Assessment of Soft Tissue Dimensional Changes After Tooth Extraction and Ridge Preservation Using Digital Tools.

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Abstract

Objectives: This randomized controlled trial aimed to answer if there are post-extraction soft tissue dimensional changes among various alveolar ridge preservation (ARP) surgical approaches.

Background: Following tooth extraction, the remodeling process affects horizontal and vertical alveolar ridge dimensions. Some surgical techniques, such as alveolar ridge preservation (ARP), aim to counteract the hard and soft tissue changes and to help preserve the 3D volume. This randomized controlled study analyzed the soft tissue dimensional changes after tooth extraction in patients receiving three different alveolar ridge preservation approaches.

Methods: 26 subjects with a failing tooth with treatment planned for extraction and Implant surgery were randomly assigned to receive allograft plus absorbable collagen wound dressing, allograft plus a Polytetrafluoroethylene (PTFE) membrane, or PTFE membrane alone followed tooth extraction. Digital impressions were obtained before and three months after surgery. STLs were superimposed and analyzed for soft tissue changes in the augmented labial area. Measurements were obtained at the gingival margin level, -3 and -5 millimeters below this point.

Results: Twenty-six patients were included in the study. A total of forty teeth were extracted and received the alveolar ridge preservation technique. Of the output variables, STL.GM-0 was not statistically significantly different by treatment groups 1-3 (p-value = 0.7672, average values of groups 1, 2, and 3 were 2.4, 2.35, and 2.17, respectively), and neither was STL.GM-3 (p-value = 0.4268, average values of groups 1, 2, and 3 were 1.83, 1.62,

and 1.64, respectively) or STL.GM-5 (p-value = 0.2837, average values of groups 1, 2, and 3 were 1. 3, 1.1, and 1.05, respectively).

Conclusions: The study demonstrated no difference among the materials utilized for ARP after tooth extraction. Regardless ARP technique used, vertical and horizontal dimensional changes are observed. Nevertheless, ARP procedures help to reduce volumetric hard and soft tissue shrinkage, thus improving clinical outcomes.

Keywords: Gingival tissue; human; grafting materials; alveolar ridge preservation; RCT; tooth extraction; digital impressions.

Background:

Tooth loss due to caries, periodontal disease, and trauma is still, to this date, a common problem among patients. After losing a tooth, a series of changes occur to the alveolar ridge and surrounding soft tissues [1, 2.] Specifically, it has been reported that there is a vertical bone loss of 11-22% and a horizontal bone loss of approximately 29-63% at six months after tooth extraction [3]. It has been demonstrated that Alveolar Ridge Preservation (ARP) can decrease these dimensional changes [4]. ARP is a procedure in which the post-extraction socket is filled with a biomaterial to help preserve the anatomical contours of the ridge by reducing dimensional changes in this area [5]. The main goal of ARP is to limit the alterations expected on the alveolar ridge after extraction, aid in hard and soft tissue healing, and allow for prosthetically driven implant placement, preventing changes in keratinized gingiva dimensions [6,7.] Regarding soft tissue changes post-extraction, Chappuis et al. (8) found soft tissue thickening in patients with thin phenotypes but not in patients with thick phenotypes. De Angelis et al. (9) also described an association between increased preservation of keratinized tissue in extraction sites with ARP. However, other authors suggest no relation between the soft tissue changes and the resorptive pattern of the alveolar bone post-extraction [10,11.]

Several methods have been used to evaluate dimensional changes in the soft tissues in sites that underwent ARP. Hard and soft tissue changes have been measured by clinical procedures such as bone sounding and digital tools [12,13.] In these techniques, a standard tessellation language (STL) file is used to assess the soft tissue volume before and after a grafting procedure, and a Digital Imaging and Communications in Medicine (DICOM) file is used to evaluate the bony dimensions. These files are merged in computer software, and the dimensional changes of both structures can be assessed. Sanz et al. used superimposition of Micro CT and . Stl files to determine the hard and soft tissue volume on immediate and delayed implant sites[14]. Clementini et al. compared soft and hard tissue volume changes using .stl files obtained from a cast on immediate implant sites where sockets were allowed to heal spontaneously. Chappuis, in 2015, also used superimposition of soft and hard tissue digital files in an 8-week follow-up in post-extraction sites. Song et al. (15) compared the sockets' buccal, palatal, and crestal soft tissue thickness changes either treated with ARP or allowed to heal spontaneously, superposing DICOM files at baseline and six months. They reported that soft tissues were thinner at ARP sites at six months, and the amount of keratinized gingiva (KG) measured by superposing intraoral scans was no different between the groups. In the mentioned studies, the

investigators did not use a measuring jig to verify that the measurement was done at the exact point. Using an intraoral measuring jig will allow for precise measurements in a specific area, reducing errors when interpreting the data of soft tissue changes before and after ARP. This study aims to evaluate soft tissue changes in patients after ARP procedures with three different techniques and evaluate the reproducibility of a novel digital measuring device.

Methods and Materials:

Institutional review board approval was obtained from the Institutional Review Board at Louisiana State University Health Sciences Center. All subjects were patients who needed dental extractions. Inclusion criteria: Patients with a failing tooth with treatment planned for extraction and Implant surgery. Mandibular canines and premolars and maxillary anterior teeth and premolars. Systemically healthy patients. Non-smokers. Adequate oral hygiene (OHI ≥80%). Exclusion criteria: Patients who were deemed medically unfit for surgery. Among those who participated in the study, additional demographic data collected included: medical history, gender, age, and ethnicity.

Surgical Data Collection:

Surgical data were collected and recorded at the initial examination and three months after surgery. In addition, 8 surgeons' findings were included in the study. Surgical data recorded included tooth number, presence/ absence of buccal plate, and pre-and post-surgical complications. The patients will be randomly divided into three study groups to avoid bias (FIG1). The method to be used is stratified randomization. This technique allows us to equally obtain the number of participants in the two experimental groups and the control group considering the influence of covariates previously established (EJ Age, site). Secondly, a simple randomization technique will provide the surgical approach for each group [16.]

Study group	Technique	Number of teeth
Group 1	Allograft + Absorbable collagen wound dressing	9
Group 2	Allograft + PTFE membrane	9
Group 3	PTFE membrane alone	8

FIG 1. Study groups

Image Acquisition:

Each patient will have an intraoral scan (3Shape Trios) made and a Cone Beam Computer Tomography (CBCT) (X-Mind Trium; Acteon). Clinical and digital measurements will be made using computer software (Exoplan; Exocad GmbH) and the data will be recorded.

Image Analysis: Dimensional changes before and three months after surgery

All patients will have an intraoral scan made (3Shape Trios) and a Pre-op (CBCT) taken before the tooth extraction and ARP procedure. A new intraoral scan and CBCT will be made at the three-month post-op visit. These STL files will be merged. The difference between the baseline and the post-op will be obtained by recording the dimensional changes at three points obtained by the different techniques. Differences will be measured at the gingival margin level and at -3 and -5 millimeters from this point. The mean and standard deviation for the measurements in each group will be obtained and compared.

Biomaterials:

In two groups, a cancellous particulate allograft (PUROS; Zimmer Biomet) will be used as the bone grafting biomaterial. Allograft is known to be an osteoconductive biomaterial that acts as a scaffold for bone formation. This material has been shown to be effective for bone preservation. It will allow for implant placement after four months of the grafting procedure and may allow adequate implant stability permitting immediate provisionalization. [17,18.] A biodegradable collagen wound dressing (CollaTape; Zimmer Biomet) will be used as a sealer in one of the groups. This biomaterial is used to stabilize the blood clot in extraction sockets, help to seal grafted sites, and accelerate healing. A PTFE membrane will be used in two of the experimental groups. These are non-absorbable membranes used for different types of grafting procedures. The purpose of a membrane is to prevent epithelial cells from the surgical flap from penetrating the grafted site before the bone has regenerated, ensuring wound stability, and promoting connective tissue ingrowth leading to adequate bone formation.

Treatment protocol

Patients will be anesthetized according to the site to intervene. The tooth will be gently extracted, and by using the periodontal probe, the buccal bone plate will be assessed linearly from the gingival margin to the alveolar crest. Subjects will be excluded if the buccal bone plate is absent (≥30%). Thereafter, participants were randomly assigned to one of the three ridge preservation techniques.

- G1: Allograft + Absorbable collagen wound dressing. The socket will be filled using particulate allograft. Following, an absorbable wound dressing will be placed. A cross suture will be used to keep materials in place.
- G2: Allograft + PTFE membrane. A Flapless surgical approach will be performed with a pouch created to fit the PTFE membrane. A Flap will be raised and recorded when the site requires it due to the presence of bony deficiencies. Once the membrane is partially in place, the socket will be filled with cancellous particulate allograft. The membrane will be stabilized with a cross-suture.
- G3: PTFE membrane alone. The same technique as described above will be used for the alveolar ridge preservation without any socket grafting procedure.

For post-extraction care, the patients were instructed to rinse twice daily with 0.2% chlorhexidine and received painkiller medication and antibiotics. Patients were recalled at 7-10 days for a check-up and suture removal. Patients in groups 2 and 3 will be seen 4 weeks later for membrane removal. All the groups will then be seen 3 months post-op for a second CBCT and intraoral scan to obtain data for comparison to the baseline data obtained.

Statistical Analysis:

Categorical variables were summarized within groups by reporting counts and percentages, while means and standard deviations were reported for continuous variables. Categorical variables were tested for associations with the groups using Fisher exact tests, while Kruskal-Wallace tests were used for continuous variables. Pairwise comparisons between groups were made using Fisher exact tests with categorical variables and Wilcoxon rank-sum tests with continuous variables. The independence assumptions of these tests were ignored.

Results:

Within the duration of this study, 40 teeth were extracted and successfully received ARP surgical techniques, with no complications reported.

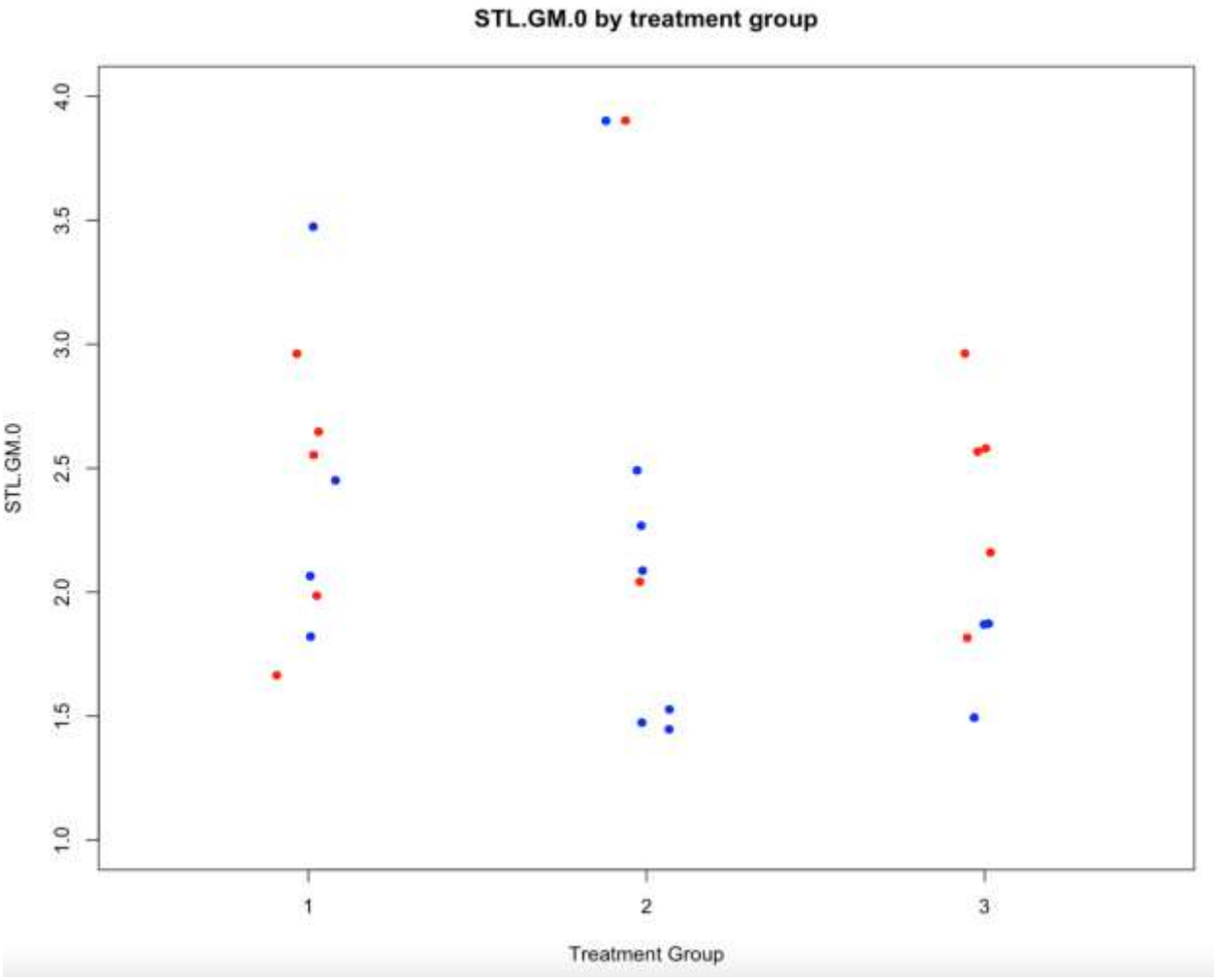
In the data, there were no statistically significant relationships between the treatment groups and the identifying variables, including tooth type (p-value = 0.2354), sex (p-value = 0.8424), or age (p-value = 0.0593). Of the tests conducted, only one was found to be significant, between age and treatment group in a pairwise comparison between treatment groups 1 and 3 (p-value = 0.03, average ages of groups 1 and 3 were 58.78 and 45.125, respectively).

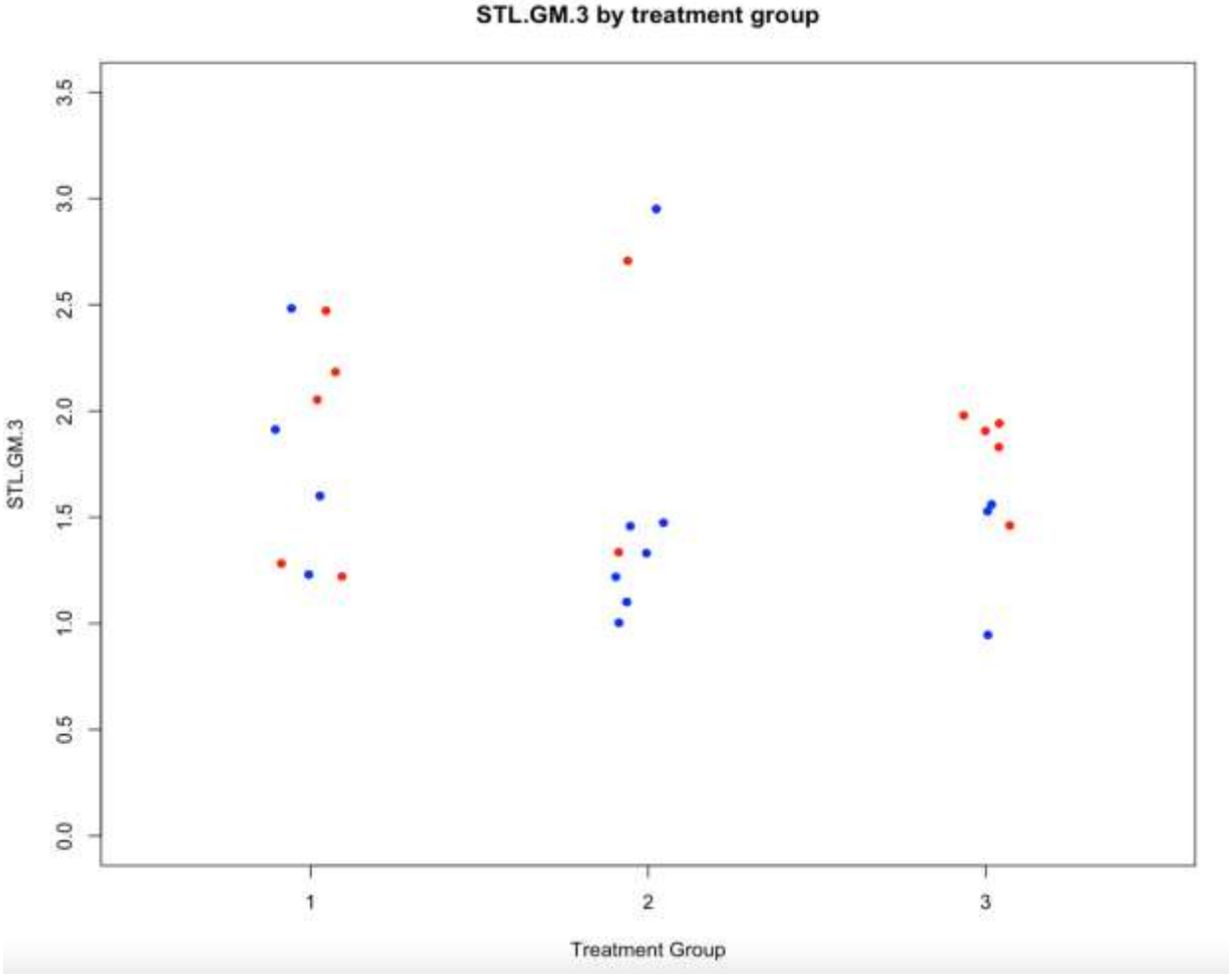
Variable Name	Allograft + Absorbable collagen wound dressing. (Group 1) (9)	Allograft + PTFE membrane (Group 2) (9)	PTFE membrane alone (Group 3) (8)	PVALS	Group 1 vs Group 2, Group 2 vs Group 3, Group 1 vs Group 3
Mandibular	**5 (55.56)**	2 (22.22)	5 (62.5)	0.2354	0.3348, 0.1534, 1
Maxillary	4 (44.44)	7 (77.78)	3 (37.5)		
Male Identity	2 (22.22)	3 (33.33)	1 (12.5)	**0.8424**	1, 0.5765, 1
Female Identity	7 (77.78)	6 (66.66)	7 (87.5)		
Continuous Variables					
Age	58.78 (6.91)	55.2 (11.04)	45.125 (13.84)	0.05925	0.376, 0.112, 0.03
STL.GM-0	2.4 (0.58)	2.35 (0.95)	2.17 (0.49)	0.7672	0.605, 0.963, 0.541
STL.GM-3	1.83 (0.51)	1.62 (0.71)	1.64 (0.35)	0. 4268	0.387, 0.277, 0.423
STL.GM-5	1.3 (0.49)	1.1 (0.44)	1.05 (0.14)	0.2837	0.1615, 0.321, 0.541
Mandibular	N = 4	N = 7	N = 3		
STL.GM-0	2.36(0.526)	2.97(1.315)	2.42(0.44)	0.764	0.6, 0.963, 0.541
STL.GM-3	1.84(0.561)	2.02(0.97)	1.82(0.21)	0.8808	0.387, 0.277, 0.605
STL.GM-5	1.41(0.628)	1.31(0.605)	1.09(0.126)	0.8508	0.161, 0.321, 0.605
Maxillary	N = 5	N = 2	N = 5		
STL.GM-0	2.45(0.729)	2.17(0.87)	1.746(0.218)	0.4708	0.605, 0.963, 0.541
STL.GM-3	1.81(0.53)	1.51(0.66)	1.34(0.346)	0.2956	0.387, 0.277, 0.423
STL.GM-5	1.16 (0.266)	1.04(0.429)	0.985(0.158)	0.3379	0.161, 0.321, 0.541

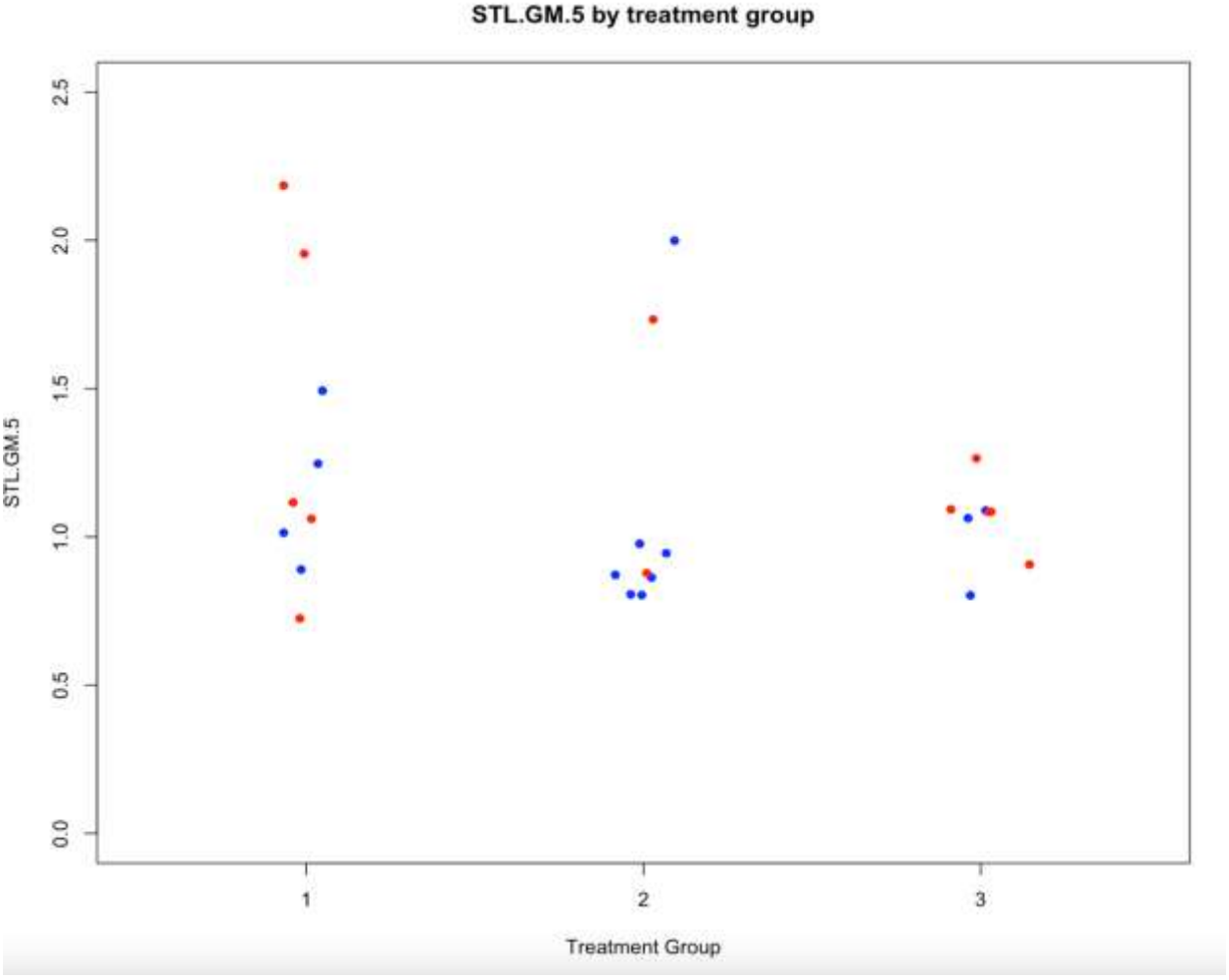
Table 1: *Descriptive characteristics by group. Counts (%) are reported for each categorical variable while means (sd) are reported for continuous variables. When present, missing values are listed in parentheses.*
In terms of age, there was no overall statistical difference between the groups (p=.059). Also there was no difference in terms of the pairwise comparisons between Column 1 vs column 2 (p=.376);Column 2 vs column 3 (p=.112),But there was a statistically significant difference detected between ages in Column 1 vs column 3 (p=.03)

Of the output variables, STL.GM-0 was not statistically significantly different by treatment groups 1-3 (p-value = 0.7672, average values of groups 1, 2, and 3 were 2.4, 2.35, and 2.17, respectively), and neither was STL.GM-3 (p-value = 0.4268, average values of groups 1, 2, and 3 were 1.83, 1.62, and 1.64, respectively) or STL.GM-5 (p-value = 0.2837, average values of groups 1, 2, and 3 were 1. 3, 1.1, and 1.05, respectively)

The data in the scatterplot also indicates that the data from maxillary and mandibular teeth are independent, as the maxillary and mandibular data points are evenly dispersed among themselves.




STL.GM.3 by treatment group
STL.GM.3
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
1
2
3
Treatment Group


STL.GM.5 by treatment group
STL.GM.5
0.0
0.5
1.0
1.5
2.0
2.5
1
2
3
Treatment Group

Discussion:

The study aimed to compare the soft tissue dimensional changes after three different ridge preservation procedures were performed following tooth extraction. After 3 months, group 1 showed the most pronounced reduction of the labial soft tissue contour (mean -3.4 mm) in the maxilla at the gingival margin level. The bone grafting plus membrane group showed the largest dimensional change in the mandible, with a value of 3.9mm at the gingival margin (GM-0).

It was noted that the mandible showed the smallest change in dimension, particularly in the membrane group. The measurement recorded was 0.72mm, which was observed 5mm below the gingival margin.

Nevertheless, in the data, there were no statistically significant relationships detected between the treatment groups and the resulting variables, indicating an independent relationship. Of the tests conducted, only one was found to be significant between age and treatment group in a pairwise comparison between treatment groups 1 and 3.

The study found that regardless of the ridge preservation technique applied, ridge reduction is likely to occur after undergoing tooth extraction. This finding is in accordance with the study published by Fickl et al. (19,20), which showed that alveolar ridge preservation techniques could not prevent alveolar ridge reduction. This dog study assessing volumetrically alterations after alveolar ridge preservation showed a resorption rate between 1.5-2.0mm, and all groups displayed contour shrinkage at the buccal aspect, which was also within the range of the present findings.

A recent systematic review summarized the data of alveolar ridge preservation in terms of efficacy when compared with natural alveolar healing [21]. Also, like some of the techniques we applied in our study, there are various treatment modalities that have been studied to reduce the volumetric changes occurring after tooth extraction [22]. Several publications have suggested that incorporating biomaterials into the socket after tooth extraction could be a suitable technique to compensate for and to maintain the ridge dimension to a certain extent [23,24.]

By overlaying the initial and 4-month STLs data, changes in soft tissues over time can be analyzed. However, this approach may have limitations since obtaining the same region of interest can be challenging.

The soft tissue variations on the labial aspect from baseline to 16 weeks postoperatively varied between 3.902mm and 0.725mm. The mean value observed at GM-0 for all three groups was 2.4mm, 2.35mm, and 2.17mm, respectively. At GM-3, it was found that a mean dimensional change of 1.83mm for group 1, 1.62mm for group 2, and 1.64mm for group 3. In addition, the analysis of GM-5 resulted in comparable mean values of 1.3mm, 1.1mm, and 1.05mm. The P values indicated that no statistically significant differences were found between the groups in all the heights studied.

Our results showed that the EPTFE group had the smallest dimensional changes when compared with the two other surgical approaches. This is in accordance with different studies comparing the use of non-absorbable membranes as a barrier for alveolar ridge preservation. Piero et al (25) found that the d-PTFE membrane proved to be effective in alveolar ridge preservation, although a second surgical intervention is required to retrieve the material.

The reported data may have been affected by certain limitations in the present study, such as the number of recruited patients and the varying levels of training experience among the surgeons involved.

This study included measurements taken from the gingival margin down to a depth of 5 millimeters, which is the relevant area of focus for analyzing differences in soft tissue, as noted by Schneider et al. findings (26).

In order to improve future research, it is recommended to consider using lingual analysis and incorporating soft tissue grafting as a technique for preserving the ridge. Additionally, prior to tooth extraction, it's crucial to establish the initial socket status as recommended in previous literature [27] to eliminate differences in hard tissue and ensure precise comparison of soft tissue changes.

Conclusion:

Within the limitations of the present study, our results found that three surgical approaches to preserve the ridge after tooth extraction resulted in varying changes in soft tissue dimensions, but these differences were not statistically significant. The socket preservation techniques used in the experiment were unable to fully restore the changes that occur after tooth extraction. However, using a non-absorbable membrane (ePTFE) may have the potential to reduce but not eliminate post-operative contour shrinkage.

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