients, has become integral in dentistry. However, there are several limitations that warrant consideration. One key issue is the accuracy of the registration process. Registration entails aligning two sets of data to generate a superimposed image. Inaccuracies in this process can result in errors during data analysis and interpretation. Factors influencing registration accuracy include patient movement, variations in head positioning, and disparities in imaging protocols.

- Another constraint of superimposition software is its ability to exclusively analyze structures visible in CBCT scans or STL files. Consequently, it may overlook changes in soft tissues or alterations occurring in areas not captured by the scan or file. Moreover, the efficacy of superimposition software hinges on the quality of initial CBCT scans or STL files. Poor-quality scans or files containing artifacts can compromise the accuracy and reliability of the superimposition process.

- An additional issue involves the possibility of measurement inaccuracies. Manual measurements are susceptible to human errors, including variations in interpretation, inconsistencies in the placement of measurement points, and differences in the measurement tools employed. These factors can result in imprecise or conflicting measurements, thereby affecting the reliability and accuracy of the analysis.

- Lastly, the impact of sutures on tissue healing could not be controlled. The presence of sutures in one group and their absence in the other may have influenced tissue response, potentially affecting the extent of tissue variation following extraction. Future studies could isolate this factor more effectively by examining the specific role of sutures in post-extraction healing.

Conclusion

Within the limitations of this study, we observed a better outcome in hard tissue dimensional change post-extraction in the experimental, in contrast with the control group. PRF may also help promote soft tissue healing and improve cicatrization; however, further research with larger sample sizes and longer follow-up periods is warranted to confirm whether PRF holds a promising role as a therapeutic autologous solution to enhance the healing process and promote bone regeneration, thus optimizing outcomes for improved clinical practice. Additionally, in this study, we found that changes in both the soft and hard tissues may differ depending on various factors, one of them studied here being the specific tooth type that has been extracted.

References

1. Joshi V, Gupta S. Immediate implant placement in anterior aesthetic region and assessment using cone-beam computed tomography scan technology. Journal of International Oral Health: JIOH. 2015;7(Suppl 2):99.
2. Kobayashi E, Flückiger L, Fujioka-Kobayashi M, Sawada K, Sculean A, Schaller B, Miron RJ. Comparative release of growth factors from PRP, PRF, and advanced-PRF. Clinical oral investigations. 2016 Dec;20(9):2353-60.
3. Blinstein B, Bojarskas S. Efficacy of autologous platelet rich fibrin in bone augmentation and bone regeneration at extraction socket. Stomatologija. 2018 Jan 1;20(4):111-8.
4. Al-Maawi S, Becker K, Schwarz F, Sader R, Ghanaati S. Efficacy of platelet-rich fibrin in promoting the healing of extraction sockets: a systematic review. International journal of implant dentistry. 2021 Dec 19;7(1):117.
5. Ghanaati S, Śmieszek-Wilczewska J, Al-Maawi S, Neff P, Zadeh HH, Sader R, Heselich A, Rutkowski JL. Solid PRF serves as basis for guided open wound healing of the Ridge after tooth extraction by accelerating the wound healing time course—A prospective parallel arm randomized controlled single blind trial. Bioengineering. 2022 Nov 8;9(11):661.
6. Schropp L, Wenzel A, Kostopoulos L, Karring T. Bone healing and soft tissue contour changes following single-tooth extraction: a clinical and radiographic 12-month prospective study. International journal of periodontics & restorative dentistry. 2003 Aug 1;23(4).
7. Temmerman A, Vandessel J, Castro A, Jacobs R, Teughels W, Pinto N, Quirynen M. The use of leucocyte and platelet-rich fibrin in socket management and ridge preservation: a split-mouth, randomized, controlled clinical trial. Journal of clinical periodontology. 2016 Nov;43(11):990-9.
8. Mangano F, Gandolfi A, Luongo G, Logozzo S. Intraoral scanners in dentistry: a review of the current literature. BMC oral health. 2017 Dec 12;17(1):149.
9. Joda T, Zarone F, Ferrari M. The complete digital workflow in fixed prosthodontics: a systematic review. BMC oral health. 2017 Sep 19;17(1):124.
10. Van der Meer WJ, Andriessen FS, Wismeijer D, Ren Y. Application of intra-oral dental scanners in the digital workflow of implantology.
11. Alhammadi MS, Al-Mashraqi AA, Alhammadi E, Halboub E. Accuracy and reliability of digital measurements of periodontal bone defects using CBCT. Imaging Sci Dent. 2019;49(1):19–27.
12. Saumya J K, Anand N . Changes in Alveolar Bone Dimension after Extraction Sockets and Methods of Ridge Preservation. Journal of Research in Medical and Dental Science. 2022; 10(11):191-4.
13. Tan WL, Wong TL, Wong MC, Lang NP. A systematic review of post-extractional alveolar hard and soft tissue dimensional changes in humans. Clinical oral implants research. 2012 Feb;23:1-21.
14. Van der Weijden F, Dell'Acqua F, Slot DE. Alveolar bone dimensional changes of post-extraction sockets in humans: a systematic review. Journal of clinical periodontology. 2009 Dec;36(12):1048-58.
15. Lin HK, Pan YH, Salamanca E, Lin YT, Chang WJ. Prevention of bone resorption by HA/β-TCP+ collagen composite after tooth extraction: a case series. International journal of environmental research and public health. 2019 Dec;16(23):4616.
16. Dohan DM, Choukroun J, Diss A, Dohan SL, Dohan AJ, Mouhyi J, Gogly B. Platelet-rich fibrin (PRF): a second-generation platelet concentrate. Part II: platelet-related biologic features. Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology. 2006 Mar 1;101(3):e45-50.
17. Choukroun J, Diss A, Simonpieri A, Girard MO, Schoeffler C, Dohan SL, Dohan AJ, Mouhyi J, Dohan DM. Platelet-rich fibrin (PRF): a second-generation platelet concentrate. Part IV: clinical effects on tissue healing. Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology. 2006 Mar 1;101(3):e56-60.
18. Alasqah M, Alansary RD, Gufran K. Efficacy of Platelet-Rich Fibrin in Preserving Alveolar Ridge Volume and Reducing Postoperative Pain in Site Preservation of Post-Extracted Sockets. Medicina. 2024 Jun 28;60(7):1067.
19. Sun TC, Chang TK. Soft tissue management around dental implant in esthetic zone–the current concepts and novel techniques. Journal of Dental Sciences. 2024 Mar 28;19(3):1348.
20. Thoma DS, Buranawat B, Hämmerle CH, Held U, Jung RE. Efficacy of soft tissue augmentation around dental implants and in partially edentulous areas: a systematic review. Journal of clinical periodontology. 2014 Apr;41:S77-91.
21. Samiraninezhad N, Rezazadeh H, Rezazadeh H, Mardaninezhad R, Tabesh A, Rezazadeh F. Platelet-rich fibrin in the management of oral mucosal lesions: a scoping review. BMC Oral Health. 2024 Oct 5;24(1):1189.

22. Miron RJ, Zucchelli G, Pikos MA, Salama M, Lee S, Guillemette V, Fujioka-Kobayashi M, Bishara M, Zhang Y, Wang HL, Chandad F. Use of platelet-rich fibrin in regenerative dentistry: a systematic review. Clinical oral investigations. 2017 Jul;21(6):1913-27.

23. Ghanaati S, Herrera-Vizcaino C, Al-Maawi S, Lorenz J, Miron RJ, Nelson K, Schwarz F, Choukroun J, Sader R. Fifteen years of platelet rich fibrin in dentistry and oromaxillofacial surgery: how high is the level of scientific evidence?. Journal of Oral Implantology. 2018 Dec 1;44(6):471-92.

24. Ghanaati S, Booms P, Orlowska A, Kubesch A, Lorenz J, Rutkowski J, Landes C, Sader R, Kirkpatrick CJ, Choukroun J. Advanced platelet-rich fibrin: a new concept for cell-based tissue engineering by means of inflammatory cells. Journal of Oral Implantology. 2014 Dec 1;40(6):679-89.

25. Miron RJ, Fujioka-Kobayashi M, Sculean A, Zhang Y. Optimization of platelet-rich fibrin. Periodontology 2000. 2024 Feb;94(1):79-91.

26. Safi Y, Behnam B, Amid R, Kadkhodazadeh M. Soft and Hard Tissue Changes Subsequent to Spontaneous Healing of the Extraction Sockets Using Cone-Beam Computed Tomography: A Cross-Sectional Study. Journal of Maxillofacial and Oral Surgery. 2022 Dec;21(4):1168-74.

27. Masuki H, Okudera T, Watanebe T, Suzuki M, Nishiyama K, Okudera H, Nakata K, Uematsu K, Su CY, Kawase T. Growth factor and pro-inflammatory cytokine contents in platelet-rich plasma (PRP), plasma rich in growth factors (PRGF), advanced platelet-rich fibrin (A-PRF), and concentrated growth factors (CGF). International journal of implant dentistry. 2016 Aug 22;2(1):19.

28. Yuan Y, Xu B, Yang J, Wu M. RETRACTED: Effects of platelet-rich fibrin on post-extraction wound healing and wound pain: A meta-analysis. International Wound Journal. 2024 Feb;21(2):e14654.

29. Misawa M, Lindhe J, Araújo MG. The alveolar process following single-tooth extraction: a study of maxillary incisor and premolar sites in man. Clinical oral implants research. 2016 Jul;27(7):884-9.

30. Udeabor SE, Heselich A, Al-Maawi S, Alqahtani AF, Sader R, Ghanaati S. Current knowledge on the healing of the extraction socket: a narrative review. Bioengineering. 2023 Sep 29;10(10):1145.

31. Chappuis V, Araújo MG, Buser D. Clinical relevance of dimensional bone and soft tissue alterations post-extraction in esthetic sites. Periodontology 2000. 2017 Feb;73(1):73-83.