RIDGE DIMENSIONAL CHANGES:

A COMPARATIVE STUDY OF SOCKET COMPRESSION AFTER DENTAL
EXTRACTION WITH NO COMPRESSION

by

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INTRODUCTION

**Exodontia- Current state of the Art:**

Exodontia is one of the foundations of routine and emergency dental treatment. It is utilized for various reasons e.g., as part of restorative, orthodontic, endodontic, periodontic and pediatric dentistry treatments. Extraction of teeth with minimal trauma to the surrounding alveolar bone is necessary to prevent harmful sequlae including alveolar osteitis, loss of ridge dimension, etc. Yet, the general principles behind extraction techniques have largely remained unchanged over the last 100 years.[1, 2] Many extraction techniques are passed down verbally from instructor to student during dental school or in post graduate training. Others have been embedded in the literature with little support for or against them. There is a greater emphasis today on techniques that preserve ridge dimension particularly in sites where teeth are planned to be replaced with dental implants. In light of this, some extraction techniques may or may not necessarily be advisable in today's modern dentistry.

One such technique that has a sound rationale, but has a paucity of evidence to support it, is the practice of compressing the socket or ridge after extraction. Historically, dentists have been trained to compress the socket post-extraction for a number of hypothetical reasons which include:

- To help retain the blood clot and thus reduce alveolar osteitis (dry socket),
- To re-approximate the buccal and lingual walls that were either damaged or stretched apart while luxating the tooth for better healing, or
- To increase the speed with which the socket will heal.

Nevertheless, the utility of this technique not been validated by evidence. Particularly, a question remains whether this practice reduces residual ridge dimension, consequently compromising esthetics and functions in sites where teeth are planned to be replaced with dental implants.

Considering this, we hypothesized that sites that are compressed post-extraction will have a greater reduction in ridge width and height when compared to sites without post-extraction ridge compression. Additionally, we hypothesized that sites that are compressed will have a faster soft tissue healing time due to faster occlusion of socket. Therefore, the objective of this pilot study was to determine if post-extraction socket compression negatively affected residual ridge dimensions when compared to sites that were not compressed post-extraction. Secondary outcome measures identified if socket compression/re-approximation affected the rate of soft tissue closure or occurrence of alveolar osteitis.

REVIEW OF LITERATURE

**Socket Compression:**

Exodontia, or tooth extraction, is one of the core procedures of dentistry. The techniques for tooth extraction are well studied and documented in the literature.[3-9] However, the principles surrounding the extraction process and post-operative care vary greatly. In fact, they are at best subjective and governed by the judgment of the individual dentist performing the extraction.[9] One such technique is post-extraction socket or ridge compression, which is usually performed per the clinical judgment and discretion of the dentist. Socket compression is the process of placing digital pressure on the buccal and lingual/palatal aspects of the alveolus following extraction of the tooth.[5, 6, 8, 10] Sufficient pressure is applied to re-approximate the alveolus that is expanded due to luxation of tooth during extraction. The compression is carefully done so as to not crush or fracture the bony walls.[3] The rationale for the compression is to reduce the wound dimensions, which in turn is theorized to lead to faster healing by re-approximating the buccal and lingual/palatal plate.[7, 10, 11] Additionally it is said to reduce the bony undercuts,[6] reduce post-operative pain,[10] and help retain the blood clot.[5]

However, as early as 1993, few investigators and clinicians began to advocate that socket compression following an extraction may not be good clinical practice, while acknowledging the historical use of this practice.[12] Their rationale revolved around anecdotal observation of compromised ridge dimensions due to socket compression resulting in inadequate ridge width to allow placement of dental implants.

More recently, the instructions regarding this practice have become less clear with some authors supporting,[7, 8, 11] while others approving, but only in certain

scenarios.[4, 6] Despite the presence of these instructions for or against the practice of socket compression, the stated rationales have not been validated or invalidated by clinical trials. The published data on socket preservation is a 100 year collection of varying opinions; all without evidentiary support. The prevalence of the practice of socket compression among practitioners is unknown. However, given the long standing presence of these instructions in the published literature,[5-8, 10, 11, 13] it is conceivable that this practice may be still widely practiced today.

**Extraction process and its effects on the socket**

The procedure of an extraction and the healing process that takes place in the extraction socket both affect the residual ridge dimension. The first step in an extraction procedure is generally the separation of the periodontal ligament from the tooth. This is done by placing an elevator in a purchase point (an area between the tooth's root and the alveolar bone) and rotating that instrument in an apical direction. This will elevate and subluxate the tooth. Extraction forceps are then often used to deliver the tooth from the socket. During this process, the socket i.e., the residual alveolar bone, is expanded.[4] One primary reason that has been put forth for socket compression is to counter this expansion of the socket's walls thereby re-approximating the width of the socket to its pre-extraction dimension. The published instructions for socket compression explicitly state that the practitioner should squeeze the walls of the socket, post-extraction, between the fingers and thumb in order to reduce distortion of the alveolus and overlying mucosa, which occur while extracting the tooth [8].

**Socket Healing and ridge dimensional changes:**

Following extraction, the socket goes through a series of healing events that have long been well characterized. At the end of day one, there is evidence of formation of the blood clot. On the third day after the tooth's extraction, osteoclasts are found at the crest of the alveolus. By the end of the third day, fibroblasts have proliferated into the site's blood clot. By day four, there is evidence of the initial stages of epithelialization. Bone regeneration is noted in the lower one third of the fundus of the socket on the fifth day. By day 20, the process of replacing the granulation tissue is active. By day 38, two-thirds of the socket is filled with trebeculae. At three months, two-thirds of the remodeling that will take place will be complete.[14-16]

While there has been some disagreement about, where the formation of bone first takes place,[17, 18] we do know that in the absence of socket grafting, there will generally be a greater reduction in the buccal dimension of the healed alveolar ridge. Classic literature has long identified that the buccal dimension is reduced to a greatest extent irrespective of location in the mouth.[19-21] When extraction sites are grafted with some form of bone substitute (otherwise known as socket grafting or ridge preservation) via a number of different techniques, there tends to be a greater stabilization of the buccal/facial wall. In the absence of ridge preservation, there will be greater reduction in the ridge width by up to 50 percent which could correspond to as much as 5-6 mm.[21-24] In fact, the most coronal aspect of the ridge moves lingually or palatally when a tooth is extracted and the ridge is not preserved.[25] In sites where implants will be placed, the literature is clear in stating that maintenance of alveolar ridge dimensions is critical.[21, 24] However, the literature is unclear regarding the post-extraction standard of care for ridges that will

receive removable prostheses or perhaps have no replacements for the extracted teeth.[9]

Consequently, the vast majority of these sites are not grafted, but are allowed to undergo

the healing process naturally. In many non-orthodontic, non-implant cases, dentists are

commonly taught to compress the socket due to various reasons that have been described

previously. What is clear is that in the absence of ridge preservation, the ridge will

atrophy significantly more than if it were preserved.[26, 27]

**Socket Compression:**

What is not known is how this process of socket compression affects the healing

and ridge dimensional change, or if it does at all. It is well understood that the reduced

residual ridge compromises the function of removable dental prostheses, reduces

esthetics for fixed dental prostheses, and negatively influences the esthetics and function

for dental implants. Socket compression and consequent compromised residual ridge

may also necessitate future additional treatments such as soft tissue grafting or guided

bone regeneration, in order to improve the esthetic and/or function.

**Objectives:**

The purpose of this pilot study is to compare the residual ridge dimension of

alveolar ridges that were compressed post-extraction versus those that were not

compressed. Ridge width and height are the primary outcome measures to be evaluated.

Secondary outcome measures will evaluate how the rate of soft tissue closure or presence of adverse events, such as alveolar osteitis, affect the rate of soft tissue closure.

**Hypothesis**

Extraction sites that are compressed will have a greater reduction in ridge width and height than sites without post-extraction ridge compression.  Additionally, sites that are compressed will have a faster rate of soft tissue healing due to faster occlusion of the socket.

**Null Hypothesis**

Extraction sites that are compressed will have no greater reduction in ridge width and height than sites without post-extraction compression.  The soft tissue healing rate of compressed sites will be similar to those sites that were not compressed.

MATERIALS AND METHODS

A randomized, single masked study design was used in this pilot study. The study was conducted in accordance with ethical guidance and review by the Indiana University Institutional Review Board (Study #1207009181). Radiation safety approval was also obtained from Indiana University Radiation Safety Office.

Subjects were recruited from various post-doctoral and pre-doctoral clinics at the Indiana University School of Dentistry via advertisements inside the Indiana University School of Dentistry and through direct referrals. Informed consent was obtained from all subjects along with authorization for the release of health information prior to the study. Subjects meeting the inclusion criteria were randomly assigned to either to the socket compression or to the non-compression groups as described later.

The inclusion and exclusion criteria used are described below and were adapted from Toloue et al. 2011.[28]

*Inclusion Criteria*

Subjects who participated in the study were required to meet all of the following criteria:

1. Subjects were required to sign an informed consent, authorization for the release of health information for research and provide medical history information including current medications.
2. Male (ages 18-75 years) and female (ages 18-50 years) were selected to avoid bone loss risk groups such as those with osteopenia or osteoporosis. [29-32]
3. Subjects were required to have no uncontrolled systemic disease (ASA 1 or 2).[33]

4. At least one non-molar tooth in need of extraction which was either non-restorable or has a hopeless prognosis was necessary.

5. The ability to communicate with the examiner and sign the consent form was required.

6. The presence of an intact facial/buccal plate was required to be verified with clinical and cone beam CT (CBCT) based evidence. The CBCT scans were taken with a limited focus. They also had a dosage equivalent to two periapical radiographs.

*Exclusion Criteria*

Subjects were excluded from the present investigation if they met any of the exclusion criteria:

1. Women could not be actively breastfeeding, report being pregnant, or intend to become pregnant during the study period. This was done to avoid hormonal changes associated with pregnancy that could affect healing.

2. Subjects could not have any unstable systemic diseases, a compromised immune system, active infectious diseases, history of radiation, history cancer therapy, and/or radiation specifically to the oral cavity within the last 6 months.

3. Subjects could not be actively taking medications that would negatively affect bone growth (i.e. Oral/IV bisphosphonates).

4. Subjects were excluded who self-reported smoking ≥20 cigarettes per day.

5. Subjects were excluded who are unwilling or unable to comply with the research protocol.

6. Subjects could not have an allergy to local anesthetic.

7. Other conditions that investigators may felt would inhibit the patient from being a good candidate for this study or which otherwise contraindicate patient participation in the study were grounds for dismissal.

*Randomization of Subjects*

An equal number of equal sized paper strips were numbered (1 and 2) and folded. These then were placed into an envelope. Prior to the extraction, one slip was selected by the single practitioner who was to complete the extraction, but who did not complete the clinical measurements. If the number 1 was selected, the subject was allocated to the non-compression group. If the number 2 was selected, the subject was allocated to the compression group. The strip was then stored separately and not returned to the envelope following selection.

A unique study number was given to each subject screened for study participation. The screening numbers were assigned in ascending numerical order according to appearance at the study site. For every subject accepted into the study, this screening number served as their unique subject randomization number. The randomization number was how each subject's data was identified.

*Measurement and Evaluation Parameters*

Measurements that were made at baseline and the 3 month follow-up appointments include the following:

1. Ridge width and height with the aid of CBCT analysis software InVivoDental Imaging Software Program (Anatomage Incorporated, San Jose, CA, USA);

2. Ridge width with the aid of an acrylic stent and calipers;

3. Wound Opening with the aid of calibrate North Carolina #15 periodontal probes.

In addition, the degree of epithelialization during socket healing was measured as similar to the technique described by Velez et. Al. [34] The North Carolina #15 periodontal probe was placed at a 90 degree angle over the wound measuring across at its greatest dimension.

The study protocol is described below:

*Appointment 1*

The purpose, procedures, risks, benefits, and remuneration were reviewed with each subject on an individual basis and informed consent was obtained by the principal investigator or designee. Impressions were taken of the arch with the affected tooth (one tooth per subject) to be extracted. A stone model was then poured. The vacuform acrylic stent was made and trimmed to extend apical to the free gingival margin on the casts mid-facially and mid-lingually. Reproducible, reference points were marked with a

perforation in the vacuform stent.  These perforations were made approximately 5 mm from the most apical extent of the gingival margin mid-facially and mid-lingually/mid-palatally. Ridge dimension measurements were made using this reference point.

*Appointment 2*

Subjects were given a dental prophylaxis or scaling and root planning if deemed necessary by the provider.

*Appointment 3*

Each subject had a limited focus CBCT scan taken within one month prior to extraction at the Indiana University School of Dentistry Graduate Endodontics clinic. The scan was performed at 85 kV, 10 mA, 10.8 S using a Kodak 9500 LFOV scanner, (Kodak Dental Systems, CareStream Health, Rochester, NY, USA).  The CBCT images were used to measure the ridge width and height radio-graphically at baseline.

*Appointment 4*

Each subject had his/her tooth that was included in the study extracted with minimal trauma to the alveolar housing under local anesthesia with help of periotomes, elevators and extraction forceps (Salvin Dental Specialties, Charlotte, NC) as necessary. Following the extraction, the width of the ridge at the level of the reference perforation

was measured in both the compression and non-compression groups. Following this, in the compression group, the socket was lightly compressed and re-approximated to its original position prior to extraction by using digital pressure with the index finger and thumb by one investigator. All measurements were completed by an examiner masked to treatment. The width of the ridge was then measured immediately following socket compression in the compression group by the same examiner. In the control group, the width of the ridge was similarly measured by the masked examiner immediately after and five minutes after the extraction was completed. The ridges were measured immediately following extraction and then 5 minutes after extraction (and compression in the compression group) in order to determine if the compression significantly reduced the width of the ridges.

Subjects in both groups were not routinely given antibiotics. Subjects were given post-operative analgesics as deemed necessary by the provider. Verbal and written post-operative instructions will be given to the subjects.

*Appointment 5 (Plus follow up visits)*

Subjects were seen for post-operative evaluation at the end of the first week and second week, 1 month after extraction and after which as necessary for every 2 weeks until complete soft tissue coverage was achieved. Maximum bucco-lingual wound dimensions were measured with a North Carolina probe (Salvin Dental Specialties, Charlotte, NC) at each visit until complete clinical soft tissue coverage was achieved. Complete soft tissue coverage was defined as a layer of soft tissue completely covering

the extraction socket irrespective of the tissues' level of maturity. Subjects with post-operative concerns returned at alternative intervals as deemed necessary by the provider.

*Final Appointment*

At three months, a limited focus CBCT scan was done for each subject. Additionally, impressions were taken at this final appointment

*Withdrawal Criteria and Guidelines*

If subjects elected to withdraw from the study or if a non-manageable adverse event occurred, they would be followed as necessary for their care. Subjects who fell within the following categories were withdrawn from the study:

1. Subject or Provider's request
2. Non-compliance with protocol
3. Adverse events in the healing process. Adverse events included, but were not limited to:

    a. Fracture of the facial/buccal or lingual/palatal plate;

    b. Excessive bleeding (cannot be controlled at the time of dismissal);

    c. Severe pain outside of the normal discomfort;

    d. Severe swelling outside of the normal post-operative swelling;

    e. Significant infection not responding to routine antibiotic use;

*CBCT Analysis*

Ridge dimensions before and after were measured from the CBCT scans using InVivoDental imaging software program (Anatomage Incorporated, San Jose, CA, USA), as modified from Pramstaller et al.[35]  Briefly, a digital line parallel to the CT scan plane was traced passing through the CEJ of the tooth mesial to the tooth to be extracted. This digital line was visualized on the section of interest (SOI) as a reference point (P) to assess the relative alveolar crest position mesial and distal to the study tooth. On the SOI selected for the radiographic recordings, lines were traced parallel to the CT scan plane and passing through (i) P (hCEJ), (ii) 7mm apically to the hCEJ , (iii) 10 mm apically to the hCEJ.  Bone width was measured as the width (in mm) of the alveolar crest recorded on h7mm (width measured 7 mm from the hCEJ) and h10mm (width measured 10 mm from the hCEJ). Relative vertical ridge position (RVRP), i.e, the distance between hCEJ and crest of the ridge (hCrest), was measured both mesially and distally for both compression and non-compression groups. In sites where the P could not be measured based on the adjacent CEJs, the edge of single crown margin was used.  All measurements will be performed using a digital ruler at 0.1 mm increments by a single trained examiner. (DB)

*Statistical Analysis*

Repeatability of the measurements was evaluated using intra-class correlation coefficients (ICCs), paired t-tests, and Bland-Altman plots. Baseline, follow-up, and changes in the relative ridge height and bone width measurements were summarized by group (mean, standard deviation, standard error, range).  Comparisons between the two

groups for differences in the changes in the rVRP and bone width measurements were performed using a non-parametric test (Mann Whitney 'U'). Significance was established following reporting of (Z statistic, P-value, and U-Value).

All post-study power calculations assume two-sided tests conducted at a 5% significance level, observed sample sizes of 8 per group for compression and 6 per group for no compression, and used the observed standard deviations. For changes within groups, the study had 80% power to find a 3.35mm change in width at 7mm in compression, a 2.1mm change in width at 10mm in compression, a 4.45mm change in width at 7mm in no compression, and a 5mm change in width at 10mm in no compression. The study had 80% power to find a 1.6mm change in mesial RVRP in compression, a 1.2mm change in distal RVRP in compression, a 1.4mm change in mesial RVRP in no compression, and a 0.7mm change in distal RVRP in no compression. The study had 80% power to find a 5mm change in ridge width at 7mm and at 10mm different between groups. The study had 80% power to find a 2.1mm change in mesial RVRP and a 1.5mm change in distal RVRP different between groups.

RESULTS

Sixteen subjects were screened for the study of which fourteen met the inclusion criteria and participated to completion of the study. Eight subjects were randomized into the compression group. Six subjects were randomized into the non-compression group. Nine subjects presented with a tooth in the maxillary arch to be extracted. Five subjects presented with a tooth in the mandibular arch to be extracted. (Figures 1-3) All subjects were seen at the minimum for a screening visit, initial CBCT scan, extractions, at least one POT visit and three month appointment where a final CBCT was taken.

*Repeatibility of measurements:*

Measurements were repeated for 10 subjects. Table 1) ICCs were high (>0.9) for lingual bone 7mm from CEJ, total ridge width 7mm from CEJ, total ridge width 10mm from CEJ, CEJ to buccal bone, and CEJ to mesial bone, however for total ridge width 7mm from CEJ, CEJ to buccal bone, and CEJ to mesial bone then first measurement was consistently lower than the second (this can be seen in the significance of the paired t-test and in the Bland-Altman plots). (Figures 4-11) For buccal bone 7mm from CEJ and CEJ to distal bone, the images with smaller measurements were higher the first time than the second time while the images with larger measurements were lower the first time than the second time. The measurements for CEJ to lingual/palatal bone showed some lack of agreement (ICC=0.78) but there was not a specific pattern to the disagreements.

*CBCT analysis - Ridge Width*

Compression:

The participants who were randomized into the compression group (n=8) had an initial mean ridge width of 8.74 ± 1.22 mm at h7mm. The final mean ridge width at h7mm was 5.25 ± 3.08 mm.  The 3 month mean change in the ridge width at h7mm (Figure 12) was statistically significant (p=0.02) and was 3.48 ± 2.90 mm.  The initial mean ridge width of this group was 8.85 ± 1.36 mm at h10mm.  The final mean ridge width when measured at the same height was 6.17 ± 2.57 mm. There was a significant (p=0.03) change in ridge width at this level, i.e. 2.68 ± 2.84 mm (Figure 13) 3 months after extraction.

Non-compression:

The participants who were randomized into the non-compression group (n=6) had an initial mean ridge width of 9.91 ± 1.84 mm at h7mm.  The final mean ridge measured at this level was 8.24 ± 2.57 mm and the 3 month mean change in ridge width  was 2.02 ± 3.07 mm (Figure 14) but this was not statistically significant (p=0.21). At h10mm the initial mean ridge width was 10.11 ± 2.27 mm and the final mean ridge width was 7.37 ± 4.09 mm. Nevertheless, the 3 month mean ridge width of 2.01 ± 3.50 mm was not significant at p = 0.12. (Figure 15)

Compression vs. Non-compression:

The change in ridge width at h7mm (Figure 16) between the compressed group (3.48 ± 2.89 mm) and the non-compressed group (2.02 ± 3.07) was not statistically

significant (Z-Score=1.0979; p-value = 0.27, U-value = 12. The critical value of U at $p \leq$ 0.05 is 6).  The change in ridge width at h10mm (Figure 17) between the compressed group (2.68 ± 2.64 mm) and the non-compressed group (2.01 ± 3.50 mm) was also not statistically significant (Z-Score=0.5123, p-value = 0.61; U= 16 and critical value of U at $p \leq 0.05$ is 6).

*CBCT analysis - Relative vertical ridge position:*

Compression Group:

In the compression group the initial RVRP was 2.44 ± 1.09 mm apical to CEJ on the mesial aspect of the tooth and the final RVRP was 3.29 ± 0.84 mm.  The mean change in mesial RVRP (Figure 18) in 3 months was -0.85 ± 1.37 mm. This change was not statistically significant (p=0.12).  On the distal aspect the initial RVRP for this group was 3.38 ± 0.87 mm and the final RVRP was 4.04 ± 1.00 mm.  The mean change (Figure 19) in distal RVRP in 3 months was -0.66 ±0.73 mm, but this change was not statistically significant (P=0.08).

Non-compression Group:

In this group the mesial RVRP was initially 3.93 ± 2.76 mm and at three months was 3.85 ± 2.21 mm.  This change in mesial RVRP i.e., 0.07 ± 0.95 mm (Figure 20) was not significant (p=0.86). Similarly the distal RVRP was initially 3.85 ± 2.21 mm and at three months was 4.99 ± 1.99 mm.  This mean change of distal RVRP i.e., -1.13 ± 0.69 mm (Figure 21) was statistically significant (p= 0.01).

Compression vs. Non-compression:

When the change in mesial RVRP of the compressed group (-0.85 ± 1.37 mm) was compared (Figure 22) with the change in the non-compressed group (0.07 ± 0.95) no statistical significance (Z-Score = -1.61; P=0.11; The U-value was 11 and the critical value of U at p≤ 0.05 was 8) was noted. Similarly the differences of change in distal RVRP (Figure 23) between the 2 (Compressed = –0.66 ± 0.73 mm; and non-compressed=-1.13 ± 0.69) was also not statistically significant (Z-Score=0.97; P=0.33; the U-value was 16 and the critical value of U at p ≤ 0.05 was 8.

*Clinical Measurements:*

All of the subjects had horizontal ridge measurements completed immediately after extraction and five minutes after the extraction with either compression or no compression. Twelve of the fourteen subjects presented at weeks one, two and four in order to have their wound opening/extraction sites measured. All subjects had wounds that were incompletely epithelialized at weeks one and two. By week four, only one subject's in the compression group had an extraction site that was completely epithelialized (maxillary tooth). At three months, all subjects presented with extraction sites that were complete epithelialized.

Compression Group:

In the compression group, immediately following the extraction, the mean ridge width was 8.71 ± 2.14 mm. Five minutes following the extraction, the mean ridge width

was 8.86 ± 1.95 mm. This change in clinical ridge width was not statistically significant (p=0.60). At the post-operative follow-up visits, the mean wound openings dimensions for the compression group were as follows; 3.6 ± 1.14 mm at week 1, 3.00 ± 0.71 mm at week 2, and 0.33 ± 0.82 mm at week 4. Changes in wound dimension from week one to week two was not significant (p= 0.37) (weeks 1-2), but changes from 2-4 weeks (p=0.01) and 1-4 weeks (p=0.01) were statistically significant.

Non-compression group:

In the non-compression group, immediately following extraction, the mean clinical ridge width was 8.5 ± 1.76 mm. Five minutes following compression, the mean ridge width was 8.17 ± 1.72 mm. This dimensional change was not significant (p=0.53). At the post-operative follow-up visits, the mean wound openings for the non-compression group were 4.33 ± 2.80 mm at week 1, 3.50 ± 2.26 mm at week 2, 0 at week 4. These changes were statistically significant for 1-2 week (p=0.04); 2-4 weeks (p=0.01) and weeks 1-4 (p=0.01).

Compression vs. Non-compression:

When changes in wound opening dimensions were compared with the Mann Whitney U test between compression and non-compression, groups no statistical significance was noted. For comparisons at weeks 1-2 (Figure 24), the Z-Score was 0.27 and the p-value was 0.79. The U-value was 13 but the critical value of U at p≤ 0.05 was 3. For weeks 2-4, (Figure 25) the Z-Score was 0.27 and the p-value was 0.79. The U-value was 13 but the critical value of U at p≤ 0.05 is 3. Similarly for weeks 1-4, (Figure

26) the Z-Score is -0.09 and the p-value is 0.93. The U-value likewise was 14 but the critical value of U at p≤ 0.05 is 3.

*Adverse Events*

In the subject total population of 14, there was only one adverse event that was noted (Figure 27) namely alveolar osteitis.  The adverse event was noted in the mandible of a subject from the compression group. No bone was present 7 mm from the CEJ in the mandible of one subject in the non-compression group 3 months after extraction based on the CBCT measurements.

TABLES AND FIGURES

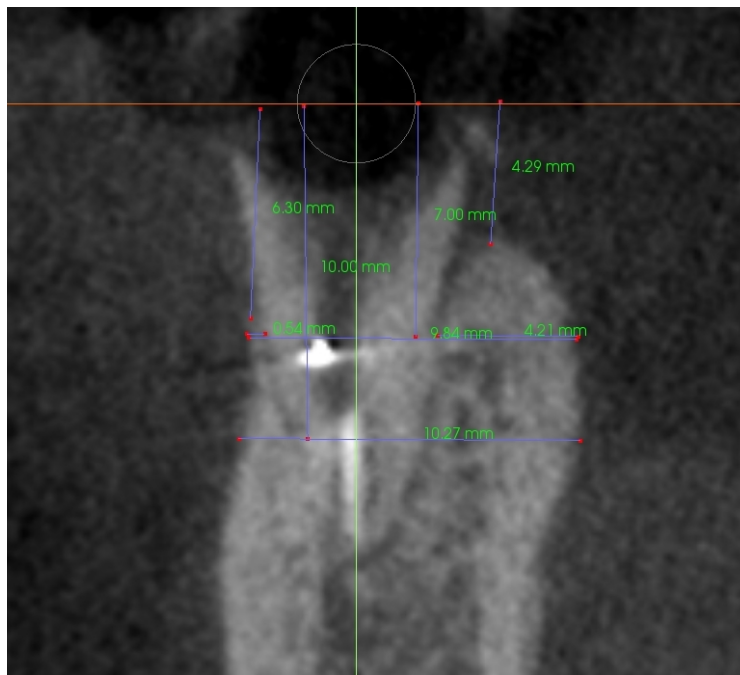Image 1:   Image is a sample CBCT slice taken from the sagittal plane. Image shows measurements including the Ridge width (at h7mm and h10mm)
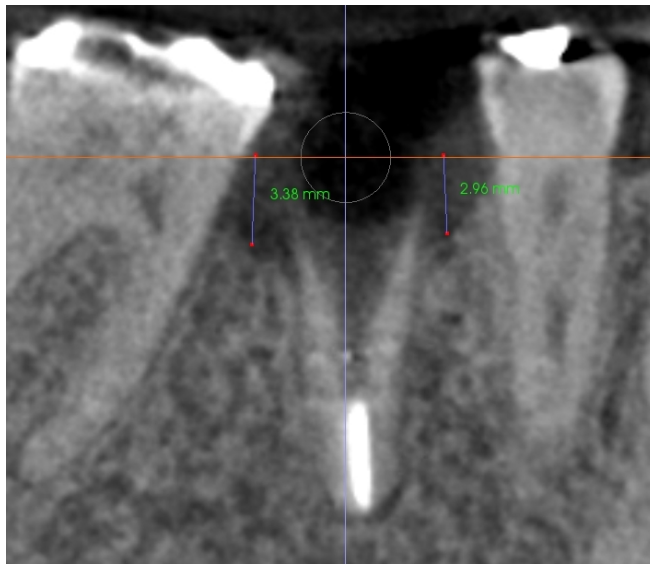
Image 2:   Image is a sample CBCT slice taken from the frontal plane. Image shows measurements including the RVRP mesial and distal to a hopeless tooth.
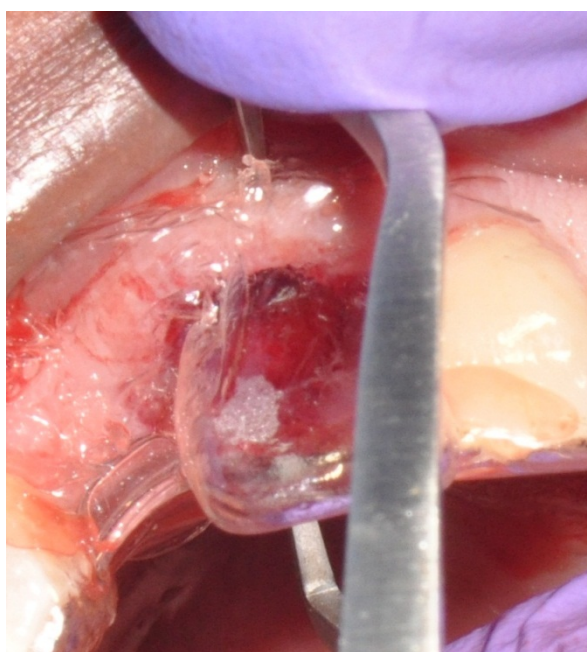
Image 3:   Illustration of measurement of the ridge width using calipers and an acrylic stent following extraction of the study tooth.

Image 4:   Illustration of measurement of the wound opening using a North Carolina #15 periodontal probe and an acrylic stent following extraction of the study tooth.
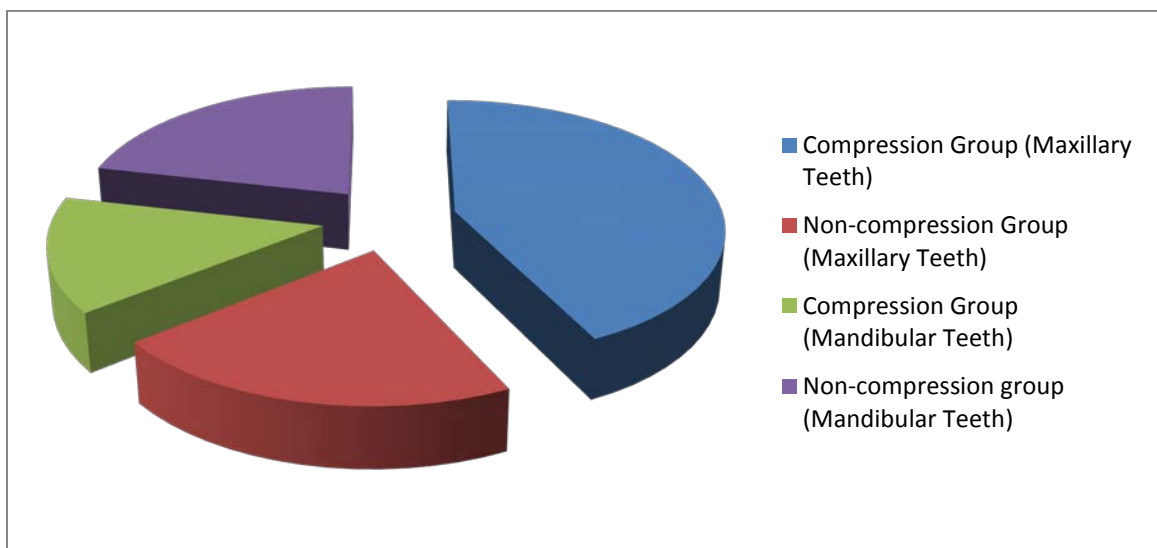
Figure 1:  Figure denotes each group in which group teeth were included. The largest section represents the number of teeth in the maxilla that were included in the compression group (6). The second largest sections represent the number of teeth in the maxilla that were included in the non-compression group and the number of mandibular teeth included in the non-compression group (3). The smallest section represents the number of mandibular teeth present in the compression group.

Figure 2:   This image shows a comparison between teeth found in the maxilla and mandible. The largest section represents the number of teeth present in the maxilla (9). The smaller section represents the number of teeth present in the mandible (5).

Figure 3: This image compares the difference in sample size between the compression (8) and non-compression (6) groups.

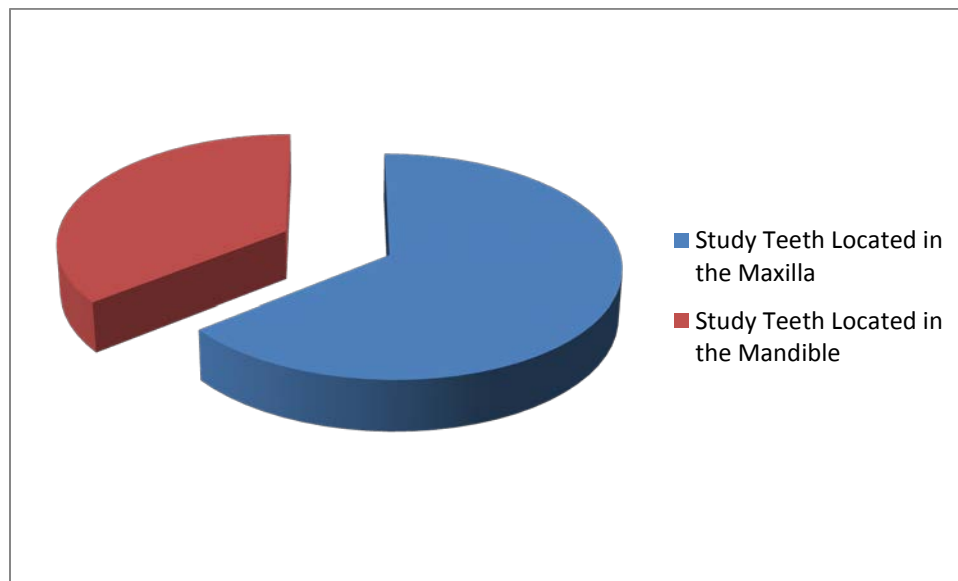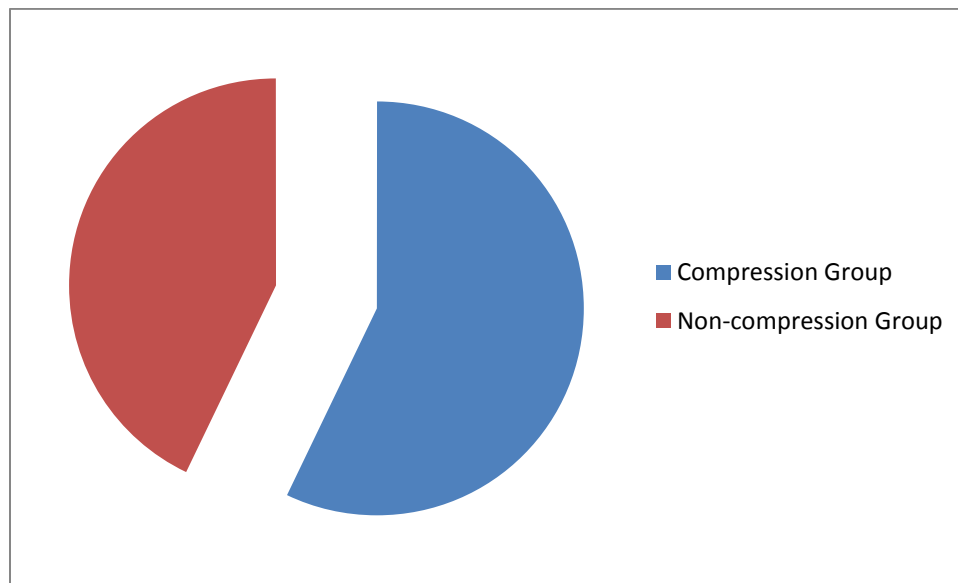| | Mean (SE) 1st | Mean (SE) 2nd | Difference Mean (SE) | Min | Max | p-value | Within-subject SD | ICC |
|---|---|---|---|---|---|---|---|---|
| buccal bone 7mm from CEJ | 1.36 (0.16) | 1.42 (0.16) | -0.07 (0.11) | -0.70 | 0.28 | 0.56 | 0.23 | 0.77 |
| lingual bone 7mm from CEJ | 2.23 (0.28) | 2.31 (0.28) | -0.09 (0.09) | -0.71 | 0.28 | 0.39 | 0.21 | 0.94 |
| total ridge width 7mm from CEJ | 10.31 (0.52) | 10.80 (0.52) | -0.49 (0.13) | -1.01 | 0.42 | 0.0042 | 0.44 | 0.93 |
| total ridge width 10mm from CEJ | 10.67 (0.63) | 10.84 (0.63) | -0.17 (0.19) | -1.40 | 0.60 | 0.39 | 0.42 | 0.95 |
| CEJ to buccal bone | 3.53 (0.49) | 3.86 (0.49) | -0.34 (0.09) | -0.73 | 0.00 | 0.0037 | 0.30 | 0.96 |
| CEJ to lingual/palatal bone | 3.59 (0.29) | 3.73 (0.29) | -0.13 (0.20) | -1.13 | 1.07 | 0.51 | 0.43 | 0.78 |
| CEJ to mesial bone | 1.75 (0.17) | 1.87 (0.17) | -0.12 (0.05) | -0.34 | 0.14 | 0.0345 | 0.13 | 0.94 |
| CEJ to distal bone | 2.36 (0.31) | 2.63 (0.31) | -0.27 (0.18) | -1.31 | 0.70 | 0.17 | 0.43 | 0.82 |

Table 1: Reliability measurements used to evaluate level of calibration prior to initiating study measurements

buccal bone 7mm from CEJ

Figure 4:   Comparison of the difference between repeated measurements and the average of repeated measurements for buccal bone at h7mm

Figure 5:   Comparison of the difference between repeated measurements and the average of repeated measurements for lingual bone measured at h7mm

Figure 6: Comparison of the difference between repeated measurements and the average of repeated measurements for total ridge width measured at h7mm

total ridge width 10mm from CEJ
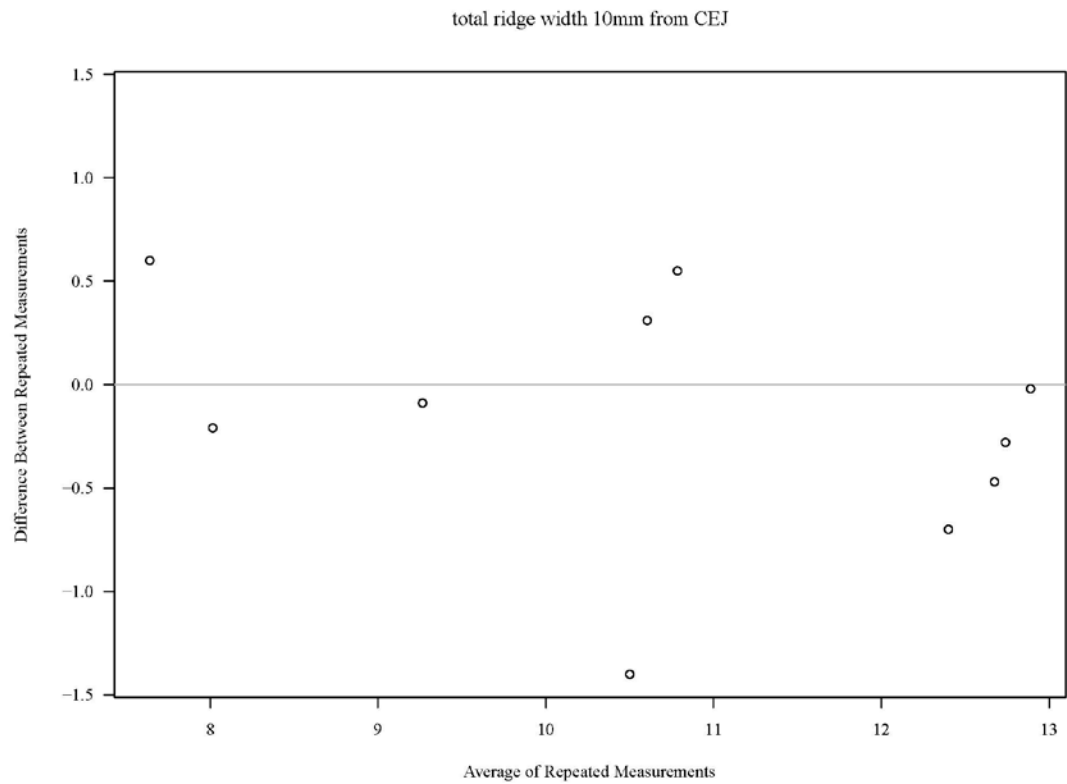
Figure 7:   Comparison of the difference between repeated measurements and the average
of repeated measurements for total ridge width measured at h10mm
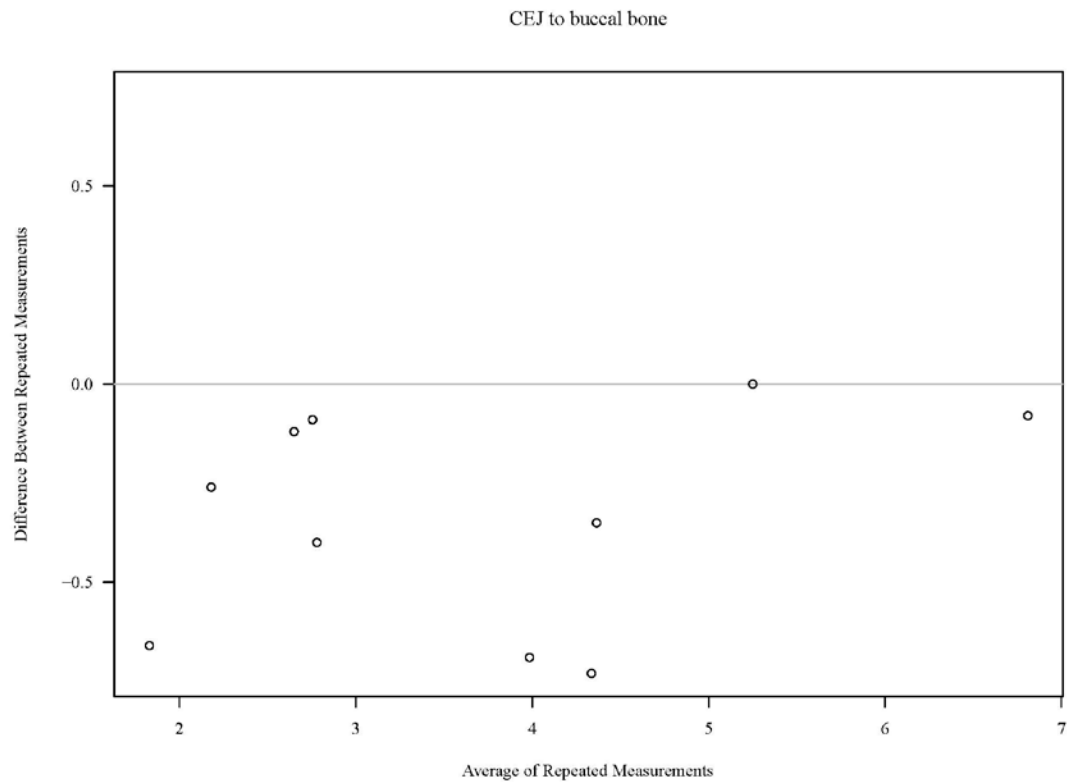
CEJ to buccal bone



Figure 8:  Comparison of the difference between repeated measurements and the average
of repeated measurements measured from the CEJ to the height of the buccal
bone
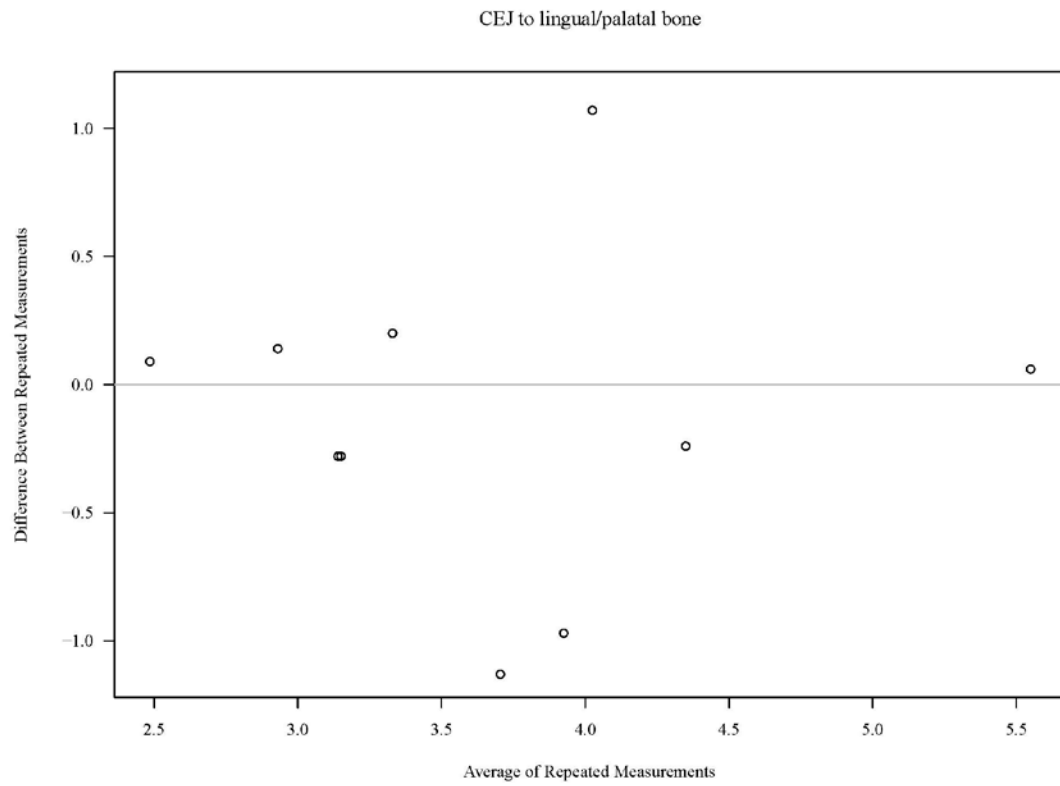
Figure 9:   Comparison of the difference between repeated measurements and the average of repeated measurements measured from the CEJ to the height of the lingual or palatal bone
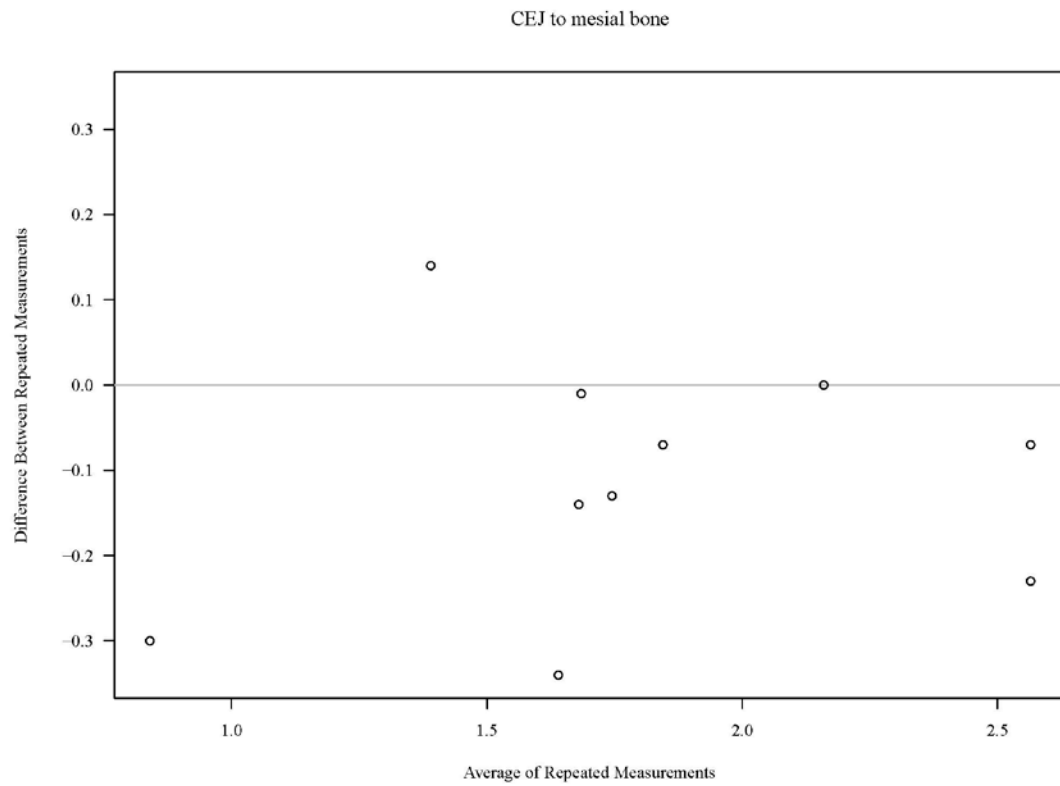
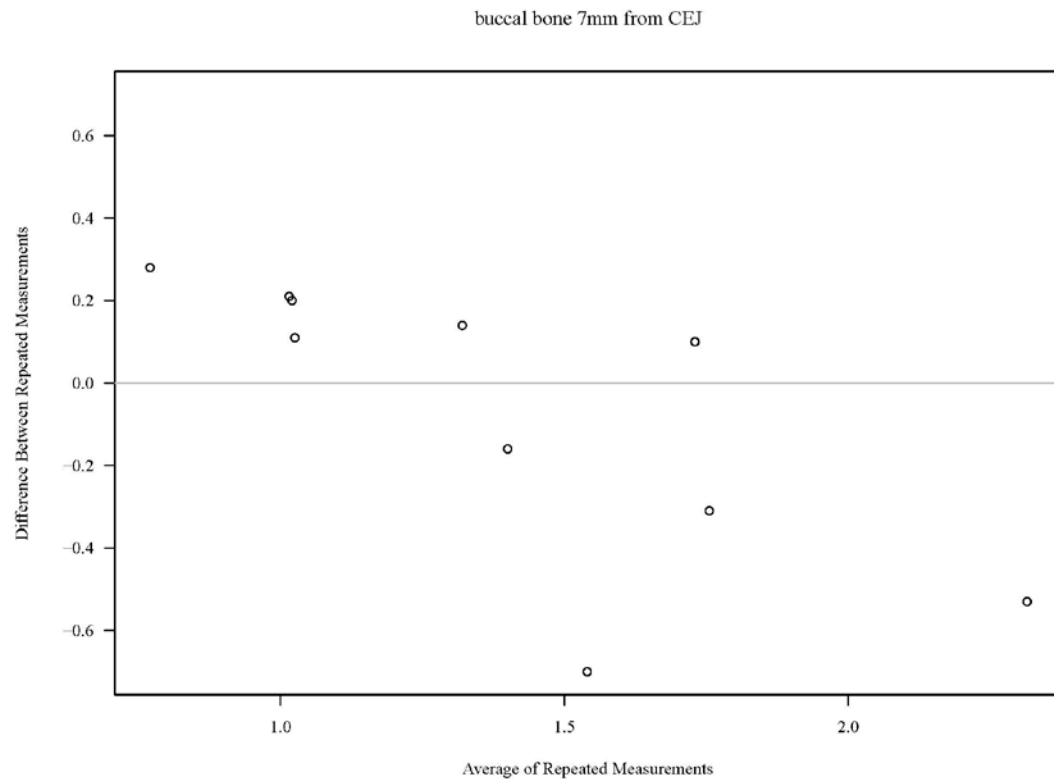Figure 10: Comparison of the difference between repeated measurements and the average of repeated measurements measured from the CEJ to the height of the mesial bone
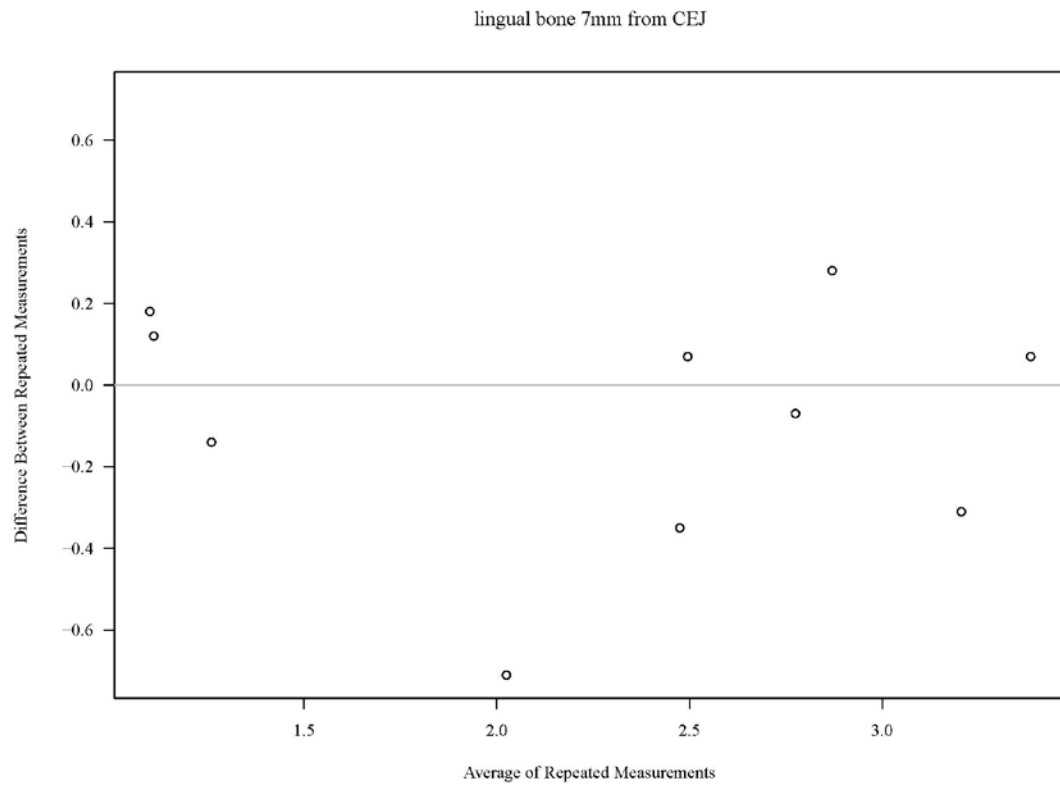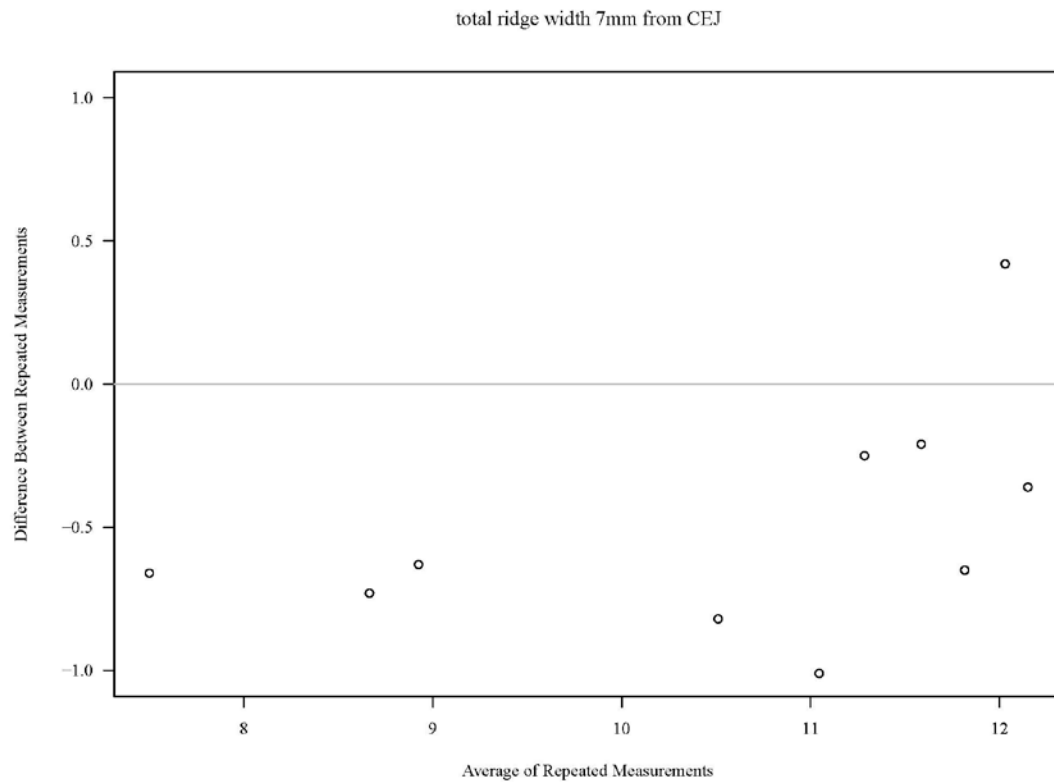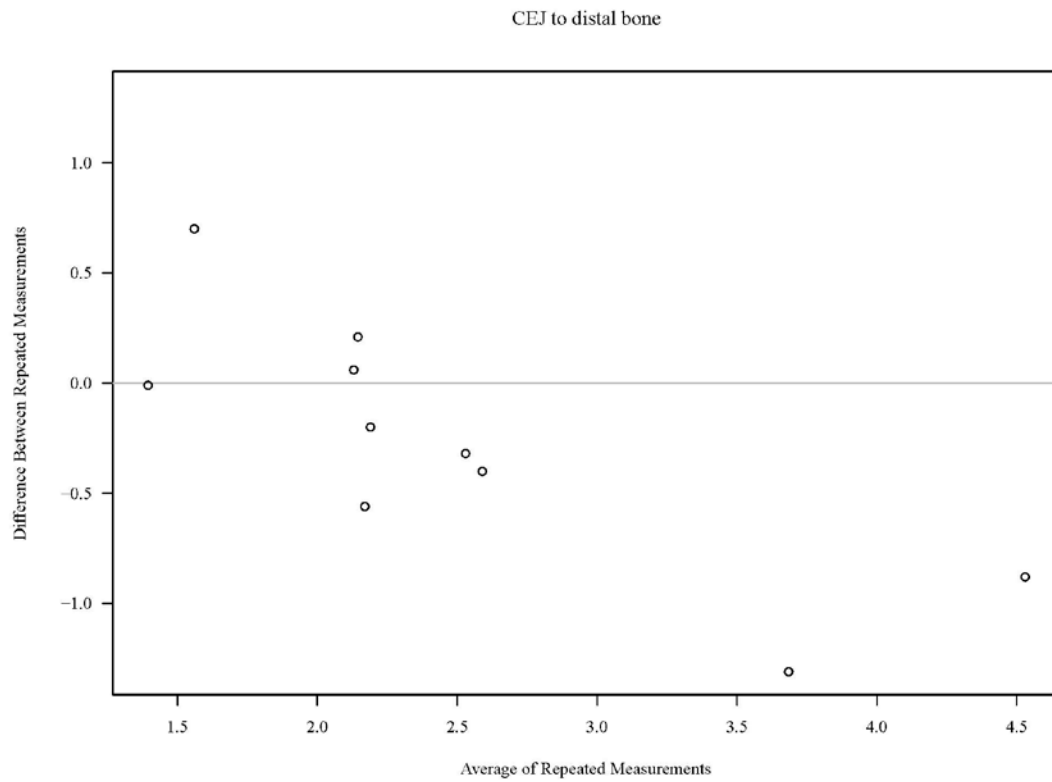
Figure 11: Comparison of the difference between repeated measurements and the average of repeated measurements measured from the CEJ to the height of the distal bone
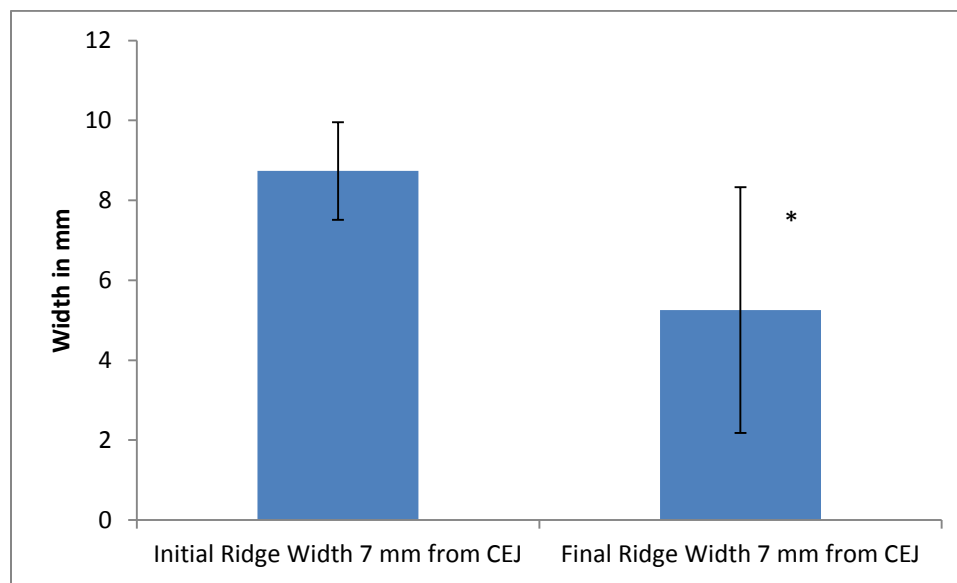
Figure 12: Comparison of the initial and final average ridge widths in mm in the compression group at h7mm. The mean change in ridge width was significant.
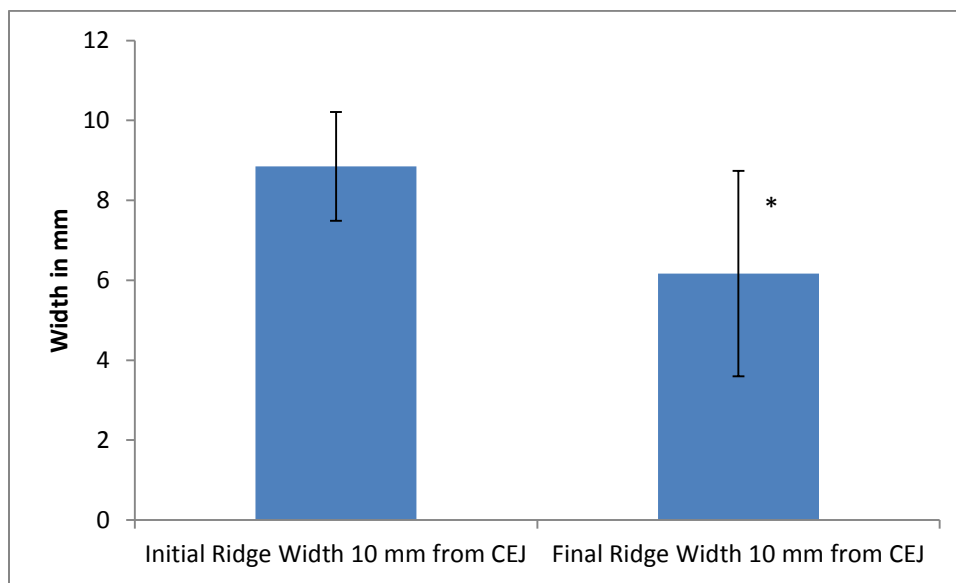
Figure 13: The graph displays the initial and final average ridge widths in mm in the compression group when measured 10 mm from the CEJ. The mean change in ridge width was significant.
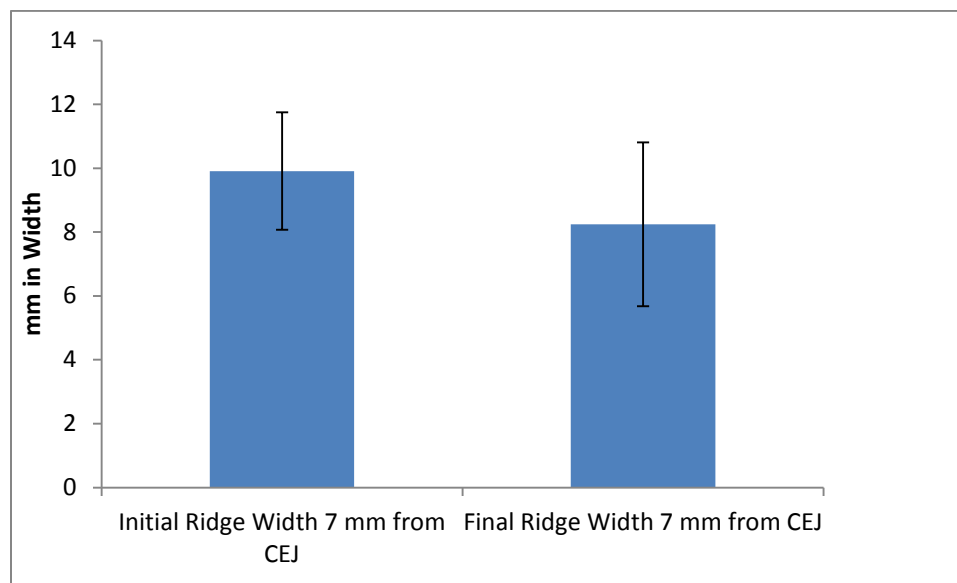
Figure 14: The graph displays the initial and final average ridge widths in mm in the non-compression group when measured 7 mm from the CEJ. The mean change in ridge width was not significant.
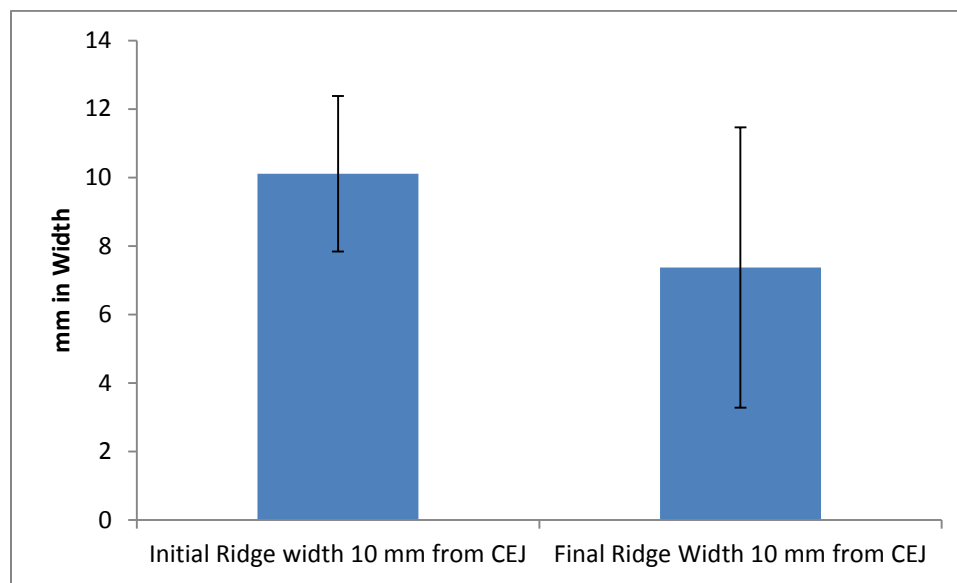
Figure 15: The graph displays the initial and final average ridge widths in mm in the non-compression group when measured 10 mm from the CEJ. The mean change in ridge width was not significant.
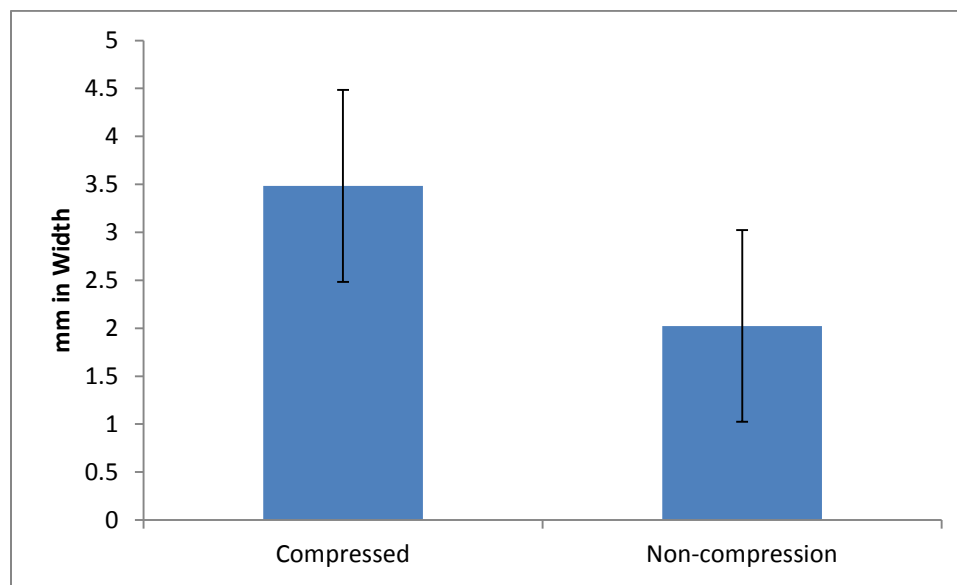
Figure 16: The image compares the average change in ridge width (in mm) when measured 7 mm from the CEJ in both the compression and non-compression groups.
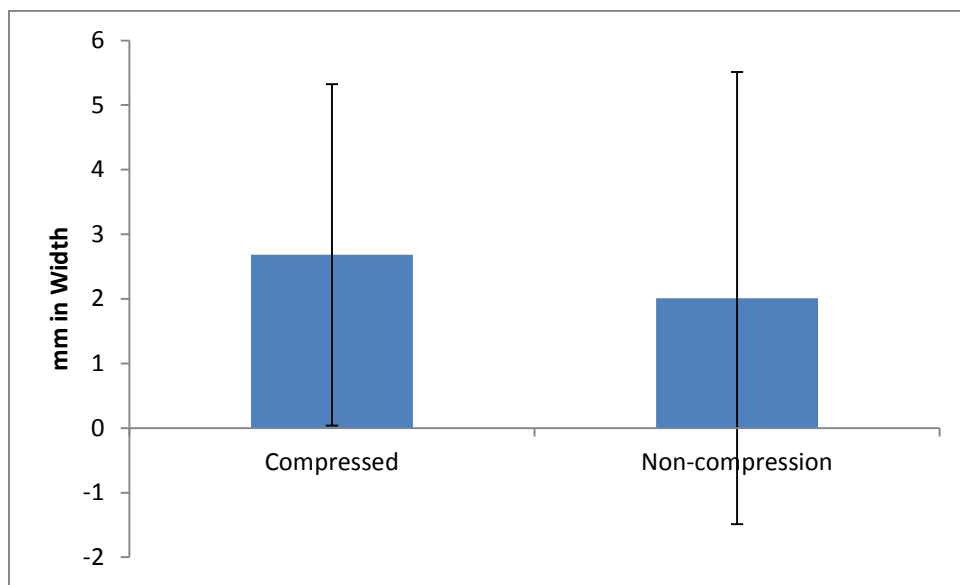
Figure 17: The image compares the average change in ridge width (in mm) when measured 10 mm in both the compression and non-compression groups. The results were not significant.
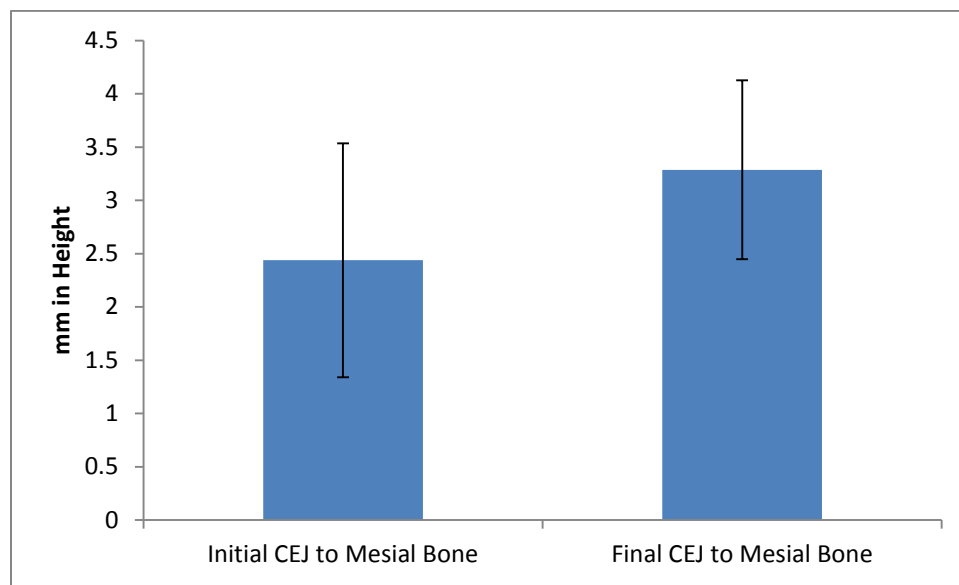
Figure 18: The graph shows the average initial and final distances (in mm) from the CEJ to the alveolar crest mesial to the teeth in the compression group.
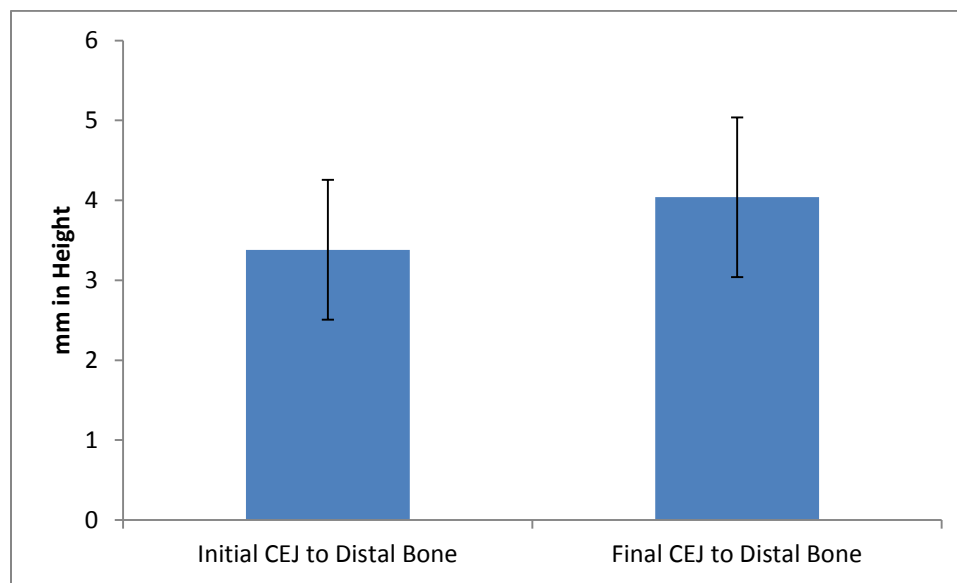
Figure 19: The graph shows the average initial and final distances (in mm) from the CEJ
to the alveolar crest distal to the teeth in the compression group.
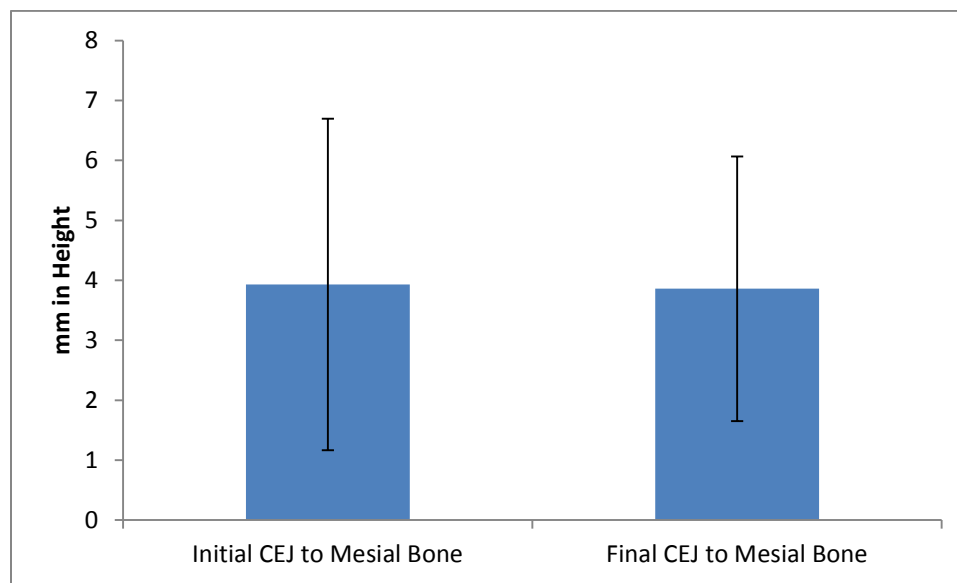
Figure 20: The graph shows the average initial and final distances (in mm) from the CEJ to the alveolar crest mesial to the teeth in the non-compression group. The mean change was not significant.
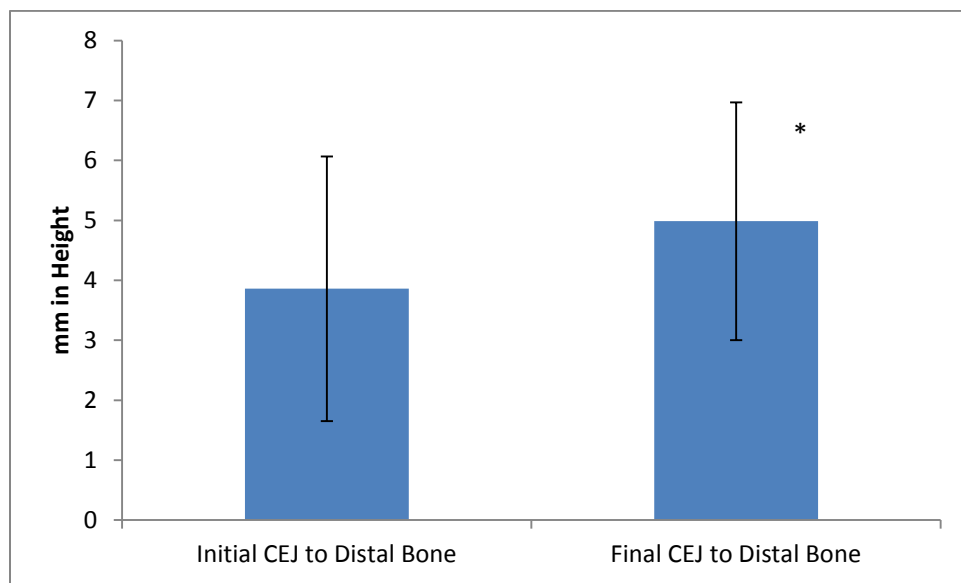
Figure 21: The graph shows the mean initial and final distances (in mm) from the CEJ to the alveolar crest distal to the teeth in the non-compression group. The change in the mean final distance is significant.
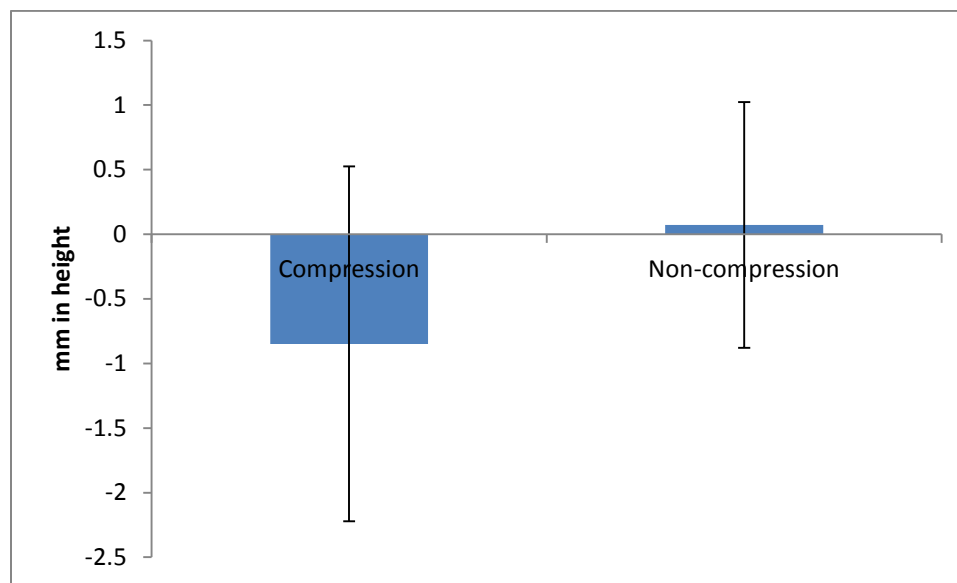
Figure 22: The distance shows the comparison of average changes in height in the compression and non-compression groups measured mesial to the CEJs. No significant differences were found.
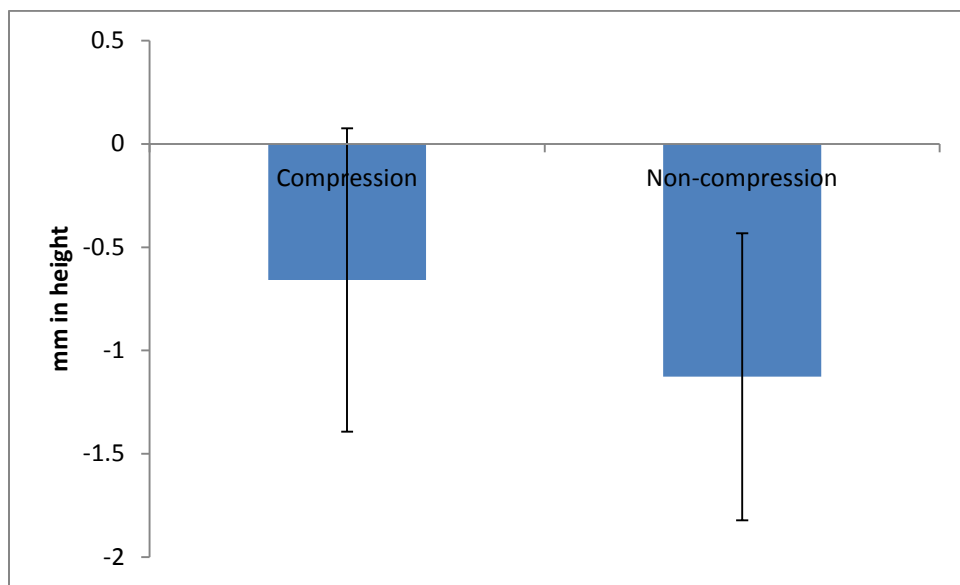
Figure 23: The image shows the comparison of the mean changes in height in the compression and non-compression groups measured distal to the CEJs. No significant differences were found.
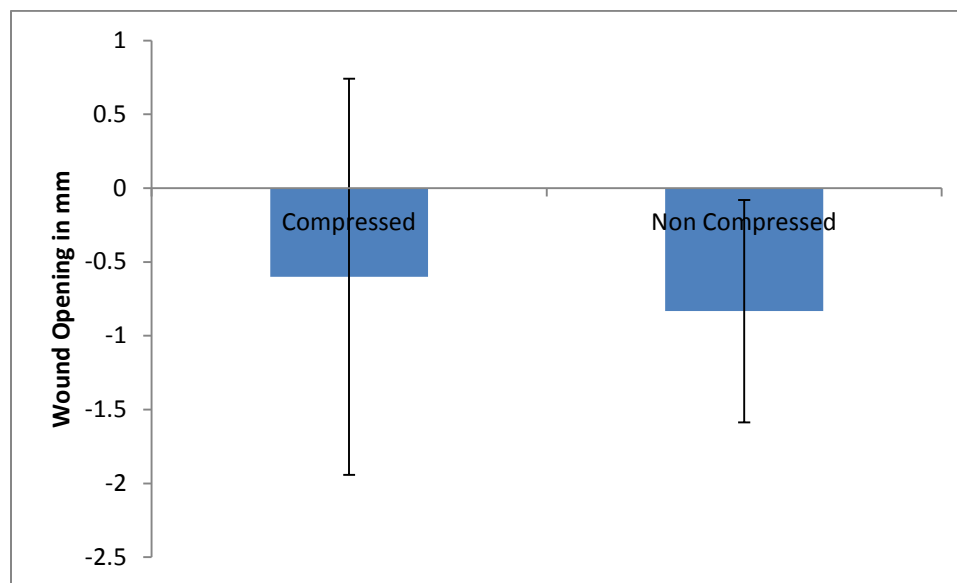
Figure 24: The image displays the mean change in wound healing (in mm) in both compression and non-compression group between weeks one and two. The difference between the two groups is not significant.
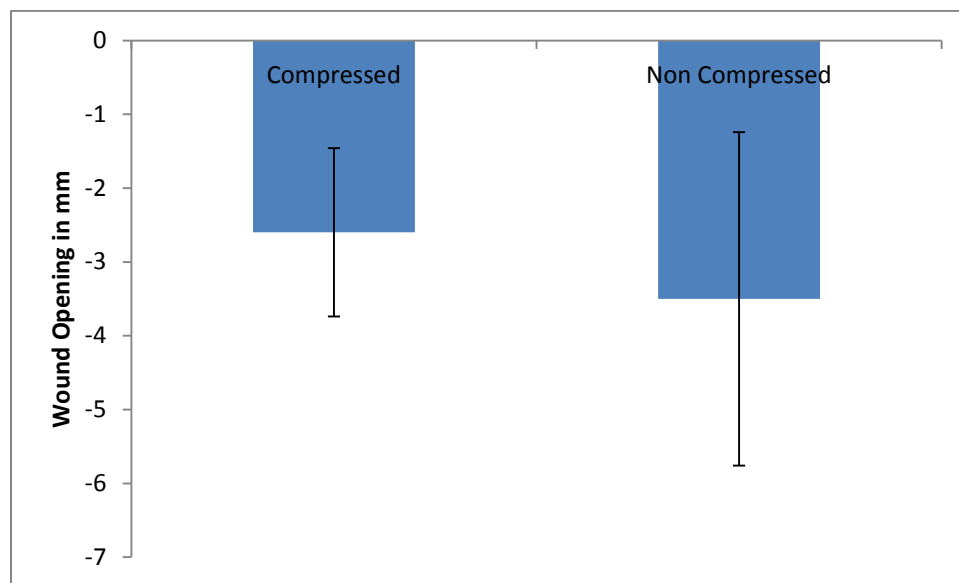
Figure 25: The image compares the mean change in wound healing (in mm) in compression and non-compression groups between weeks two and four. The difference between the two groups is not significant.
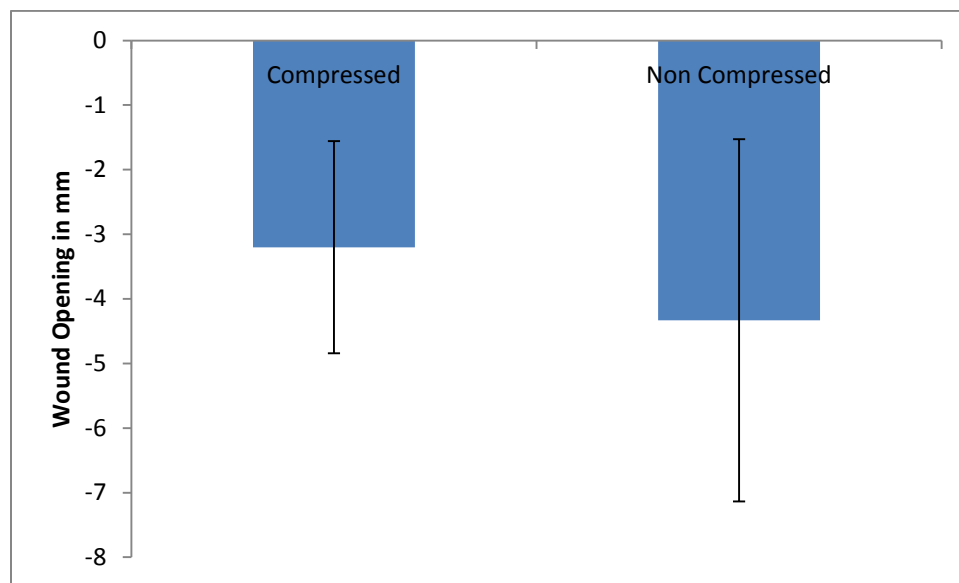
Figure 26: The image compares the mean change in wound healing (in mm) in the compression and non-compression groups between weeks one and four. The difference between the two groups is not significant.
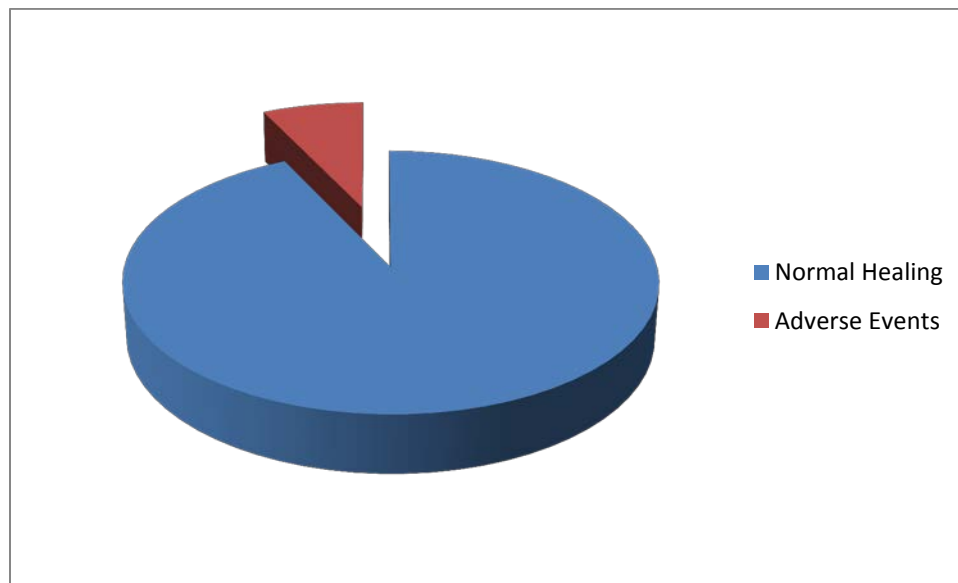
Figure 27: This image shows a comparison between the numbers of subjects who experienced an adverse event (1) verses those who didn't (2).

DISCUSSION

Techniques of exodontia have remained relatively unchanged for the last 100 years. Extracted teeth have traditionally been replaced with removable partial dentures or fixed partial dentures. Replacement of extracted teeth with dental implants is increasingly becoming the treatment of choice.[36] Due to this, different techniques for site development after dental extraction have evolved.[37] Greater emphasis is also placed on controlling how a site remodels after dental extraction.[38, 39] Better techniques of dental extraction that minimize trauma to the extraction site partly aid in this process. By reducing the trauma to the site, the residual ridge post-extraction is more predictable.[40, 41]

Socket compression has been documented consistently in oral surgery texts as a part of the protocol for the proper extraction/post-extraction technique.[3-8, 10, 11] Surgeons intuitively omit this step post-extraction because it appears to be counterproductive to compress a site where ridge dimensional preservation is aimed.[13] This study explored the effects of socket compression on ridge dimension in comparison to changes when sockets are not compressed. Additionally, it documented adverse events that occurred when either of these techniques was utilized.

Interestingly, the compression group showed significant reduction in ridge width both at 7mm (39.88%) and 10mm (30.30%) apical to CEJ of adjacent tooth (Figures 12 and 13). In contrast, in the non-compression group, changes in ridge width were not statistically significant both at 7mm (16.85%) and 10mm (27.04%) apical to CEJ of adjacent tooth (Figures 14 and 15). Nevertheless, when the changes in ridge width in the two groups were compared, no statistical significance was noted (Figures 16 and 17). The significant 3 month reduction in ridge width in the compression group can be potentially attributed to reduced dimension that may have occurred intra-operatively

when the sockets were compressed. To test this we measured ridge dimension intra-operatively immediately after extraction prior to compression in the compression group and five minutes later with or without compression. (Image 3) Surprisingly, in the compression group there were no significant changes in clinically measured ridge width when measured immediately after extraction (8.71 ± 2.14 mm) and five minutes after extraction (8.86 ± 1.95 mm). In the non-compression group there were no significant changes in ridge width when measured immediately after extraction (8.5 ± 1.76 mm) and five minutes after compression (8.17 ± 1.72 mm) as was anticipated. This is indicative that the differences between compression group and non-compression group cannot be attributed to the immediate dimensional changes that may occur due to compression/re-approximation of the socket walls.

Previous reports indicate that most of the total ridge remodeling occurs in the first 3 months of healing.[42] Therefore, the final ridge measurements that were made can be fairly indicative of the trajectory of ridge remodeling. In both the compression and non-compression groups, total ridge width decreased by less than 40%. Previous studies have shown on an average 50% ridge width loss.[42] Over 5 mm reduction in ridge width can occur in non-grafted sites with 2/3[rds] taking place in the first 3 months.[16] Interestingly, in the present study, in both groups the ridge width reduction on average was only approximately 3.5mm. This reduced loss of dimension as compared to previous reports can potentially be attributed to minimum trauma techniques used in this study. The present study's ridge width change is in line with the dimensional changes reported in Van de Weijdan's[43] systematic review where the mean reduction width was 3.87 mm.

*Relative vertical ridge Position*

Greater vertical dimensional loss has been also reported in non-grafted sites. One systematic review reported an average of 1.3mm reduction in crestal height.[43] To measure this crestal bone loss, the present study calculated the relative vertical ridge position both before and 3 months after extraction in both groups through CBCT analysis as described earlier. In the mesial aspect of both groups, no statistically significant changes in the RVRP were noted. (Figures 18 and 20) In the distal aspect the non-compression group, the distal aspect had a statistically significant higher RVRP after 3 months (Figure 21), but the dimension of change may not be clinically significant (-1.13 $\pm$ 0.69 mm; p = 0.01). Between groups analysis in the RVRP did not reveal any significant differences between the two groups. The present investigation did not explore the location of the crest. However, it has been reported that the crest shifts lingually or palatally due to the loss of buccal bone.[25]

The process and stages of ridge healing have been well documented in the dental literature.[14, 15, 44] Amler[14] described the extraction socket healing in five stages. On day one, a clot formed in the extraction socket. By day four, there was evidence of epithelialization. By day seven, the blood clot was completely replaced by granulation tissue. By day 20, the process of replacing the granulation tissue with connective tissue was active. By day 38, two thirds of the socket fundus was filled with trabeculae. In a dog study, Fickl[45] found that the severity of the extraction affects the amount of bone remodeling that takes place. If the periosteum is separated from the buccal bone, this will lead to more buccal ridge resorption. Extractions that are performed with a flapless

approach lead to significantly less ridge resorption. In humans, relative variability in the initial formation of bone has been reported.[38]

Soft tissue closure:

As discussed earlier, part of the rationale for compression is that it may help to create a faster soft tissue closure due to reduced 'jump' distance for wound healing. Ramfjord found that epithelium migrates at 0.5 mm per day. Additionally, the epithelium would migrate from the edges of the wound towards the center.[46] Therefore, it was speculated that if the distance to migrate or heal was shorter, then healing process may be quicker. To test this, the present study measured soft tissue closure of the socket in the bucco-lingual direction at weeks 1, 2, 4, and every week after extraction continuing until complete clinical closure was noted. When dimensions of the patent wound were compared between week 1 and week 2 to our surprise, we did not see any significant change in the compression group. Comparison between week 1 & week 4, as well as comparison between week 2 & 4, showed statistical significance as expected. In the non-compression group, significant differences were noted as early as week 2 and soft tissue closure at each was significantly different. One explanation could be that there may be a slight retardation of the healing process due to compression resulting in the some delay in the initial healing. Our results may indicate that socket compression may not necessarily decrease wound healing time or soft tissue closure as had been previously speculated.[3, 7] .

*Adverse Events*

There was only one adverse reported in the present investigation, i.e., dry socket (Figure 27). Amler[44] stated that dry sockets result from disturbances in the transition from the blood clot to granulation tissue stage. Historically, dentists have been encouraged to compress the alveolar ridge post-extraction in order to better retain the blood clot so as to avoid dry socket occurrence. It is interesting to note that the one instance of dry socket in our study occurred in the compression group, which is the opposite that one would expect.

*Limitations*

As this was a pilot study, the present investigation included only 14 subjects. Interpretation of the present study's results must be done in the light of the small sample size and its associated limitations. The reliability of the measurements i.e., calibration was done and intra-class correlations were fairly consistent. Nevertheless, correlations were not ideal for measurements that evaluated coronal position of the crest. This could be in part attributed to minor errors that may have occurred in subject orientation when the CBCT scans were taken.

Another limitation is that the compression force used in the compression group may have varied as there was no reliable way of measuring the force of compression. Considerable variations may arise due to various reasons like density, resilience and thickness and quality of bone. The present investigation controlled for operator variations by limiting the compression process to one investigator (DB).

Smoking status was self-reported by each individual and individuals who smoked greater than 20 cigarettes each day were excluded from the study. Meechan[47] found that there are higher incidences of dry sockets or alveolar osteitis in smokers who smoked more than 20 cigarettes each day . Nevertheless, some of the subjects were smokers who reported smoking less than that threshold. The effects of smoking below this threshold may have had potential implications on the ridge dimensional changes and the wound healing process. Tobacco products are widely known to affect wound healing, however, the specific mechanism is unknown.[48] Mayfield found that a single cigarette combined could cause a reduction of peripheral blood velocity by 40%. This is in part because tobacco is a peripheral blood vasoconstrictor. There are also other chemicals such as carbon monoxide that are produced while smoking. These reduce blood flow in the capillaries. In an animal study involving rats, Roberto[49] found that alveolar healing was delayed by nicotine. Angiogenesis was reduced greatly in sites where ossification was took place. Overall, they stated that extraction site healing was affected directly by the amount of nicotine present.  Saldanha[50] found that smoking affected the ridge dimensional reduction of the alveolar ridge post-extraction. Additionally, they found that it could postpone the extraction site's healing.

The sex and age of the subjects were not analyzed with respect to healing time and loss of ridge dimension due to the small sample size. Studies have shown that age can affect the time it takes for sites to heal. This investigation attempted to account for the differences in healing based on age by stringent inclusion and exclusion criteria. Post-menopausal women (women over the age of 50) and older men (men over the age of 75) who have the potential for reduced bone density were excluded from the study. Age and

sex have both been shown to play critical roles in healing.  Engeland[51] found that when controlled for ethnicity, alcohol or nicotine use, or body mass index, older individuals healed significantly slower than younger individuals. They also found that women healed more slowly than men irrespective to the age in which they were measured.  Engeland[52] later found that it is the amount of testosterone present which could be the causative factor in this change in healing with respect to age. Additionally, the effects on slower healing in women at increased ages could be secondary to menopause.

*Clinical Implications*

One present trend in dentistry is moving toward the placement of implants. For implants to be placed there is a critical amount of alveolar ridge width and height that is necessary. Without a critical amount of bone present, dental implants cannot be appropriately placed. It is clear in the literature that sites that are preserved following extraction maintain ridge width significantly greater than those that are not.[24, 45] However, some patients might elect to have a hopeless tooth extracted and manage the replacement options at a later date due to cost, indecision, or lack of knowledge. The dentists who extract these teeth should be aware that compressing the socket may reduce the ridge with. The reduction in ridge width may not necessarily affect the critical mass of bone left for implant placement, but could potentially compromise the esthetic outcome in a particular case.

SUMMARY AND CONCLUSIONS

Exodontia is used in a variety of patient situations including restorative, orthodontic, endodontic, and periodontic patient scenarios. The atraumatic extraction of teeth is preferred to reduce the amount of damage to the buccal/facial, lingual/palatal, interdental and interseptal bone. Yet, the general principles behind how to extract teeth have changed little over the last 100 years.[1, 2] Many extraction techniques are passed down verbally from instructor to student during dental school or in post graduate training. Others have been embedded in the literature with little support for or against them. In today's modern dentistry, some of these techniques may or may not necessarily be favorable, especially in light of replacement of teeth with dental implants where maximum preservation of alveolar bone dimension is desired. One of these techniques is that of post-extraction socket compression.

The purpose of this study was to determine if post-extraction socket compression negatively affects alveolar ridge dimensions when compared to sites that were not compressed post-extraction. Secondary outcome measures were to identify if socket compression/re-approximation affected the rate of soft tissue closure or occurrence of alveolar osteitis.

The present investigation found that with respect to changes in ridge width, sites that were compressed did not lose significantly more dimension than those that were not when multi-group analysis was performed. With respect to ridge height, sites that were compressed did not lose significantly more dimension than those that were not. Sites that were compressed and sites that were not, healed at approximately the same rate, with respect to soft tissue closure.

While the results showed a lack of significance between both groups, ridge width did trend towards the ridge compression group having a smaller ridge width. The small sample size of this pilot study limits the interpretation of the results.

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ABSTRACT

Exodontia, or extraction of teeth, has been a well-documented dental treatment that forms one of the foundations of dentistry. The steps associated with extracting teeth have changed little in the last century and these steps are largely part of the dogma of dentistry. One such step is that of socket compression post-extraction. Rationale for socket compression after extraction is manifold. They include: shorter healing times, fewer dry sockets and re-approximating walls that were stretched in the elevation and delivery stages of extractions. The purpose of this study was to determine if post-extraction ridge compression negatively affected alveolar ridge dimensions when compared to sites that are not compressed post-extraction. Secondary outcome measures will identify if socket compression/re-approximation affects the rate of soft tissue closure or occurrence of alveolar osteitis.

In this study, 14 subjects were recruited. Eight subjects formed the compression group, while six formed the non-compression group. The subjects in the compression group received compression of their alveolar ridges after extraction to approximate their original pre-extraction width. The subjects in the non-compression group did not receive ridge compression. Each subject had pre-extraction and post-extraction CBCT scans along with post-operative follow up visits at 1, 2, and 4 weeks post-extraction.

The present investigation found that with respect to changes in ridge width, sites that were compressed did not lose significantly more dimension than those that were not. With respect to ridge height, sites that were compressed did not lose significantly more dimension than those that were not. Sites that were compressed and sites that were not, healed at approximately the same rate, with respect to soft tissue closure. While the results showed a lack of statistical significance between both groups, there appears to be

a trend towards the ridge compression group having a smaller ridge width. Such a trend was not noted with soft tissue closure, thereby invalidating the rationale for socket compression after extraction. One of the limitations of this pilot study is the small sample size. Further validation of these results must be done with a larger sample size in order to provide clinical guidance to dental practitioners.

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