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Comparing the Efficacy of Scalpel, Electrosurgical, and Laser Gingivectomies for the Management of Gingival Enlargement Following Orthodontic Therapy

Mehdi Garashi
Nova Southeastern University

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By

Mehdi Yousuf Garashi, D.D.S.

A Thesis Presented to the Faculty of the College of Dental Medicine of Nova Southeastern University in Partial Fulfillment of the Requirements for the Degree of

MASTER OF SCIENCE

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Approved as to style and content by:

APPROVED BY:_____
Saulius Drukteinis, DMD, MS, PhD (Mentor) Date

APPROVED BY:_____
Maria Hernandez, DDS (Committee Member) Date

APPROVED BY:_____
Shiva Khatami, DDS, PhD (Committee Member) Date

APPROVED BY: _____
Linda C. Niessen, DMD, MPH (Dean) Date

NOVA SOUTHEASTERN UNIVERSITY

Health Professions Division

Department of Periodontology

College of Dental Medicine

STUDENT NAME: Mehdi Yousuf Garashi, D.D.S.

STUDENT E-MAIL ADDRESS: mg2091@mynsu.nova.edu

STUDENT TELEPHONE NUMBER: (954) 614-1699

COURSE DESCRIPTION: Master of Science with specialization in postgraduate Periodontology

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I certify that I am the sole author of this thesis, and that any assistance I received in its preparation has been fully acknowledged and disclosed in the thesis. I have cited any sources from which I used ideas, data, or words, and labeled as quotations any directly quoted phrases or passages, as well as providing proper documentation and citations. This thesis was prepared by me, specifically for the M.S. degree and for this assignment.

STUDENT SIGNATURE: _____

Mehdi Yousuf Garashi, D.D.S. Date

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ABSTRACT

Introduction: Gingival enlargement can occur during orthodontic therapy and often may not subside following removal of the orthodontic appliances. It may lead to esthetic concerns, as well as potential reservoirs for bacteria and hinder oral hygiene efforts. Treatment has included nonsurgical debridement alone or in combination with gingival resection using laser, electrosurgery, or conventional scalpel.

Objectives: To compare the clinical effectiveness of three resective techniques in the management of gingival enlargement following orthodontic therapy with regards to: Gingival margin position (GMP), probing depths (PDs), bleeding scores, plaque index (PI), gingival index (GI) and patient postoperative discomfort.

Materials and Methods: 17 healthy adult patients, who recently completed orthodontic treatment and presented with at least two posterior teeth in each quadrant with 4 mm or greater gingival pocketing were screened. Six qualified for the study. A periodontal evaluation and the GMP were recorded using a customized stent. The patients received initial nonsurgical debridement and were re-evaluated after 4-6 weeks. Two patients dropped during the course of the study (one relocated, and the other no longer had gingival enlargement). The four remaining patients underwent surgical treatment by a Secondary Investigator (experienced periodontist) in a split mouth design. Three quadrants were randomly assigned a surgical treatment (laser, electrosurgery, or scalpel) while the fourth quadrant served as a control, with all quadrants receiving additional nonsurgical debridement during that visit. The Primary Investigator was blind to the surgical treatment and returned after the procedure to measure the GMP. The first follow-up visit was at 1-2

weeks post-surgery during which patients were also asked about postoperative discomfort. Further evaluations were performed at 4-6 and 12-14 weeks post-surgery.

Results: Four patients with a total of 61 posterior teeth (29 premolars and 32 molars) completed the study. Three of the four patients reported more postoperative discomfort in the electrosurgery treated regions, while one patient reported the laser treated region causing the most discomfort. All three surgical groups (laser, electrosurgery, and scalpel) showed significantly more reduction in the GMP compared to the control. All subjects had statistically significant reduction in the overall PDs, bleeding scores and PI by the end of the study, while not in the GI. Furthermore, when comparing the three surgical techniques to each other, no statistically significant differences were found for any of the clinical parameters (PD, bleeding, GMP, PI, and GI), however, the laser group had the most reduction in all the evaluated clinical parameters. Lastly, analysis by tooth type revealed that premolar teeth had significantly more reduction than molar teeth in bleeding score, PI, and GI, but not with respect to GMP and PDs.

Conclusion: Within the limitations of this study, it was shown that all three resective techniques (laser, electrosurgery, and scalpel) were more effective at reducing gingival enlargement than nonsurgical therapy alone. Most patients reported the electrosurgery treated group as having the most postoperative discomfort, followed by the laser treated group. Although there was no statistically significant difference when comparing the three techniques to each other, the laser had the most reduction in all clinical parameters (GMP, PDs, bleeding score, PI, and GI). Further studies with longer follow-up are recommended to strengthen the evidence in support of their effectiveness.

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ABBREVIATIONS

AG	Attached gingiva
ANOVA	Analysis of Variance
B	Buccal
BOP	Bleeding on Probing
CDM	College of Dental Medicine
CEJ	Cemento-enamel Junction
CHX	Chlorhexidine gluconate
DB	Disto-Buccal
DL	Disto-Lingual
FG	Free gingiva
FGM	Free gingival margin
GI	Gingival Index
GMP	Gingival Margin Position
IRB	Institutional Review Board
L	Lingual
M	Mesial
M.G.	Mehdi Garashi, DDS
MB	Mesio-Buccal
mg	Milligram
ML	Mesio-Lingual
MGJ	Mucogingival junction
mm	Millimeter
NSU	Nova Southeastern University
P	Palatal
PDs	Probing depths
PI	Plaque Index
S.D.	Saulius Drukteinis, DDS, MS, PhD
wk	Week

INTRODUCTION

The Gingival Tissues

The gingiva, periodontal ligament, and alveolar bone are the three main supporting tissues that surround the teeth. The gingiva is further divided into attached and unattached gingiva. The unattached gingiva includes the free gingival margin, while the attached gingiva starts from the free gingival groove, which corresponds to the bottom of the sulcus, extending to the mucogingival junction[1] as seen in Figure 1.

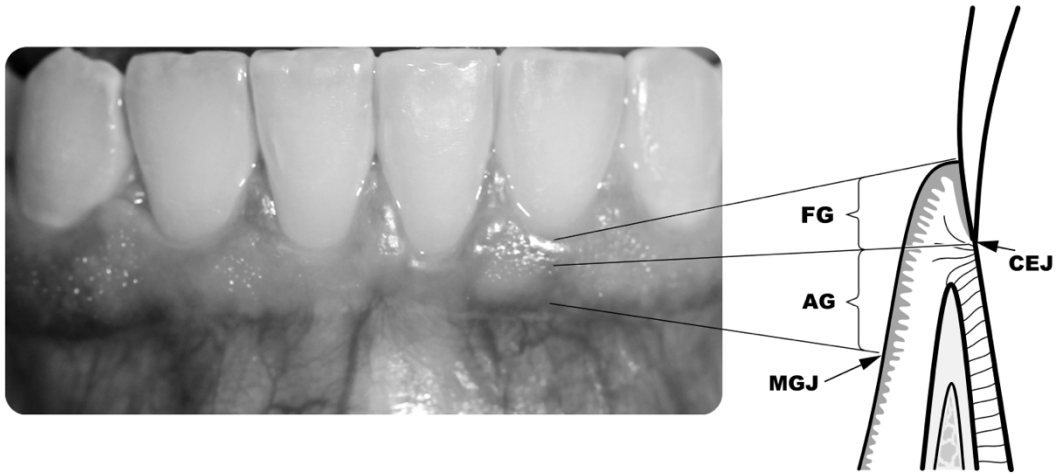

Figure 1. Gingival Tissues of the Mandibular Anterior Teeth. Three parts of gingiva can be identified: 1)Free Gingiva; 2)Interdental Gingiva; 3)Attached Gingiva

The gingiva normally surrounds the teeth and terminates at, or slightly above, the cemento-enamel junction (CEJ); where the crown of the tooth ends and the root begins. This gingival location is reached by two phases of tooth eruption: active and passive eruption. Active eruption has been described as the eruption of a tooth and its alveolus through the gingival tissues[2], and this phase ceases once contact is made with the opposing teeth, unless there is occlusal wear or loss of opposing teeth.[3] Passive eruption begins once active eruption is

complete, which involves the apical migration of the dentogingival unit till it reaches the CEJ.[4] The combination of active and passive eruption results in the final location of the gingival margin in relation to the CEJ, which is normally approximately 1.5-2.0 mm coronal to the CEJ.[1]

Gingival Enlargement

Gingival enlargement may result from chronic or acute inflammatory changes, with chronic changes being more common. The main etiologic factor associated with chronic inflammatory gingival enlargement is prolonged exposure to dental plaque.[5] In addition, other factors that favor plaque accumulation and retention which are associated with gingival enlargement. Those include poor oral hygiene, anatomic abnormalities, faulty restorations, and orthodontic appliances.[6-9]

Gingival enlargement is also a well-known side effect of certain medications; such as certain anticonvulsants, immunosuppressants, and calcium channel blockers.[10, 11] In addition, some other causes of gingival overgrowth include: mouth breathing, neoplasia, scurvy,[12] granulomatous conditions, hormonal changes, and hereditary gingival fibromatosis.[5] In many cases, even after eliminating the cause; the gingival overgrowth often doesn't completely subside[13] and surgical intervention becomes necessary to correct the position of the gingival margin.

There are other conditions associated with the gingival tissues partially or significantly covering the crown of the tooth. Altered Passive eruption is one of those conditions which is due to irregular tooth eruption.[14] This condition was later described as Delayed Passive Eruption,[15] and was further classified by Coslet[16] into four types. In all of these types, the

gingiva failed to recede apically toward the CEJ, and specifically in type 1A the bone is at the normal distance from the CEJ, therefore, the treatment recommended to remove this excess tissue is the gingivectomy procedure.

Orthodontic Treatment and the Gingiva

The introduction of orthodontic appliances to the patient's teeth has been shown to increase plaque retention sites and make plaque control more difficult.[7, 17] In fact, according to a study by Kloehn[18] the percentage of patients who could maintain proper oral hygiene dropped from 20% to 6.5% with the introduction of orthodontic appliances. Zacchrisson[7] reported plaque induced gingivitis within 1 to 2 months after commencing orthodontic treatment in all patients, even the ones with excellent oral hygiene prior to orthodontic treatment. The proximity of these orthodontic attachments to the gingival sulcus, along with their plaque retentive capacity may pose a challenge for effective home care. Consequently, the compromised oral hygiene and periodontal health may further complicate the process of effective orthodontic care.[7, 18-20]

Chronic inflammation associated with the prolonged exposure to dental plaque during orthodontic treatment, has been linked to several unfavorable gingival outcomes, such as gingival recession, attachment loss, and most commonly inflammatory gingival hyperplasia.[21] One study that performed biopsies from the gingival margin before and during orthodontic treatment, reported an increase in inflammatory cells such as lymphocytes in samples taken shortly after initiation of orthodontic treatment. However, histologic analysis of the samples taken later on demonstrated a progression to chronic inflammation in which plasma cells predominated and hyperplasia and proliferation of

pocket epithelium was evident.[7] Previous studies reveal that gingival inflammation and enlargement affects a large percentage of orthodontic patients.[7, 8, 18, 22] Moreover, studies have shown that this gingival enlargement occurs five times more frequently in the posterior teeth compared to the canines and incisors. This hyperplastic tissue has been shown to be four times more prevalent in interproximal areas as opposed to the central region of the teeth.[7, 18]

Some studies have reported increased probing depths during orthodontic treatment. However, these increased probings have been attributed to the presence of pseudopockets and not to attachment loss, and to the increased height of the inflamed gingival margin.[18, 21] Most patients experienced some resolution over time, but not all of the gingival enlargement subsided after removal of the orthodontic appliances.[8, 18] In fact, Kouraki et al[8] reported that 80% of the subjects they examined still had signs of gingival enlargement 3 to 12 months post orthodontic treatment. The authors proposed that fibrotic changes in the gingiva prevent the tissue from returning to its normal physiologic architecture regardless of the improvement in oral hygiene and recommend that surgical intervention should be considered for these cases.

Gingivectomy for the Treatment of Gingival Enlargement

As mentioned previously, orthodontic patients often complete treatment with less than ideal gingival health and esthetics. Gingival enlargement and altered passive eruption are two post-orthodontic treatment findings often resulting in deep pseudopockets, unfavorable tooth proportions, and gingival asymmetry.[18, 23] The gingivectomy procedure has been the treatment of choice by most clinicians to remove this excess tissue and improve the

gingival esthetics. The gingivectomy procedure is defined as" the surgical excision of unsupported gingival tissue to the level where it is attached, creating a new gingival margin apical in position to the old".[24] However, when considering surgical intervention for the patient, the clinician should first confirm the relationship between the alveolar bone and the cementoenamel junction of the associated teeth. In most adults, the distance from the alveolar crest to the CEJ of the teeth is approximately 2 mm.[25] This measurement is first confirmed through bitewing radiographs and then more accurately by bone sounding at the time of the surgical procedure. The surgeon initially identifies the CEJ and then inserts the periodontal probe through the sulcus until bone is reached. If this normal distance is confirmed, excisional surgery in the form of a gingivectomy may be indicated. On the other hand, if the crest of the bone is at or very near the CEJ, or if there is a narrow band of keratinized gingiva, bone removal and/or apically positioned flap may be required.[26]

The gingivectomy traditionally has been performed using a scalpel blade.[27] Two other established tools used for gingivectomy procedures are electrosurgery[28-30] and lasers.[31, 32] These three methods have been successful in eliminating excess tissue. However, some studies have shown differences between these techniques in the postoperative healing of the gingiva, stability of the gingival margin, and postsurgical pain experienced by patients.[28-31, 33-35] The advantages of using a scalpel include ease of use, low cost, and uneventful healing. However, significant bleeding, decreased visibility, patient fear, and tissue rebound are some reported disadvantages mentioned in previous studies.[31, 33-38] On the other hand, electrosurgery which involves the application of a high-frequency electric current to the gingiva has been shown to produce minimal bleeding and reduced postoperative pain, however, there are some conflicting studies regarding the

possibility of delayed healing after its use.[30, 38-41] Last but not least, studies on lasers have demonstrated that they cause less bleeding, pain, and overall postoperative discomfort both during and after surgery.[6, 32, 42-44] A study by Mavrogiannis et al[31] demonstrated that the use of diode laser for gingivectomy yielded superior results in the management of drug induced gingival enlargement when compared to conventional scalpel gingivectomy. In addition, higher patient acceptance is another significant advantage of lasers.[32, 44]

Scalpels, electrosurgery, and lasers are three tools used in gingival surgery. However, to date, there is a lack of studies comparing these three methods side by side to determine which has the most favorable outcomes and highest patient acceptance, particularly in patients presenting gingival enlargement post orthodontic therapy. When comparing outcomes of dental lasers and electrosurgery to scalpel surgery, studies have shown the first two procedures cause less bleeding, pain, and overall postoperative discomfort.[32, 42, 43] Laser equipment utilized in the medical and dental fields are generally expensive. However, continued advancements in technology have made new and more affordable laser equipment available for the dental clinician. The proposed laser device for use in this study is affordable and easy to work with compared to the larger and more complicated laser equipment available.[43] Given the advancements in medical and dental health, patients expect a faster healing process, lower recurrence rates, and minimal discomfort. Therefore, exploring the best treatment approach for the management of this gingival enlargement has great benefit for both clinicians and patients.

Research Objectives

The purpose of this study was to compare three resective techniques (scalpel, electrosurgery, and laser) in the management of gingival enlargement following orthodontic therapy up to three months postoperatively with the following research objectives in mind:

I. To evaluate the difference among the three techniques in the amount of reduction of the Gingival Margin Position (GMP).

II. To evaluate the difference among the three techniques in the resulting postoperative Probing Depths (PDs).

III. To evaluate the difference among the three techniques in the resulting postoperative Bleeding Score.

IV. To evaluate the difference among the three techniques in the resulting postoperative Gingival Index.

V. To evaluate the difference among the three techniques in the reported patient postoperative discomfort.

Research Hypotheses

I. Laser gingivectomy yields significantly more reduction in the GMP when compared to gingivectomies by scalpel and electrosurgery.

II. Laser gingivectomy yields significantly smaller overall postoperative probing depths when compared to gingivectomies by scalpel and electrosurgery.

III. Laser gingivectomy yields significantly smaller overall postoperative bleeding score when compared to gingivectomies by scalpel and electrosurgery.

IV. Laser gingivectomy yields significantly smaller overall postoperative gingival index when compared to gingivectomies by scalpel and electrosurgery.

V. Laser gingivectomy yields significantly less reported patient postoperative discomfort when compared to gingivectomies by scalpel and electrosurgery.

MATERIALS AND METHODS

Regulatory Approvals

This study received approval from the Nova Southeastern University Institutional Review Board in accordance with the Helsinki Declaration of 1975, as revised in 2000. NSU IRB No. 2016-210F. IRB Protocol No. 02041502F.

Sample Collection

The Primary Investigator (M.G.) offered a screening appointment in the Postgraduate Periodontics Department at NSU CDM to healthy adults who met the following criteria: aged at least 18 years, have recently completed orthodontic treatment within 1 year (either at the Postgraduate Orthodontic Department of NSU CDM, Faculty Practice at NSU CDM, or from private orthodontic offices in the surrounding areas), with at least two posterior teeth in each quadrant with 4 mm or greater gingival pocketing (w/o loss of periodontal attachment levels), and haven't had a prophylaxis after termination of orthodontic treatment.

Informed Consents

Consent forms were reviewed and approved by NSU IRB prior to commencing the study. The consent forms were reviewed in detail with each subject and all questions and concerns were addressed. The potential subjects were made aware that the research protocol followed the standard of care routinely used for orthodontic patients following orthodontic therapy; including a periodontal examination, prophylaxis (nonsurgical debridement), re-evaluation, and surgical treatment of any persistent gingival enlargement present. It was

explained to the subjects that the materials and methods used throughout the study are not experimental and are routinely used in practice.

The subjects were made aware that due to the nature of conducting a research project, additional time may be required during each appointment.

Methodology Flow Chart

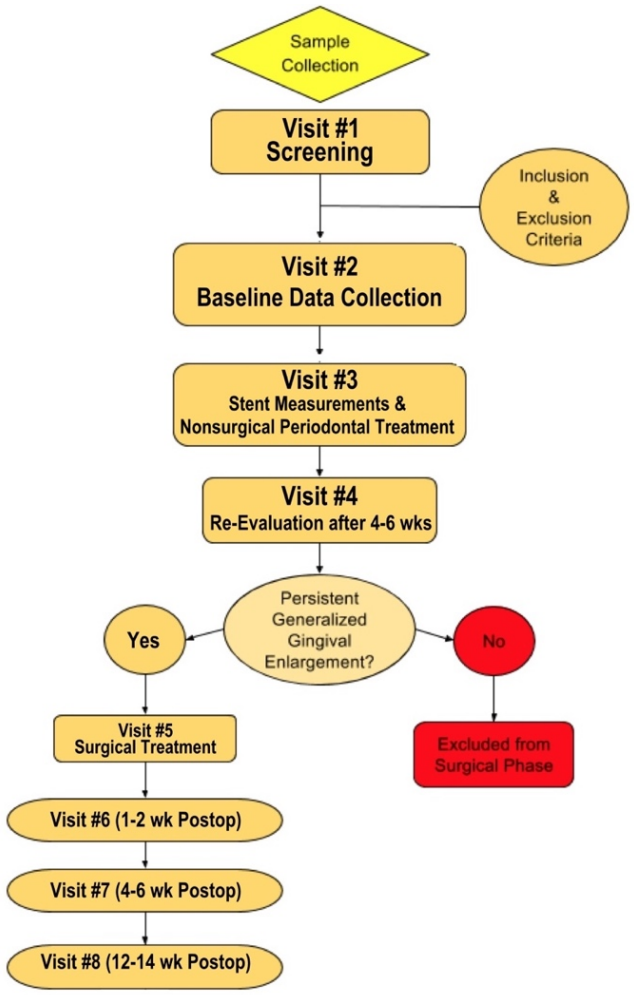

Figure 2. Methodology Flow Chart showing the sequence of visits for the present study.

Synopsis of Study Design

Subjects that were referred were screened to determine eligibility for the study (presence of at least two posterior teeth in each quadrant with 4 mm or greater gingival pocketing). The second visit consisted of baseline data collection which included full mouth periodontal evaluation and radiographic examination which further confirmed subjects were satisfying the inclusion criteria. The third visit included measurements of the Gingival Margin Position (GMP) from a customized stent unique to each subject, followed by a prophylaxis (nonsurgical debridement including supra- and subgingival scaling) for all the teeth. The fourth visit occurred after 4-6 weeks which included a full mouth periodontal re-evaluation that determined which subjects remained eligible to continue the study. The fifth visit included another nonsurgical debridement for all the teeth by the Primary Investigator, followed by surgical treatment of the posterior teeth with the enlarged gingiva by a Secondary Investigator (S.D.) in a split-mouth design; three quadrants were randomly assigned and received surgical treatment (laser, electrosurgery, and scalpel), while the forth quadrant served as control. The Primary Investigator was blind to the surgical treatment performed and returned after the procedure to measure the GMP. The sixth visit was performed within 1-2 weeks postsurgery and the seventh and eighth visit occurred after 4-6 weeks, and 12-14 weeks, respectively. These postoperative visits included periodontal evaluation and measurements of the GMP. Detailed description of each visit will follow.

Subject Screening

The screening visit included a review of the medical history, brief periodontal exam, review of panoramic radiograph provided by the orthodontist, discussion about the study process, and review of the consent form to determine eligibility for participation in the study. An important overview of the study was mentioned to the subjects at this visit. Subjects were informed that after baseline data collection and prophylaxis, another data collection would be performed after 4-6 weeks to determine if the gingival enlargement was still present to be eligible for the surgical phase of the study. They were also informed of the study surgical protocol which involved a split mouth, each quadrant receiving a different treatment; one quadrant scalpel, one quadrant laser, one quadrant electrosurgery, and a control quadrant of nonsurgical therapy. The subjects who completed the study would receive surgical treatment for the control quadrant if indicated and the subject desired to. All questions and concerns were answered and subjects who were eligible and provided informed consent were scheduled for the first appointment (baseline data collection). Incentives for subject participation in the study were explained; such as, treatment was at no charge and that they received $5 gift cards for attending follow-up visits to a maximum of $25 per subject.

Inclusion and Exclusion Criteria

Healthy adult subjects, aged from 18-65 years, who recently completed comprehensive orthodontic treatment (within 1 year and haven't had a prophylaxis yet), and present with at least two posterior teeth in each quadrant with 4 mm or greater gingival pocketing (w/o loss of periodontal attachment levels). The following was the exclusion criteria:

I. Patients with active periodontal disease, periodontal attachment loss and/or evidence of radiographic bone loss (bone > 2 mm from CEJs of associated teeth).

II. Women who are pregnant, nursing, or intend to become pregnant.

III. Patients with a pace maker.

IV. Adults unable to consent for themselves.

V. History of smoking.

VI. History of anti-microbial and anti-inflammatory therapies during previous two months.

VII. History of taking drugs that are commonly associated with Drug Induced Gingival Overgrowth (DIGO) such as Anticonvulsants (Dylantin/Phenytoin), Calcium Channel Blockers (Procardia/Norvsc), and Immunosuppressants (Cyclosporin A).

VIII. History of adverse reaction to local anesthesia.

IX. Diabetic and immunocompromised patients.

X. Patients that completed orthodontic treatment more than 1 year ago.

XI. Patients that already had a prophylaxis after completion and removal of the orthodontic appliances.

XII. Wisdom teeth.

Subject Selection

A total of 17 patients were referred to the Primary Investigator for screening. Eleven of these patients did not satisfy the inclusion criteria as the gingival enlargement was only localized to a few posterior teeth or it was mainly involving the anterior teeth which were not included in this study. Of the remaining six patients, two patients that attended the re-evaluation after nonsurgical therapy were dropped from the study; one patient was eligible for the surgical phase but moved to a different city and another patient no longer had gingival enlargement after the nonsurgical therapy. The remaining four patients completed the study (three females and one male) with a mean age of 23 years. Of this group, three patients were African-American (one male and two females) and one was Hispanic (female). These four patients provided a total of 61 posterior teeth that fit the inclusion criteria that were evaluated during the study.

Study Design

This study was a randomized double-blinded split mouth clinical study. The Primary Investigator performed all the clinical measurements throughout the study including Gingival Probing Depths (PDs), Bleeding on Probing (BOP), Keratinized Gingiva (KG), Plaque Index (PI), and Gingival Index (GI) and Gingival Margin Position (GMP). The Secondary Investigator performed the surgical treatment in a randomized split mouth design without informing the Primary Investigator which quadrant received which treatment. Randomization of the treatment per quadrant was accomplished by having eight pieces of paper, four of them assigning a quadrant (UR, UL, LL, LR), and the remaining four assigning a treatment (scalpel, electrosurgery, laser, and control). Detailed description of each visit will be explained below:

1. **Screening:**

   Performed by the Primary Investigator and included a review of the medical history, brief periodontal exam (a periodontal probe was used to determine if the subject has at least two posterior teeth in each quadrant with 4 mm or greater gingival pocketing), review of panoramic radiograph provided by the orthodontist, discussion about the study process, and review of the consent form to determine eligibility for participation in the study. In addition, all questions and concerns of the subjects regarding the study were answered. Subjects who were eligible and provided informed consent were scheduled for the first appointment (baseline data collection) within four weeks from this visit.

2. **Baseline Data Collection**

   Performed by the Primary Investigator, the following was accomplished:

   i. The following clinical parameters were documented for all the teeth (PD, BOP, KG, PI and GI [Loe[45]]).

   ii. Four vertical bitewing radiographs (Paralleling Technique was used) were obtained of the posterior teeth (premolars and molars).

   iii. Review of the periodontal charting and radiographs to confirm the presence of gingival enlargement and/or altered passive eruption (type 1A) was present in at least two posterior teeth in all four quadrants with no evidence of periodontal attachment loss.

iv. Patients that presented with the proper inclusion criteria and provided consent, were offered to schedule the next visit (Stent Measurements and Prophylaxis).

v. Alginate impressions of maxillary and mandibular teeth were obtained for diagnostic dental casts and stent fabrication (to be used at visit #3).

3. Stent Measurements and Prophylaxis (nonsurgical debridement)

Performed by the Primary Investigator, the following was accomplished:

i. Measurements were taken of the GMP using the patient's customized stent.

ii. Local anesthesia was administered to the teeth which presented with gingival enlargement, followed by nonsurgical debridement for all the teeth using an ultrasonic unit (Dentsply Cavitron Plus) and hand instruments (Periodontal scalers and curettes). Subgingival scaling was emphasized in all areas of enlarged gingiva.

iii. Oral Hygiene Instructions were given (soft toothbrush and waxed dental floss).

4. Re-evaluation 4-6 weeks after prophylaxis

Performed by the Primary Investigator, the following was accomplished:

i. The following clinical parameters were documented for all the teeth (PD, BOP, KG, PI and GI [Loe[45]]).

ii. Measurements were taken of the GMP using the patient's customized stent.

iii. Review of the periodontal charting to confirm gingival enlargement and/or altered passive eruption (type 1A) was still present in at least two posterior teeth in all four quadrants.

iv. Patients that presented with the proper inclusion criteria and provided consent, were scheduled the next visit (Surgical Treatment).

5. Surgical Treatment of the teeth with gingival enlargement

Performed by the Primary Investigator, the following was accomplished:

i. The PI administered local anesthesia to the teeth which presented with gingival enlargement and then nonsurgical debridement was performed for all the teeth using an ultrasonic unit (Dentsply Cavitron Plus) and hand instruments (Periodontal scalers and curettes). Subgingival scaling was emphasized in all areas of enlarged gingiva.

ii. The Secondary Investigator performed the randomization process as described previously to assign each treatment to a quadrant without informing the PI who left the operatory after nonsurgical therapy was completed.

iii. The Secondary Investigator performed the surgical treatment for the three quadrants (scalpel, electrosurgery, and laser) which will be

discussed in detail in the next section. The 4th quadrant served as the control.

iv. After the surgical treatment was completed, the Primary Investigator returned and took measurements of the GMP.

v. The patient was given post-operative instructions (oral and written) and directed to take OTC analgesics for discomfort as needed. The patient was instructed to avoid oral hygiene practices for 24 hours and then resume normally.

Description of Surgical Treatment

The Secondary Investigator performed the gingivectomy procedures for all teeth with gingival enlargement. The gingival tissues were excised (either with scalpel, electrosurgery, or laser) to reduce the pocket depth to a sulcus depth of 1-2 mm on the buccal/lingual aspects and to a sulcus depth of 2-3 mm on the interproximal aspects, with no area excised to less than a mucogingival dimension of 2 mm (preventing formation of a mucogingival defect). For scalpel gingivectomy procedures, a 15 or 15c or 12 blade was used to excise the tissues using an external bevel incision. For electrosurgery gingivectomy procedures, an electrosurgery unit (Ellman Dento-Surg Radiolase II) was used at Monopolar Cut/Coag setting (Power was set at 5 out of 10) with an incising electrode. For laser gingivectomy procedures, an AMD Picasso Lite Diode Laser was used at the continuous mode setting at 2.0Watts with a disposable laser tip.

6. **First Post-Gingivectomy Evaluation (within 1-2 weeks post-surgery)**

   All patients were contacted by the Primary Investigator exactly at 1 week post-surgery and asked which quadrant had the most discomfort during the first week of healing and it was noted in the patient's chart. The patients also attended the clinic to be seen by the Primary Investigator and the following was accomplished at this visit:

   I. The PI and GI (Loe[45]) were recorded for all teeth.

   II. Measurements were taken of the GMP using the patient's customized stent.

7. **Second Post-Gingivectomy Evaluation (within 4-6 weeks post-surgery)**

   Performed by the Primary Investigator, the following was accomplished:

   I. The following clinical parameters were documented for all the teeth (PD, BOP, KG, PI and GI [Loe[45]]).

   II. Measurements were taken of the GMP using the patient's customized stent.

8. **Third Post-Gingivectomy Evaluation (within 12-14 weeks post-surgery)**

   Performed by the Primary Investigator, the following was accomplished:

   I. The following clinical parameters were documented for all the teeth (PD, BOP, KG, PI and GI [Loe[45]]).

   II. Measurements were taken of the GMP using the patient's customized stent.

Diagnostic Procedures used in the study

1. Periodontal Charting

Included measurements of the following parameters: PDs, BOP, and KG. The measurements were entered in the patient's clinical chart as seen in Figure 3.

I. Probing Depths (PDs)

Measurements were recorded to the nearest millimeter for six regions around each tooth using a standard UNC Probe (MB, B, DB, ML, L, DL).

II. Bleeding on Probing (BOP)

Assessed at the same six sites which were probed as described by Ainamo 1975 (presence or absence of bleeding on gentle probing).[46]

III. Keratinized Gingiva (KG)

Measurements were recorded to the nearest millimeter for one site on the mid-buccal and one site on the mid-lingual of each tooth (except the palatal surfaces of maxillary teeth).

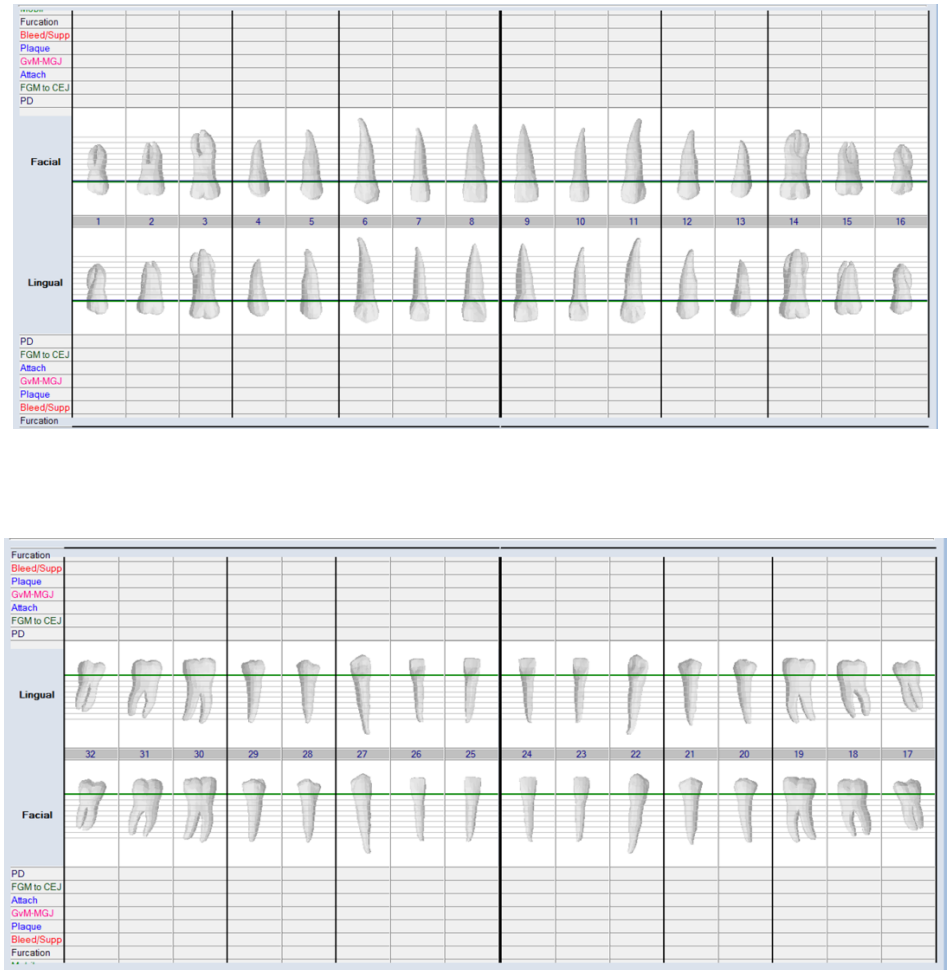

Figure 3. Periodontal Charting System used in the study for collecting measurements and entering them in the patient's electronic chart.

2. Plaque and Gingival Index Criteria

The PI was recorded to assess the subject's oral hygiene and quantity of plaque present, while the GI was recorded to assess the health status of soft tissues based on the criteria described by Loe[45] as seen in Figure 4 and Figure 5. The measurements were recorded starting with the PI followed by the GI for four regions around each tooth (Mesial, Buccal, Distal, Lingua/Palatal as described by Loe 1967.(45)

Score	Criteria
0	No Plaque
1	Tooth appears clean, but plaque made visible by probe in gingival third
2	Moderate accumulation of plaque that is visible to naked eye
3	Heavy accumulation of soft material which fills out the niche produced by gingival margin and tooth surface

Figure 4 .Plaque Index Criteria as described by Loe 1967.[45]

Score	Criteria
0	No inflammation, normal appearance
1	Mild inflammation, slight change in color, mild edema, no bleeding on probing
2	Moderate inflammation, redness, edema, hypertrophy, bleeding on probing
3	Severe inflammation: marked redness, edema, ulceration, hypertrophy, spontaneous bleeding

Figure 5. Gingival Index Criteria as described by Loe 1967.[45]

3. **Fabrication of a customized stent unique to each subject**

Alginate impressions of the maxillary and mandibular arches were obtained for eligible subjects as seen in Figure 6. The impressions were immediately poured with Microstone and the models were cleaned and trimmed as needed.

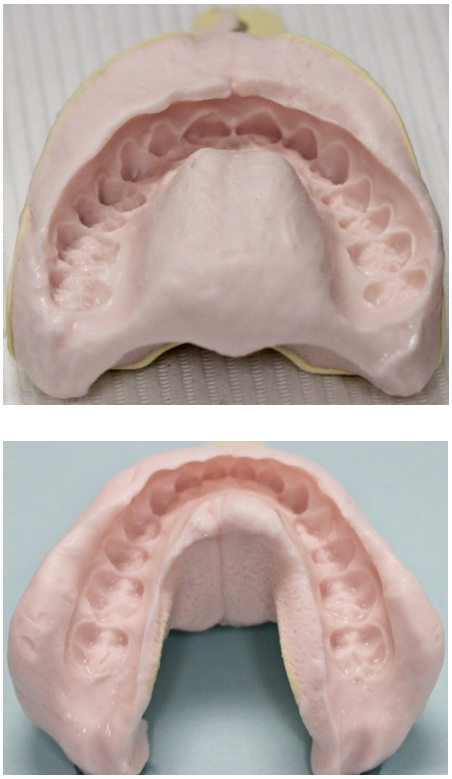

Figure 6. Maxillary and Mandibular Alginate Impressions. These impressions were taken at the Baseline Visit and were poured with Microstone.

A vacuum formed rigid plastic stent was fabricated on the model and trimmed away from the gingival margin, while maintaining enough coverage on the teeth to remain stable during measurements (Figure 7).

Figure 7. A vacuum formed rigid plastic stent was fabricated on the model and trimmed away from the gingival margin. Three marks/grooves were placed for each tooth on buccal and palatal/lingual aspects.

The stent was placed on the teeth and measurement of the GMP were taken using the periodontal probe kept parallel to the long axis of the tooth within the groove on the stent as seen in Figure 8.

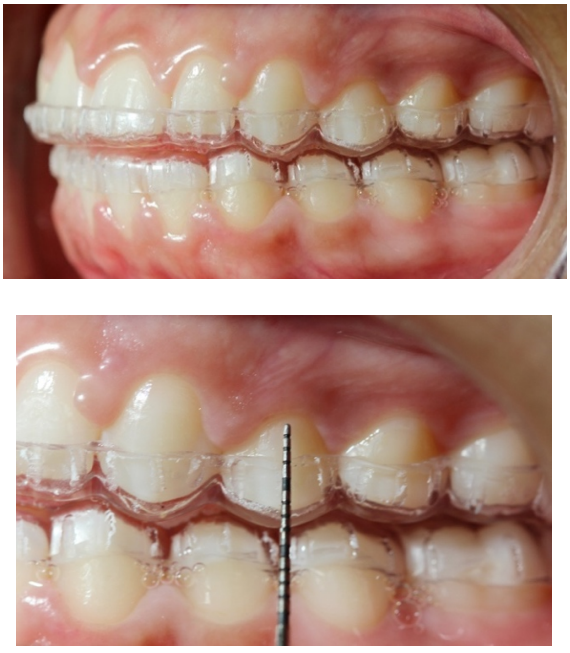

Figure 8. Measurements were taken from the gingival margin to the marks on the stent while keeping probe parallel to long axis of the tooth. This method of measuring was consistent throughout the clinical study.

Products and Materials used in the study

1. Ultrasonic Unit

Provided by the Postgraduate Periodontics Department at NSU CDM. The unit as seen in Figure 9 (Dentsply Cavitron Plus).

Figure 9. Ultrasonic Unit used for nonsurgical periodontal therapy as described previously.

2. Laser Unit

Purchased for the study through a grant provided by NSU Health Professions Division (HPD). The laser unit and protective eyewear can be seen in Figure 10 (AMD Picasso Lite Diode Laser).

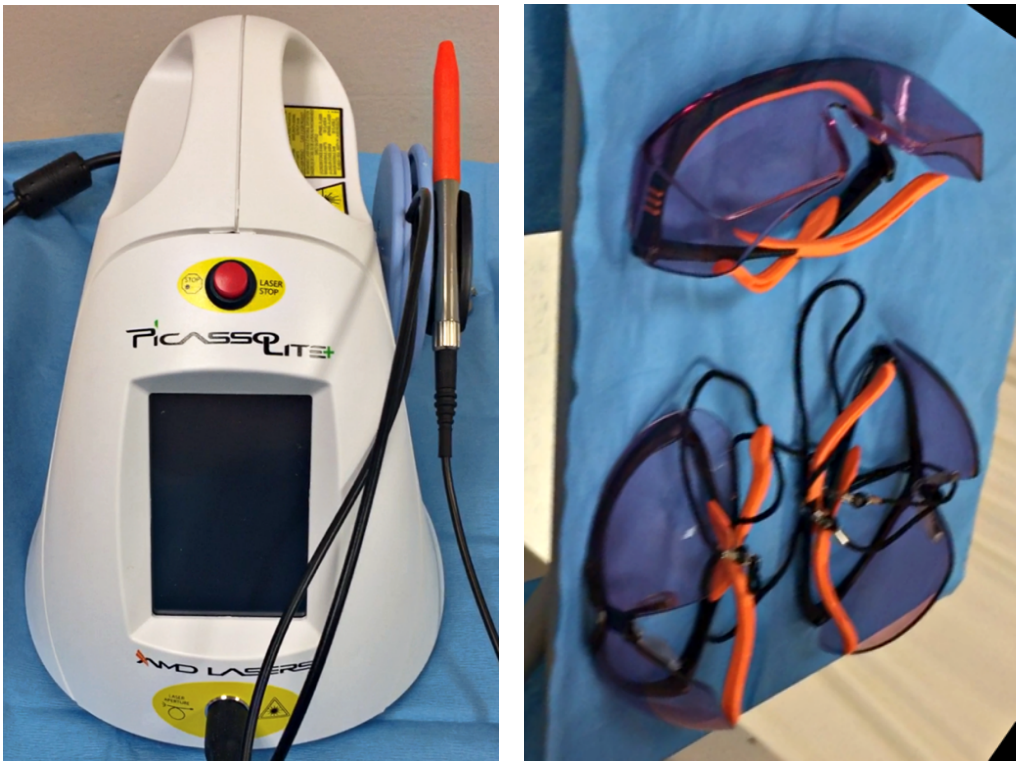

Figure 10. Diode Laser used for gingivectomy procedures as described previously. Three pairs of protective eyewear; for the surgeon, assistant, and patient.

3. Electrosurgery Unit

Provided by the Postgraduate Periodontics Department at NSU CDM. The unit as seen in Figure 11 (Ellman Dento-Surg Radiolase II).

Figure 11. Electrosurgery unit used for gingivectomy procedures as described previously.

Data Interpretation and Statistical Analysis

All data was collected and de-identified and entered into Microsoft Excel spreadsheets which were analyzed by a biostatistician. Five mixed, general linear models using robust-standard errors were created. The fixed effects were Visit (Baseline, 4-6 Weeks After Prophylaxis, Immediately After Surgery, 1-2 Weeks Post-Surgery, 4-6 Weeks Post-Surgery, or 12-14 Weeks Post-Surgery), Treatment Group (Laser, Electrosurgery, Scalpel, or Control), and Tooth Type (Premolar or Molar). The Random Effect was Patient. Post-hoc tests were done using a Bonferroni adjustment.. For all tests used, values of $P < 0.05$ were considered statistically significant.

RESULTS

Four subjects with a total of 61 posterior teeth (29 premolars and 32 molars) completed the study. At exactly 1 week post-surgery, all subjects either presented for follow-up or were contacted and were asked which quadrant had the most discomfort during the 1st week of healing. Three of the four patients reported the electrosurgery quadrant was associated with the most discomfort, while the remaining patient chose the laser quadrant. All subjects reported no complications and overall minimal discomfort associated with the surgical procedures.

Subsequent evaluations were performed at 4-6 and 12-14 weeks post-surgery and the results for each clinical parameter (GMP, PDs, Bleeding Score, PI, and GI) will be discussed below.

Gingival Margin Position (GMP)

For this clinical parameter, as discussed previously (Materials and Methods Section), the distance was measured between the gingival margin and the stent. As such, larger values indicate a more apical GMP. In Figure 12 and Table 1, the data is presented as the mean difference in the GMP from the Baseline. Upon completion of the study period, all subjects showed larger values in the overall GMP compared to Baseline. However, the laser and electrosurgery treated groups had the most reduction in GMP with similar mean values, followed closely by the scalpel treated group, while the control group had the smallest effect on the GMP. The graph also shows minimal change in GMP for all groups for the period from Baseline to After Prophylaxis, followed by a steep increase in the graph only for the surgical groups at the evaluation performed After Surgery. This represent the large

change resulting from the surgery, which then steadily declined up to the final evaluation. On the other hand, the control group exhibited small changes throughout the different time points.

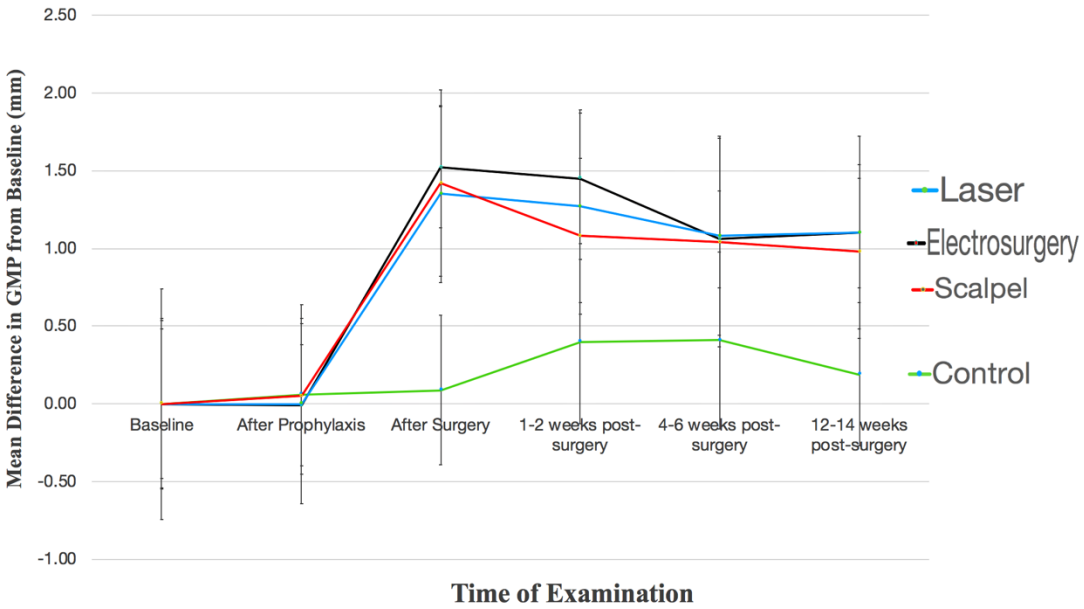

Figure 12. Line graph showing Mean Difference in GMP from Baseline for each group at various time points throughout the study. All three surgical groups reached statistically significant difference compared to the control group in GMP immediately after surgery and at subsequent examinations. (N=15 for Electrosurgery, Laser, and Scalpel groups and N=16 for Control Group. Error Bars represent standard deviation).

Examining the statistical significance values between the four treatment groups as shown in Table 2 (in the appendix), it is observed that all surgical modalities (Laser, Electrosurgery and Scalpel) had significantly more reduction in GMP compared to the Control group at the After Surgery, 4-6 week and 12-14 Week Evaluations. However, upon comparing the three surgical modalities to each other, no statistically significant difference was found among the three techniques (laser, electrosurgery, and scalpel) at any time point.

Probing Depth measurements

By the end of the study period, all subjects showed significant reduction in the overall PDs compared to Baseline. As seen in Figure 13 and Table 3, the laser treated group had the most reduction in PDs, followed by electrosurgery, scalpel, and control, respectively. The graph shows a small decline in PDs for all groups for the period from the Baseline to After Prophylaxis, followed by a steep decline at the 4-6 Week Evaluation, which then remained steady throughout the remaining period.

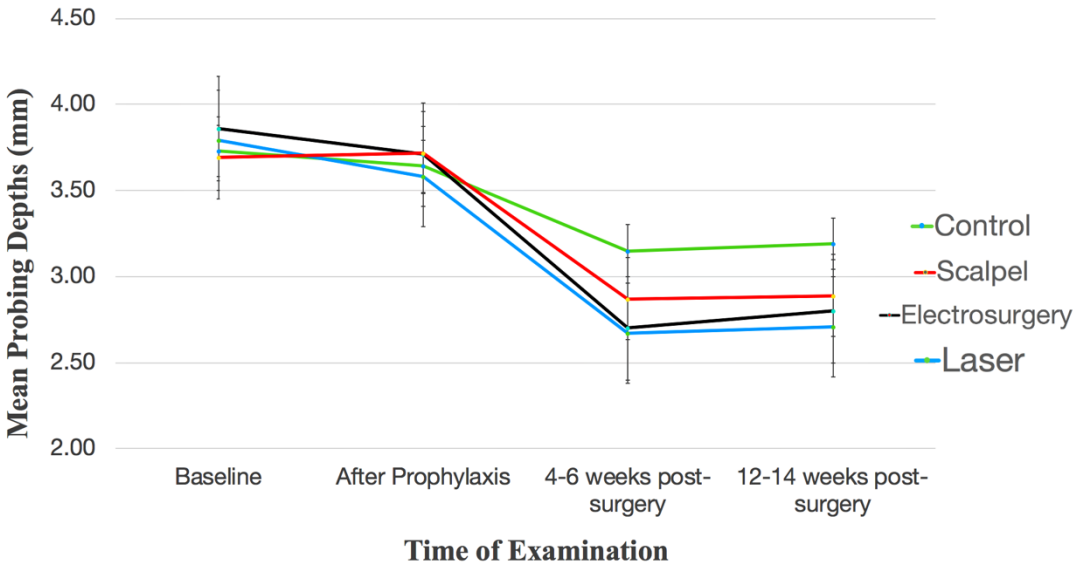

Figure 13. Line graph showing Mean Probing Depths for each group at various time points throughout the study. All Groups showed statistically significant reduction in PD at the 4-6 and 12-14 week evaluations compared to Baseline. (N=15 for Electrosurgery, Laser, and Scalpel Groups and N=16 for Control Group. Error Bars represent standard deviation).

Examining the statistical significance values between the treatment groups as shown in Table 4 (in the appendix), it is observed that laser and electrosurgery treated groups had a statistically significantly reduction in PDs compared to the control group at the 4-6 and 12-14 week Evaluations. However, the scalpel treated group did not exhibit a significant

difference from the control group at these time points. Upon comparing the three surgical modalities to each other, no statistically significant difference was found among the three techniques (laser, electrosurgery, and scalpel) at any time point.

Bleeding Scores

At the end of the study period, all subjects showed reduction in the overall bleeding scores compared to Baseline. As seen in Figure 14, all treatment groups had a steep decline in bleeding scores at the first evaluation (After Prophylaxis), which then exhibited small fluctuations throughout the remaining period. At the final evaluation (12-14 week post-surgery), The control group had the smallest mean bleeding score, followed by the laser, scalpel, and electrosurgery treated groups, respectively as seen on the graph and Table 5.

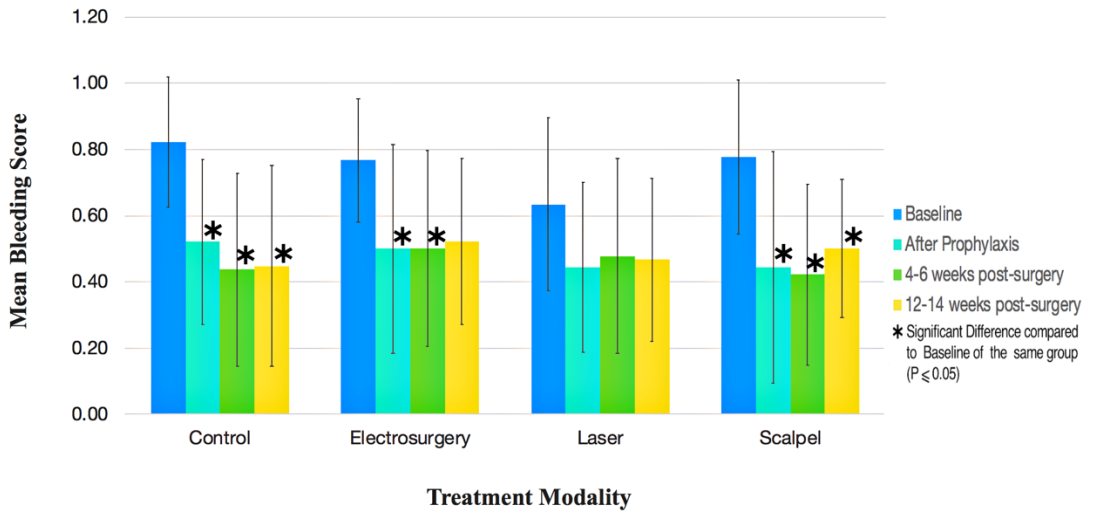

Figure 14. Clustered Column graph showing Mean Bleeding Scores for the various Treatment Modalities at various time points throughout the study. (N=15 for Electrosurgery, Laser, and Scalpel groups and N=16 for Control Group. Error Bars represent standard deviation).

Additionally, as seen in Figure 14, there are some statistical differences within each treatment group marked by the asterisk in the graph, however, referring to the statistical significance values between the treatment groups as shown in Table 6 (in the appendix), no statistically significant differences are detected when comparing the different treatment modalities (Laser, Electrosurgery, Scalpel, and Control) with regards to the overall reduction in bleeding scores throughout the study.

Plaque Index (PI)

By the end of the study period, all subjects showed reduction in the overall mean PI compared to Baseline (Table 7). As seen in Figure 15, there was a decline in the PI for all treatment groups, followed by fluctuations throughout the study with no specific patterns.

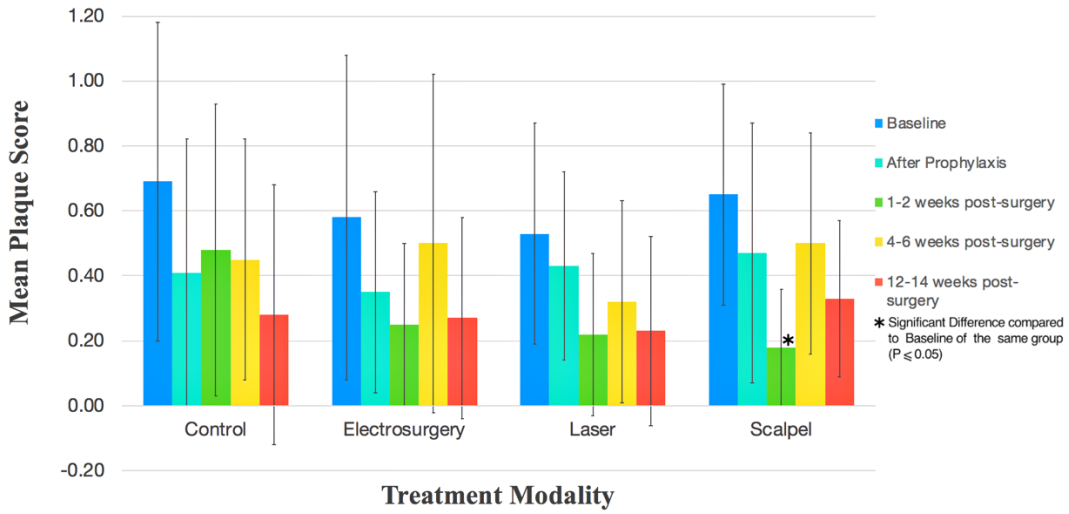

Figure 15. Clustered Column graph showing Mean Plaque Index for the various Treatment Modalities at various time points throughout the study. (N=15 for Electrosurgery, Laser, and Scalpel groups and N=16 for Control Group. Error Bars represent standard deviation).

Referring to the statistical significance values between the treatment groups as shown in Table 8 (in the appendix), one significant relationship was detected within the scalpel

treated group, which can be seen on the graph, at the 1-2 week post-surgery evaluation compared to the Baseline. However, no statistically significant differences are detected when comparing the different treatment modalities (Laser, Electrosurgery, Scalpel, and Control) with regards to the overall reduction in PI throughout the study.

Gingival Index (GI)

At the end of the study period, the mean GI for the electrosurgery treated group was higher compared to the Baseline, while in all other groups (Laser, Scalpel, and Control) the GI was lower than Baseline. Additionally, as seen in Figure 16 and Table 9, the electrosurgery treated group had a higher mean GI compared to all other treatment groups at all post-surgery evaluations (1-2, 4-6, and 12-14 week post-surgery evaluations).

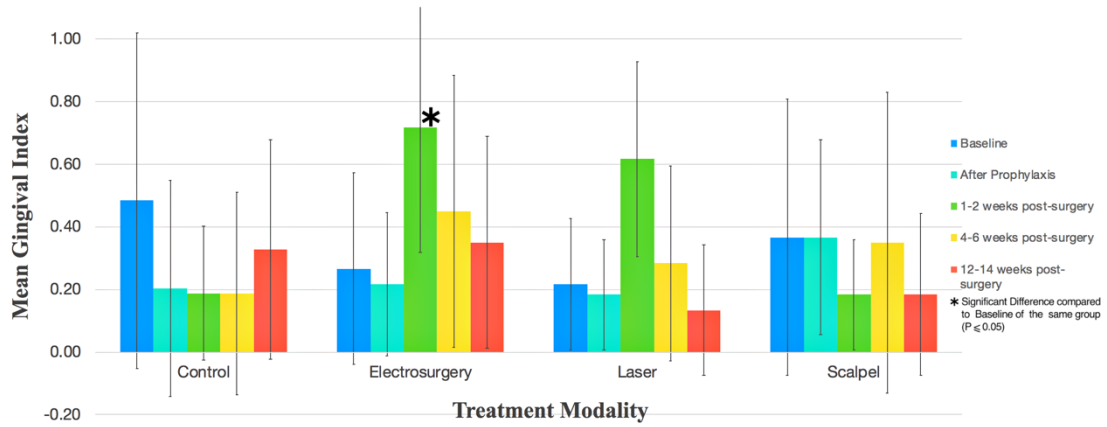

Figure 16. Clustered Column graph showing Mean Gingival Index for the various Treatment Modalities at various time points throughout the study. (N=15 for Electrosurgery, Laser, and Scalpel groups and N=16 for Control Group. Error Bars represent standard deviation).

Referring to the statistical significance values between the treatment groups as shown in **Table 10** (in the appendix), when comparing the different treatment modalities (Laser, Electrosurgery, Scalpel, and Control) with regards to the overall GI scores, no statistically

significant differences were found. However, when comparing the GI at specific time points throughout the study, there was significantly higher GI for both electrosurgery and laser treated groups when compared to the control and scalpel treated groups at the 1-2 week evaluation, however, no statistically significant difference was found when electrosurgery and laser treated groups were compared.

Analysis by tooth type

From the total 61 posterior teeth evaluated, there were 29 premolars and 32 molars. Referring to Table 2, 4, 6, 8, and 10 in the appendix, which contain a comparison in the overall data for premolar versus molar, no statistically significant difference was found for GMP and PDs. However, with regards to bleeding score, PI, and GI there was a statistically significant difference in favor of premolar tooth type.

DISCUSSION

Chronic inflammation associated with the prolonged exposure to dental plaque during orthodontic treatment, has been linked to several unfavorable gingival outcomes, such as gingival recession, attachment loss, and most commonly inflammatory gingival hyperplasia.[21] The primary aim of this study was to compare the efficacy of different surgical techniques in the treatment of gingival enlargement of recently treated orthodontic patients. As mentioned previously, studies revealed that gingival inflammation and enlargement affects a large percentage of orthodontic patients.[7, 8, 18, 22] Moreover, studies have shown that this gingival enlargement occurs more frequently in the posterior teeth compared to the canines and incisors.[7, 18] Some possible reasons for this distribution include; 1) the location of the orthodontic appliances which are more prone to contacting the gingiva of the posterior teeth causing mechanical irritation; 2) presence of exposed cement on the apical aspect of the bands may cause chemical irritation; 3) proximity of the wires to the tissues in the posterior regions causes increased possibility of food impaction; and 4) the tendency for less effective oral hygiene by patients in the posterior teeth.[18]

In the first part of the study, the patients that presented with generalized gingival enlargement after removal of the orthodontic appliances were treated with nonsurgical periodontal therapy (nonsurgical debridement) and were re-evaluated after 4-6 weeks to determine if the gingival enlargement was still present. This step is critical since some studies have reported varying amounts of resolution of gingival inflammation and enlargement following removal of the orthodontic appliances.[7, 8, 18] In the present sample, there was a statistically significant improvement in the overall Bleeding Score and Plaque

Index after the initial nonsurgical debridement, which shows there was improvement in the patients' oral hygiene and gingival health. However, no significant difference was found with regards to GMP and PDs, which indicates that the gingival enlargement in these subjects did not resolve from the nonsurgical periodontal therapy despite the improvement in the other clinical parameters. The reason for this can be attributed to the fibrotic changes that occur in the gingival connective tissues. Even after eliminating the inflammatory components (supra- and subgingival bacteria) and removing the irritating factors (orthodontic appliances), the gingival tissues didn't return to their normal physiologic contour.[8, 47] In such cases, surgical intervention is indicated which was carried out in the second part of the study.

The second part of the study involved an additional round of nonsurgical full mouth debridement, followed by surgical excision of the enlarged gingival tissues in three of the four quadrants in a split-mouth design with three different techniques (laser, electrosurgery, and scalpel), while the fourth quadrant served as control. Evaluations were performed at 1-2 weeks, 4-6 weeks, and 12-14 weeks post-surgery. Three of the four patients reported more discomfort with the electrosurgery treated quadrant, while one patient reported the laser treated quadrant as the most uncomfortable. One study that compared laser and scalpel gingivectomies reported no significant difference between the two techniques.[31] Two studies that compared electrosurgery to scalpel also found no significant difference.[29, 48] It is important to note that two of these studies used a periodontal dressing during the first week of healing, while the third one involved localized gingivectomies for the treatment of gingival clefts. These differences in methodology from the current study may play a role in the different outcomes found with regards to patient post-operative

discomfort. In the present study, the comparison was broader involving all three techniques simultaneously. There seems to be a trend of more discomfort with electrosurgery, possibly due to the extent of heat accumulation associated with this device, which has also been linked to delayed healing as mentioned in previous studies.[30, 41]

By the final evaluation visit (12-14 week post-surgery), all three resective techniques were effective at reducing the gingival enlargement better than the control group. This was evident by the significant reduction in the GMP, while the control group only had minimal effect on the GMP. On the other hand, with regards to PDs, all treatment groups (laser, electrosurgery, scalpel, and control) showed significant reduction compared to the baseline visit. The reduction in PDs and increase in clinical crown height obtained in the surgically treated groups, is in agreement with a previous study by Monefeldt and Zachrisson[49] that reported a mean of 1 mm increase in clinical crown height and mean reduction of 1 mm in probing depth following gingivectomy procedures.

All three surgical modalities (laser, electrosurgery, and scalpel) showed statistically significant reduction in the GMP immediately after surgery and at all subsequent examinations compared to baseline. This indicates that there was not a significant amount of coronal regrowth of these surgically treated tissues during the three months of healing. On the other hand, when comparing the three surgical approaches to each other, there were no statistically significant differences among the three techniques (laser, electrosurgery, and scalpel). This finding is different than other previous studies comparing these surgical techniques. For example, a study by Mavrogiannis et al[31] that compared laser and scalpel gingivectomies and found more regrowth of the tissues in the scalpel treated group. Additionally, looking at the control group alone, there were no significant changes in the

GMP comparing baseline to the final evaluation (12-14 Week Visit). This is consistent with Kouraki et al[8] study which reported that 80% of the subjects they examined still had signs of gingival enlargement 3 to 12 months post orthodontic treatment.

With regards to PDs, at the 4-6 and 12-14 week evaluations, two surgical modalities (laser and electrosurgery) had significantly more reduction in PDs compared to the control group, while the scalpel treated group did not reach a significant difference from the control group at these time points. Yet, when comparing the three surgical modalities to each other, no statistically significant difference was found among the three techniques (laser, electrosurgery, and scalpel) at any time point. In the present study, the laser group achieved more reduction in PDs compared to the scalpel treated group which is in agreement with a study that compared laser and scalpel gingivectomies for the treatment of drug induced gingival enlargement[31], that also found significantly higher reduction of PDs in the laser compared to the scalpel treated group.

When looking at the control group alone, PDs were significantly smaller at the final evaluation compared to the baseline measurements. Although, there was a reduction in PDs, it is interesting that the GMP remained more coronal with no significant changes compared to baseline as mentioned previously. This could be due to elimination of the inflammatory factors and tightening of the gingival tissues resulting in a shallower probing depth upon examination.

With respect to the bleeding scores, there was a significant reduction in the overall bleeding scores throughout the study compared to the baseline. This is in agreement with other studies that also reported reductions in the bleeding scores after removal of the orthodontic

appliances starting at the first month and up to four to five months post treatment.[50, 51] In the present study, this finding may be linked to the parallel reductions that occurred in the PDs and PI over the course of the study.

With regards to the PI, the reported results in the literature vary as to what occurs to the PI post-orthodontic therapy. It may significantly decrease as time progresses, which was reported in a longitudinal study by Sallum et al[51], or it may initially decrease, then rebound back near the baseline levels as reported by Zachrisson and Zachrisson's study.[7] In the present study, the over PI initially reduced after the nonsurgical debridement and oral hygiene instructions were given, followed by fluctuations in the PI at the subsequent visits, however, remained lower than the baseline level.

On a different note, the overall GI did not show significant change throughout this study, however, there was a higher GI for the electrosurgery and laser treated groups at the 1-2 week post-surgery evaluation compared to the scalpel and control groups. These higher GI values may be due to the small variations in the early stages of healing which has been reported by some studies.[41-43]

Finally, with respect to tooth type comparison, the treated premolars had significantly lower bleeding scores, PI, and GI compared to treated molars. This finding is consistent with what the literature reports in longitudinal studies that compare response to periodontal therapy of single versus multi-rooted teeth.[52, 53] In addition, another likely factor is that the premolars are more accessible for oral hygiene compared to the molar teeth. On the other hand, with regards to the GMP and PDs, no significant difference was found between the premolars and molars in this study. While most longitudinal studies show improved

outcomes for single rooted teeth as mentioned previously, these studies are mainly were concerning periodontally involved teeth. The present study sample involved periodontally healthy teeth, which could be the reason that both single and multi-rooted teeth responded similarly.

CONCLUSION

Within the limitations of this study, it was shown that all three resective techniques (laser, electrosurgery, and scalpel) were effective at reducing the gingival enlargement better than nonsurgical therapy. There was no significant difference when comparing the three techniques to each other, however, there was more postoperative discomfort reported for the electrosurgery treated group, followed by the laser and scalpel treated groups, respectively. Additionally, all treatment groups (laser, electrosurgery, scalpel, and control) showed significant reduction in PDs compared to Baseline values, however, the laser and electrosurgery treated groups had significantly more reduction in PDs compared to the control group.

Although the present study did not reveal statistically significant differences between the three gingivectomy techniques when compared to each other, the laser treated group had the most reduction in PDs, bleeding score, PI and GI when compared to the other surgical modalities, and similar to electrosurgery with regards to reduction of the GMP. Lasers provide a promising method for the treatment of gingival enlargement following orthodontic therapy that doesn't subside after nonsurgical debridement. They also offer additional advantages such as increased hemostatic effects, improved visibility, bacteriostatic effect, and increased patient acceptance. However, future studies with longer follow-up are recommended to strengthen the evidence in support of their effectiveness.

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APPENDIX

TABLES OF STATISTICS AND COMPARISONS

Table 1. Mean difference in GMP from Baseline for each treatment group at various time points throughout the study in millimeter (N=number of readings, M=Mean, SD=Standard Deviation)

Group		Control	Electrosurgery	Laser	Scalpel
Baseline	N	16	15	15	15
	M	0.00	0.00	0.00	0.00
	SD	0.48	0.54	0.74	0.55
After Prophylaxis	N	16	15	15	15
	M	0.06	-0.01	0.00	0.05
	SD	0.46	0.4	0.64	0.5
After Surgery	N	16	15	15	15
	M	0.09	1.52	1.35	1.42
	SD	0.48	0.39	0.57	0.6
1-2 weeks post-surgery	N	16	15	15	15
	M	0.40	1.45	1.27	1.08
	SD	0.53	0.42	0.62	0.5
4-6 weeks post-surgery	N	16	15	15	15
	M	0.41	1.06	1.08	1.04
	SD	0.57	0.31	0.64	0.67
12-14 weeks post-surgery	N	16	15	15	15
	M	0.19	1.10	1.10	0.98
	SD	0.46	0.35	0.62	0.56

Table 2. Statistical Significance Values with respect to GMP measurements based on Time, Treatment Group, Tooth Type, and Time by Control Group

			Difference	Lower 95% CI	Upper 95% CI	P Value
Time						
After Prophylaxis	vs	Baseline	0.020	-0.230	0.270	1.000
After Surgery	vs	Baseline	1.090	0.840	1.340	0.000
1-2 weeks post-surgery	vs	Baseline	1.050	0.800	1.300	0.000
4-6 weeks post-surgery	vs	Baseline	0.900	0.650	1.150	0.000
12-14 weeks post-surgery	vs	Baseline	0.830	0.580	1.080	0.000
After Surgery	vs	After Prophylaxis	1.070	0.820	1.320	0.000
1-2 weeks post-surgery	vs	After Prophylaxis	1.030	0.780	1.270	0.000
4-6 weeks post-surgery	vs	After Prophylaxis	0.880	0.630	1.130	0.000
12-14 weeks post-surgery	vs	After Prophylaxis	0.810	0.560	1.060	0.000
1-2 weeks post-surgery	vs	After Surgery	-0.050	-0.290	0.200	1.000
4-6 weeks post-surgery	vs	After Surgery	-0.190	-0.440	0.050	0.326
12-14 weeks post-surgery	vs	After Surgery	-0.260	-0.510	-0.010	0.032
4-6 weeks post-surgery	vs	1-2 weeks post-surgery	-0.150	-0.400	0.100	1.000
12-14 weeks post-surgery	vs	1-2 weeks post-surgery	-0.210	-0.460	0.030	0.170
12-14 weeks post-surgery	vs	4-6 weeks post-surgery	-0.070	-0.310	0.180	1.000
Treatment Group						
Electrosurgery	vs	Control	0.610	0.430	0.790	0.000
Laser	vs	Control	0.670	0.490	0.850	0.000
Scalpel	vs	Control	0.500	0.320	0.680	0.000
Laser	vs	Electrosurgery	0.060	-0.130	0.240	1.000
Scalpel	vs	Electrosurgery	-0.110	-0.300	0.070	0.596
Scalpel	vs	Laser	-0.170	-0.350	0.010	0.084

Table 2. Continued.

			Difference	Lower 95% CI	Upper 95% CI	P Value
Tooth Type						
Premolar	vs	Molar	-0.03	-0.13	0.07	0.558
Time by Control Group						
After Prophylaxis + Control	vs	Baseline + Control	0.050	-0.570	0.670	1.000
After Surgery + Control	vs	Baseline + Control	0.080	-0.540	0.700	1.000
1-2 weeks post-surgery + Control	vs	Baseline + Control	0.400	-0.220	1.010	1.000
4-6 weeks post-surgery + Control	vs	Baseline + Control	0.410	-0.210	1.020	1.000
12-14 weeks post-surgery + Control	vs	Baseline + Control	0.190	-0.430	0.810	1.000
After Surgery + Control	vs	After Prophylaxis + Control	0.030	-0.590	0.650	1.000
1-2 weeks post-surgery + Control	vs	After Prophylaxis + Control	0.340	-0.270	0.960	1.000
4-6 weeks post-surgery + Control	vs	After Prophylaxis + Control	0.350	-0.260	0.970	1.000
12-14 weeks post-surgery + Control	vs	After Prophylaxis + Control	0.140	-0.480	0.750	1.000
1-2 weeks post-surgery + Control	vs	After Surgery + Control	0.310	-0.310	0.930	1.000
4-6 weeks post-surgery + Control	vs	After Surgery + Control	0.320	-0.300	0.940	1.000
12-14 weeks post-surgery + Control	vs	After Surgery + Control	0.100	-0.510	0.720	1.000
4-6 weeks post-surgery + Control	vs	1-2 weeks post-surgery + Control	0.010	-0.610	0.630	1.000
12-14 weeks post-surgery + Control	vs	1-2 weeks post-surgery + Control	-0.210	-0.830	0.410	1.000
12-14 weeks post-surgery + Control	vs	4-6 weeks post-surgery + Control	-0.220	-0.840	0.400	1.000

Table 3. Mean Probing Depths for each treatment group at various time points throughout the study in millimeter (N=number of readings, M=Mean, SD=Standard Deviation)

Group		Control	Electrosurgery	Laser	Scalpel
Baseline	N	16	15	15	15
	M	3.73	3.86	3.79	3.69
	SD	0.3	0.24	0.22	0.24
After Prophylaxis	N	16	15	15	15
	M	3.64	3.71	3.58	3.72
	SD	0.21	0.23	0.35	0.35
After Surgery	N	N/A	N/A	N/A	N/A
	M	N/A	N/A	N/A	N/A
	SD	N/A	N/A	N/A	N/A
1-2 weeks post-surgery	N	N/A	N/A	N/A	N/A
	M	N/A	N/A	N/A	N/A
	SD	N/A	N/A	N/A	N/A
4-6 weeks post-surgery	N	16	15	15	15
	M	3.15	2.7	2.67	2.87
	SD	0.46	0.43	0.33	0.38
12-14 weeks post-surgery	N	16	15	15	15
	M	3.19	2.8	2.71	2.89
	SD	0.47	0.35	0.32	0.34

Table 4. Statistical Significance Values with respect to Probing Depth measurements based on Time, Treatment Group, Tooth Type, and Time by Control Group

			Difference	Lower 95% CI	Upper 95% CI	P Value
Time						
After Prophylaxis	vs	Baseline	-0.100	-0.240	0.030	0.224
4-6 weeks post-surgery	vs	Baseline	-0.920	-1.050	-0.790	0.000
12-14 weeks post-surgery	vs	Baseline	-0.870	-1.000	-0.740	0.000
4-6 weeks post-surgery	vs	After Prophylaxis	-0.820	-0.950	-0.690	0.000
12-14 weeks post-surgery	vs	After Prophylaxis	-0.760	-0.900	-0.630	0.000
12-14 weeks post-surgery	vs	4-6 weeks post-surgery	0.050	-0.080	0.180	1.000
Treatment Group						
Electrosurgery	vs	Control	-0.170	-0.300	-0.040	0.004
Laser	vs	Control	-0.250	-0.380	-0.120	0.000
Scalpel	vs	Control	-0.150	-0.280	-0.010	0.020
Laser	vs	Electrosurgery	-0.080	-0.210	0.050	0.657
Scalpel	vs	Electrosurgery	0.020	-0.110	0.160	1.000
Scalpel	vs	Laser	0.110	-0.030	0.240	0.216
Tooth Type						
Premolar	vs	Molar	-0.16	-0.33	0.01	0.072
Time by Control Group						
After Prophylaxis + Control	vs	Baseline + Control	-0.090	-0.440	0.250	1.000
4-6 weeks post-surgery + Control	vs	Baseline + Control	-0.580	-0.930	-0.240	0.000
12-14 weeks post-surgery + Control	vs	Baseline + Control	-0.540	-0.890	-0.200	0.000
4-6 weeks post-surgery + Control	vs	After Prophylaxis + Control	-0.490	-0.830	-0.150	0.000
12-14 weeks post-surgery + Control	vs	After Prophylaxis + Control	-0.450	-0.790	-0.100	0.001
12-14 weeks post-surgery + Control	vs	4-6 weeks post-surgery + Control	0.040	-0.300	0.390	1.000

Table 5. Mean Bleeding Scores for each treatment group at various time points throughout the study (N=number of readings, M=Mean, SD=Standard Deviation)

Group		Control	Electrosurgery	Laser	Scalpel
Baseline	N	16	15	15	15
	M	0.82	0.77	0.63	0.78
	SD	0.20	0.19	0.26	0.23
After Prophylaxis	N	16	15	15	15
	M	0.52	0.50	0.44	0.44
	SD	0.25	0.31	0.26	0.35
After Surgery	N	N/A	N/A	N/A	N/A
	M	N/A	N/A	N/A	N/A
	SD	N/A	N/A	N/A	N/A
1-2 weeks post-surgery	N	N/A	N/A	N/A	N/A
	M	N/A	N/A	N/A	N/A
	SD	N/A	N/A	N/A	N/A
4-6 weeks post-surgery	N	16	15	15	15
	M	0.44	0.50	0.48	0.42
	SD	0.29	0.30	0.29	0.27
12-14 weeks post-surgery	N	16	15	15	15
	M	0.45	0.52	0.47	0.50
	SD	0.30	0.25	0.25	0.21

Table 6. Statistical Significance Values with respect to Bleeding Score based on Time, Treatment Group, Tooth Type, and Time by Control Group

			Difference	Lower 95% CI	Upper 95% CI	P Value
Time						
After Prophylaxis	vs	Baseline	-0.273	-0.368	-0.177	0.000
4-6 weeks post-surgery	vs	Baseline	-0.291	-0.386	-0.195	0.000
12-14 weeks post-surgery	vs	Baseline	-0.266	-0.361	-0.170	0.000
4-6 weeks post-surgery	vs	After Prophylaxis	-0.018	-0.114	0.077	1.000
12-14 weeks post-surgery	vs	After Prophylaxis	0.007	-0.089	0.102	1.000
12-14 weeks post-surgery	vs	4-6 weeks post-surgery	0.025	-0.071	0.120	1.000
Treatment Group						
Electrosurgery	vs	Control	0.010	-0.085	0.105	1.000
Laser	vs	Control	-0.057	-0.152	0.038	0.683
Scalpel	vs	Control	-0.026	-0.121	0.069	1.000
Laser	vs	Electrosurgery	-0.067	-0.163	0.030	0.406
Scalpel	vs	Electrosurgery	-0.036	-0.132	0.060	1.000
Scalpel	vs	Laser	0.031	-0.066	0.127	1.000
Tooth Type						
Premolar	vs	Molar	-0.08	-0.13	-0.03	0.003
Time by Control Group						
After Prophylaxis + Control	vs	Baseline + Control	-0.302	-0.551	-0.053	0.002
4-6 weeks post-surgery + Control	vs	Baseline + Control	-0.385	-0.635	-0.136	0.000
12-14 weeks post-surgery + Control	vs	Baseline + Control	-0.375	-0.624	-0.126	0.000
4-6 weeks post-surgery + Control	vs	After Prophylaxis + Control	-0.083	-0.333	0.166	1.000
12-14 weeks post-surgery + Control	vs	After Prophylaxis + Control	-0.073	-0.322	0.176	1.000
12-14 weeks post-surgery + Control	vs	4-6 weeks post-surgery + Control	0.010	-0.239	0.260	1.000

Table 7. Mean Plaque Index for each treatment group at various time points throughout the study in millimeter (N=number of readings, M=Mean, SD=Standard Deviation)

Group		Control	Electrosurgery	Laser	Scalpel
Baseline	N	16	15	15	15
	M	0.69	0.58	0.53	0.65
	SD	0.49	0.5	0.34	0.34
After Prophylaxis	N	16	15	15	15
	M	0.41	0.35	0.43	0.47
	SD	0.41	0.31	0.29	0.4
After Surgery	N	0	0	0	0
	M	0	0	0	0
	SD	0	0	0	0
1-2 weeks post-surgery	N	16	15	15	15
	M	0.48	0.25	0.22	0.18
	SD	0.45	0.25	0.25	0.18
4-6 weeks post-surgery	N	16	15	15	15
	M	0.45	0.5	0.32	0.5
	SD	0.37	0.52	0.31	0.34
12-14 weeks post-surgery	N	16	15	15	15
	M	0.28	0.27	0.23	0.33
	SD	0.4	0.31	0.29	0.24

Table 8. Statistical Significance Values with respect to Plaque Index based on Time, Treatment Group, Tooth Type, and Time by Control Group

			Difference	Lower 95% CI	Upper 95% CI	P Value
Time						
After Prophylaxis	vs	Baseline	-0.200	-0.370	-0.030	0.010
1-2 weeks post-surgery	vs	Baseline	-0.330	-0.500	-0.160	0.000
4-6 weeks post-surgery	vs	Baseline	-0.170	-0.340	0.000	0.049
12-14 weeks post-surgery	vs	Baseline	-0.330	-0.510	-0.160	0.000
1-2 weeks post-surgery	vs	After Prophylaxis	-0.130	-0.300	0.040	0.318
4-6 weeks post-surgery	vs	After Prophylaxis	0.030	-0.140	0.200	1.000
12-14 weeks post-surgery	vs	After Prophylaxis	-0.140	-0.310	0.040	0.258
4-6 weeks post-surgery	vs	1-2 weeks post-surgery	0.160	-0.010	0.330	0.089
12-14 weeks post-surgery	vs	1-2 weeks post-surgery	0.000	-0.180	0.170	1.000
12-14 weeks post-surgery	vs	4-6 weeks post-surgery	-0.160	-0.330	0.010	0.070
Treatment Group						
Electrosurgery	vs	Control	-0.060	-0.210	0.080	1.000
Laser	vs	Control	-0.110	-0.250	0.030	0.279
Scalpel	vs	Control	-0.030	-0.170	0.110	1.000
Laser	vs	Electrosurgery	-0.040	-0.190	0.100	1.000
Scalpel	vs	Electrosurgery	0.040	-0.110	0.180	1.000
Scalpel	vs	Laser	0.080	-0.060	0.220	0.865

Table 8. Continued.

			Difference	Lower 95% CI	Upper 95% CI	P Value
Tooth Type						
Premolar	vs	Molar	-0.30	-0.37	-0.23	0.000
Time by Control Group						
After Prophylaxis + Control	vs	Baseline + Control	-0.280	-0.710	0.150	1.000
1-2 weeks post-surgery + Control	vs	Baseline + Control	-0.200	-0.640	0.230	1.000
4-6 weeks post-surgery + Control	vs	Baseline + Control	-0.230	-0.670	0.200	1.000
12-14 weeks post-surgery + Control	vs	Baseline + Control	-0.410	-0.840	0.030	0.117
1-2 weeks post-surgery + Control	vs	After Prophylaxis + Control	0.080	-0.350	0.510	1.000
4-6 weeks post-surgery + Control	vs	After Prophylaxis + Control	0.050	-0.390	0.480	1.000
12-14 weeks post-surgery + Control	vs	After Prophylaxis + Control	-0.130	-0.560	0.310	1.000
4-6 weeks post-surgery + Control	vs	1-2 weeks post-surgery + Control	-0.030	-0.460	0.400	1.000
12-14 weeks post-surgery + Control	vs	1-2 weeks post-surgery + Control	-0.200	-0.640	0.230	1.000
12-14 weeks post-surgery + Control	vs	4-6 weeks post-surgery + Control	-0.170	-0.600	0.260	1.000

Table 9. Mean Gingival Index for each treatment group at various time points throughout the study in millimeter (N=number of readings, M=Mean, SD=Standard Deviation)

Group		Control	Electrosurgery	Laser	Scalpel
Baseline	N	16	15	15	15
	M	0.48	0.27	0.22	0.37
	SD	0.54	0.31	0.21	0.44
After Prophylaxis	N	16	15	15	15
	M	0.20	0.22	0.18	0.37
	SD	0.34	0.23	0.18	0.31
After Surgery	N	0	0	0	0
	M	0	0	0	0
	SD	0	0	0	0
1-2 weeks post-surgery	N	16	15	15	15
	M	0.19	0.72	0.62	0.18
	SD	0.21	0.40	0.31	0.18
4-6 weeks post-surgery	N	16	15	15	15
	M	0.19	0.45	0.28	0.35
	SD	0.32	0.44	0.31	0.48
12-14 weeks post-surgery	N	16	15	15	15
	M	0.33	0.35	0.13	0.18
	SD	0.35	0.34	0.21	0.26

Table 10. Statistical Significance Values with respect to Gingival Index based on Time, Treatment Group, Tooth Type, and Time by Control Group.

			Difference	Lower 95% CI	Upper 95% CI	P Value
Time						
After Prophylaxis	vs	Baseline	-0.090	-0.250	0.070	1.000
1-2 weeks post-surgery	vs	Baseline	0.090	-0.070	0.250	1.000
4-6 weeks post-surgery	vs	Baseline	-0.020	-0.170	0.140	1.000
12-14 weeks post-surgery	vs	Baseline	-0.080	-0.240	0.070	1.000
1-2 weeks post-surgery	vs	After Prophylaxis	0.180	0.030	0.340	0.010
4-6 weeks post-surgery	vs	After Prophylaxis	0.080	-0.080	0.230	1.000
12-14 weeks post-surgery	vs	After Prophylaxis	0.010	-0.150	0.160	1.000
4-6 weeks post-surgery	vs	1-2 weeks post-surgery	-0.110	-0.270	0.050	0.550
12-14 weeks post-surgery	vs	1-2 weeks post-surgery	-0.180	-0.340	-0.020	0.020
12-14 weeks post-surgery	vs	4-6 weeks post-surgery	-0.070	-0.230	0.090	1.000
Treatment Group						
Electrosurgery	vs	Control	0.130	0.000	0.260	0.060
Laser	vs	Control	0.020	-0.120	0.150	1.000
Scalpel	vs	Control	0.020	-0.110	0.150	1.000
Laser	vs	Electrosurgery	-0.110	-0.250	0.020	0.160
Scalpel	vs	Electrosurgery	-0.110	-0.240	0.020	0.190
Scalpel	vs	Laser	0.000	-0.130	0.140	1.000

Table 10. Continued.

			Difference	Lower 95% CI	Upper 95% CI	P Value
Tooth Type						
Premolar	vs	Molar	-0.20	-0.27	-0.13	0.000
Time by Control Group						
After Prophylaxis + Control	vs	Baseline + Control	-0.280	-0.680	0.120	1.000
1-2 weeks post-surgery + Control	vs	Baseline + Control	-0.300	-0.700	0.110	1.000
4-6 weeks post-surgery + Control	vs	Baseline + Control	-0.300	-0.700	0.110	1.000
12-14 weeks post-surgery + Control	vs	Baseline + Control	-0.160	-0.560	0.250	1.000
1-2 weeks post-surgery + Control	vs	After Prophylaxis + Control	-0.020	-0.420	0.390	1.000
4-6 weeks post-surgery + Control	vs	After Prophylaxis + Control	-0.020	-0.420	0.390	1.000
12-14 weeks post-surgery + Control	vs	After Prophylaxis + Control	0.120	-0.280	0.530	1.000
4-6 weeks post-surgery + Control	vs	1-2 weeks post-surgery + Control	0.000	-0.400	0.400	1.000
12-14 weeks post-surgery + Control	vs	1-2 weeks post-surgery + Control	0.140	-0.260	0.540	1.000
12-14 weeks post-surgery + Control	vs	4-6 weeks post-surgery + Control	0.140	-0.260	0.540	1.000