Title

The Effects of Orthodontic Movement on the Periodontium in the Esthetic Zone: A 12 month follow up study

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Publication Date

2024

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THESIS
Submitted in partial satisfaction of the requirements for degree of
MASTER OF SCIENCE

in

Oral and Craniofacial Sciences

in the

GRADUATE DIVISION
of the
UNIVERSITY OF CALIFORNIA, SAN FRANCISCO

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The Effects of Orthodontic Movement on the Periodontium in the Esthetic Zone:

A 12 month follow up study

Tiffany Tse

ABSTRACT

One of the strongest influential factors of achieving acceptable esthetic orthodontic results is attributed to soft tissue outcomes. Most patients seek orthodontic treatment due to their dissatisfaction of aesthetics. Thus, successful orthodontic treatment is typically measured with proper teeth alignment and soft tissue outcomes such as lack of recession or black triangles. This prospective cohort study evaluates the effects of orthodontic rotation and proclination of teeth in the esthetic zone (canine to canine) on the alveolar bone housing and soft tissue parameters, keratinized tissue width, midfacial recession, papilla height and width, and soft tissue biotype during the first 6 and 12 months of treatment. The patients enrolled in the study are from the University of California, San Francisco postgraduate orthodontic clinic receiving orthodontic treatment. These patients were measured immediately prior to beginning orthodontic treatment, 6 and 12 months after the start of treatment. During the first 12 months of orthodontic treatment, this study found that 1) rotation of the tooth into proper alignment is correlated with a decrease in alveolar housing width at the level of S1; 2) orthodontic rotation has minimal impact on the periodontium in the aesthetic anterior region; 3) changes in the upper centrals inclination are correlated with a decrease in midfacial recession; 4) There is also a positive correlation with an increase in KTW at the level of S1.

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INTRODUCTION

One of the strongest influential factors of achieving acceptable esthetic orthodontic results is attributed to the soft tissue outcomes (Sfondrini et al. 2020). Most patients seek orthodontic teeth treatment due to their dissatisfaction of aesthetics. Thus, parameters of judging whether or not a case is successful is due to patient satisfaction of both proper teeth alignment and lack of recession or black triangles (Abdelhafez et al. 2021). Although there are predictable methods in the treatment of recession through soft tissue surgical augmentation, missing papilla still presents as one of the most challenging clinical situations to correct (Cardaropoli et al. 2005, Monal et al. 2024). Various surgical and nonsurgical methods have been proposed (Monal et al. 2024) to regenerate the missing papilla but there lacks good long term studies. Furthermore, while there are techniques to attempt unsightly recession or papilla absence, it would be more fruitful to be able to avoid corrective procedures in the first place. As a result, it is crucial to understand the effects of orthodontic movement on the periodontium.

There are numerous studies that demonstrate gingival architecture is affected by orthodontic teeth movement (Coatoam et al. 1981, Wang et al. 2019). The different gingival parameters this study will focus on are keratinized tissue width (KTW), midfacial recession, papilla height and width, soft tissue biotype, and plaque index.

The significance of KTW has been evaluated by many studies with differing conclusions. Wang et al. (2019) demonstrated KTW decreased with increasing orthodontic forces and that incisors are more prone to these changes than canines and premolars. Furthermore, the orthodontic intrusion or retraction of teeth did not affect the KTW. In contrast, Alzoman et al. (2021) demonstrated that extrusion, intrusion, and retrusion movements increased KTW while protrusion movements decreased the width of keratinized tissue. Coatoam et al. (1981) reported a significant loss of KTW in lateral incisors and significant gain of KTW in maxillary cuspids and central incisors.

Conflicting studies exist regarding whether orthodontic tooth movements result in mid-facial gingival recessions. Wenstrom et al. (1987) looked at soft tissue changes that were orthodontically moved into areas with varying thickness and quality of periodontal tissues in monkeys. They observed that while the gingival margin became apically displaced during orthodontic movement, that movement was small and only two teeth had demonstrated a loss in connective tissue (Wenstrom et al. 1987). There was no relationship between the initial KTW and the degree of apical displacement of the gingival margin during orthodontic therapy. Morris et al. (2017) was also in agreement as they found no relationship between mandibular incisor proclination during treatment and posttreatment gingival recession. However, their study showed 5.8% of teeth exhibited recession at the end of orthodontic treatment (0.6% had recession >1 mm) and 41.7% of the teeth showed recession after retention, 7.0% of patients showing >1 mm of recession. Another study found that the prevalence of gingival recession after orthodontic treatment was 10.3% (8.6% Miller Class I, 1.7% Miller Class II) and were found predominantly on central incisors (Vasconcelos et al. 2012). It appears that while orthodontic tooth movements may result in mid-facial gingival recessions, the recessions are relatively minor.

Incomplete papilla fill resulting in a "black triangle" in the proximal embrasure between teeth is a strong esthetic concern especially in the visible anterior teeth region. The presence or absence of the interproximal papilla depends on the distance between the crest of the bone and the contact point of adjacent teeth (Tarnow et al. 1992). Papilla is predictably present when the distance from the base of the contact point to the crest of bone was within 5mm (Tarnow et al. 1992). If the distance was 6mm or more, then papilla would not only be less predictable, but as the contact point distance increased, the papilla would actually be more predictably absent

(Tarnow et al. 1992). Orthodontic treatment may stimulate or increase interdental papilla as the realignment of adjacent teeth creates a proper distance of contact point to interdental bone. Kandasamy et al. (2007) evaluated the changes in interdental papilla heights following the alignment of anterior teeth. They found that interdental papilla increased when teeth were orthodontically moved palatally but decreased with teeth were orthodontically moved labially or when diastemas were closed. Jeong et al. (2016) also found a decrease in papilla dimensions after orthodontic closure of diastemas. They noted that papilla height decreased by 0.8mm. However, papilla base thickness increased by 0.5mm after orthodontic closure of maxillary diastemas. It was also noted that papilla dimensions prior to orthodontic treatment were significant influential factors of papilla height and base thickness after diastema closure. Then perhaps it is the plaque-induced inflammation and the thickness (volume) of the marginal soft tissue, rather than the apico-coronal KTW and attached gingiva that are the determining factors for the development of gingival recession and attachment loss during orthodontic movement.

A thin gingival phenotype may predispose the initiation and/or progression of mid-facial recession. Teeth that erupt too buccally have been shown to have thinner width of attached, tissue, which may predispose these teeth to recession either by plaque accumulation and traumatic tooth brushing during orthodontic treatment (Vijayalakshmi et al. 2009). Those with thick gingival phenotype are associated with more favorable clinical outcomes following long term periodontal care. Livia et al. (2022) found that patients who had non-extraction orthodontic treatment performed with controlled forces and biomechanics, did not appear to affect the development of gingival recession or the periodontal health after retention. However, they did note that there was a slight increased risk for buccal gingival recession development for patients with thin gingival phenotype and mainly in patients that had eventually developed gingivitis following the initiation of orthodontic treatment (bleeding on probing developed in 66.6% of patients and 76.2% of patients developed plaque in the anterior teeth) (Livia et al. 2022).

To date, only one study has evaluated the effect of orthodontic treatment on the periodontium. Abedelhafez et al. (2021) evaluated patients who had completed orthodontic treatment versus those that were not indicated for orthodontic treatment. Overall, they did not find significant differences between these two groups when it comes to overall crestal bone level, smile line, recession, and papilla fill. They did note a significant difference in KTW between extraction and non-extraction groups. However, this study did not provide baseline data as the orthodontic patients were evaluated 6 months after orthodontic treatment. Furthermore, there was no clear definition of what does not need orthodontic treatment but can be subjective as most patients desire orthodontic treatment for esthetic reasons. This study was limited to adults and no baseline was noted for patients undergoing orthodontic treatment.

As periodontal soft tissue undergo constant and continuous remodeling throughout orthodontic treatment, the investigation of the changes of soft tissue (KTW, recession, papilla fill, and phenotype) is crucial in understanding the significance of orthodontic alignment on these parameters. By evaluating the effects of specific low orthodontic forces, such as degrees of rotation and proclination of teeth, this study can help clarify specific periodontal tissue changes that happen throughout treatment. Furthermore, as favorable esthetics are a leading goal of successful orthodontic treatment, the teeth most noticeable and therefore most sensitive, to orthodontic movement are those in the anterior region, especially the central incisors. Therefore, this study will evaluate the effects of orthodontic movement on the ongoing periodontal adaptation of teeth in the esthetic zone.

HYPOTHESIS

The effects of orthodontic movements of rotation and inclination on teeth in the esthetic zone would lead to several changes in the periodontium such as 1) a decrease in KTW, 2) an increase in midfacial recession, 3) an alteration in soft tissue phenotype, 4) a change in interdental papilla dimensions (an increase width and a decrease height), and 5) a change in alveolar bone width.

The aim of the study is to 1) describe changes in the periodontal soft tissue parameters that occur during the 12 months of orthodontic treatment and 2) identify potential associations between orthodontic tooth movement and changes in the periodontal hard and soft tissue.

MATERIALS AND METHODS

Study Design

This is a prospective cohort study with a follow up of 1 year from the start of orthodontic treatment. Ethical approval for this study was obtained from the Human Research Protection Program of the Institutional Review board (IRB) at the University of California, San Francisco (UCSF). Patients were selected from the postgraduate orthodontic clinic at UCSF beginning treatment in 2022 through 2024 with either full fixed appliances or removable clear aligners. Initial consultation consisted of an intraoral and extraoral exam, beginning records, and discussion of treatment expectations. At this time, the study investigators were notified if the patient was recommended a non-extraction treatment plan. A cone beam computed tomography (CBCT, Carestream 9600, Carestream Dental, Trophy, Marne La Vallee, France) scan, iTero digital scan (iTero Element Scanner, Align Technology, Tempe, Arizona, USA) of the dentition, and intraoral and extraoral facial photographs were acquired as part of the beginning records. Inclusion and exclusion criteria were checked by evaluating the records. At the final orthodontic consult appointment, patients were informed of the final treatment plan and were informed of the study. Consent forms were obtained for treatment and for research study. Patients were treated with either full fixed appliances with Ormco .022 MBT bracket prescription (Ormco, Brea, California, USA) or Invisalign removable clear aligners (Invisalign, Align Technology, Tempe, Arizona, USA).

Inclusion criteria are: 1) with permanent dentition 11-30 years old at the start of treatment 2) with misaligned, rotated teeth, defined by the American Board of Orthodontics (ABO) model grading system and 3) with a non-extraction orthodontic treatment plan. Exclusion criteria are patients who have: 1) craniofacial anomalies, 2) previous orthodontic treatment or who are currently in treatment, 3) ongoing active periodontal disease, 4) preexisting clinical attachment loss and/or recession, 5) malocclusion does not allow for use of a continuous archwire, 6) congenitally missing or impacted teeth in the esthetic zone.

Orthodontic Protocol

Two orthodontic data collectors (AJ, JO) were calibrated to measure alveolar housing and rotation, and traced all cephalometric radiographs. The intra- and inter-examiner agreement for the two orthodontic examiners (AJ and JO) was > 90% within 5 degrees for rotation measurement and within 0.5 mm for alveolar bone housing measurement by repeating CBCT measurements two times using 12 representative teeth.

The CBCT scans acquired were ones that are normally acquired as part of standard orthodontic care to avoid excess radiation exposure. CBCT images were obtained on the Carestream 9600 machine with the following dimensions: 16x17 cm, 300 µm field of view, 120kV, 5.0 mA, 24.0 second exposure time, and 0.125 voxel resolution. All CBCTs were oriented in the coronal, axial and sagittal planes by two examiners (AJ and JO). Dolphin Imaging (Dolphin Imaging and Management Solutions, Patterson Dental, Chatsworth, California, USA) was used to generate a lateral cephalogram and to measure alveolar bone thickness from the captured CBCT.

Periodontal Protocol

Variables measured for this study were degree of tooth rotation, degree of central incisor proclination, KTW, papilla height and width, papilla fill, soft tissue biotype, mid-facial recession, and plaque index. These variables were measured at three time points: prior to beginning orthodontic treatment (T0), 6 months after beginning orthodontic treatment (T1), and 12 months after beginning orthodontic treatment (T2). Two periodontal providers (GHL, TT) were calibrated to take periodontal measurements. The intra- and inter- examiner agreement for the two periodontal examiners (TT and GHL) was > 90% within 1 mm by repeating clinical measurements two times using 12 representative teeth.

Oral Hygiene Protocol

All patient's received thorough oral hygiene instructions from their respective provider on the day of bonding. Proper brushing using modified Bass (Weng et al. 2023) and flossing techniques with braces and Invisalign were explained and demonstrated to every patient. Participants were instructed to brushing at least twice a day and floss at least once a day. All patients received an oral hygiene kit which includes a toothbrush and orthodontic floss threaders.

Variables And Measurements

Rotation: Dental rotation was measured on iTero digital casts using Dolphin Imaging software. Rotation was assessed by measuring the angle between a constructed vertical line drawn between the central incisors in the maxillary and mandibular arches and the extended line of the incisal edges of each tooth (Figure 1) (Kim et al., 2018 and Al-Jasser et al., 2020).

Incisor Proclination: Lateral cephalograms was constructed from the CBCT data. The lateral cephalogram was traced using Dolphin Imaging software. The angle between the long axis of the upper incisors to the palatal plane (U1-PP) and long access of the lower incisors to the mandibular plane (L1-MP) was measured using Bjork analysis (Figure 2) (Ngan et al. 2015).

Alveolar Housing: The buccal lingual widths of the alveolar housing was measured on Dolphin Imaging software. Each tooth in the maxilla and mandible was measured at three levels apical to the cementoenamel junction (CEJ). Measurements were taken at every 3 mm along the long axis of the tooth: crestal (S1), midroot (S2, 3 mm apical to S1), and apical levels (S3, 3 mm apical S2), respectively (Figure 3) (Chaimongkol et al., 2018).

KTW: The width of keratinized tissue was measured with a UNC probe from the midfacial gingival margin to the mucogingival junction following the long axis of the teeth

(Figure 4).

Interdental papilla fill: Classification of papillary fill was determined based on Norland and Tarnow's classification system (Norland and Tarnow 1998). Papilla fill was classified as normal, Class I, Class II, or Class III (Figure 5). Normal is defined as the complete interdental papilla fill in the embrasure space to the apical extent of the interdental contact point. Class I is defined as the tip of the interdental papilla located between the interdental contact point and the most coronal extent of the interproximal CEJ. Class II is defined as the tip of the interdental papilla lying at or apical to the interproximal CEJ but coronal to the apical extent of the facial CEJ. Class III is defined as the tip of the interdental papilla lying level with or apical to the facial CEJ.

Interdental papilla width and height: Papilla height and width was assessed using a UNC probe. The papilla height is defined as the distance from the base of the papilla to a line connecting the mid-facial soft tissue margin of the two adjacent teeth (Figure 6). Papilla width is defined as the distance between the two adjacent midfacial soft tissue margins (Olsson et al.,1993).

Gingival biotype: The gingival biotype was recorded as "thick" or "thin" based on the probe transparency when a UNC probe placed in the buccal gingival sulcus (De Rouck et al. 2009). Tissue phenotype was determined to be "thin", if the periodontal probe was visible through the gingival margin. Tissue phenotype was determined to be "thick", if the periodontal probe was not visible through the gingival margin (Figure 7).

Mid-facial recession: The amount of mid-facial recession was measured from the CEJ to the most apical point of the facial gingival margin. If the gingival margin was coronal to the CEJ, the recession was recorded as a negative number; if the gingival margin was apical to the CEJ, the recession was recorded as a positive number. The measurement was performed with a UNC probe.

Plaque index: The presence or absence of plaque was recorded at T0, T1, and T2. If plaque is present on any surface of the tooth, that tooth received a score of 1. If plaque was not present on any surface of the tooth, that tooth received a score of 0 (Ainamo & Bay 1975).

Statistical Analysis

Descriptive statistics were calculated to examine trends in the data. Data were summarized using medians and interquartile ranges as the data were not normally distributed. Differences between T0-T1 and T0-T2 were calculated. The average of the differences across all teeth were calculated for each patient. Non-parametric Spearman's correlation tests were used to show associations at a patient level between 1) rotation and periodontal variables, 2) the angle formed between the long axis of upper central incisor and the palatal plane (U1-PP) and periodontal variables at the maxillary centrals, and 3) the angle formed between the long axis of lower central incisor and the mandibular plane (IMPA) and periodontal variables at the mandibular centrals.

RESULTS

Patient Demographics

Initially 21 patients were recruited to participate in the study. Four patients were excluded at the halfway timepoint (T1) and then another four more were unable to complete the study at the final timepoint (T2). Two participants were excluded initially due to a change in treatment plan, thus no longer complying to the inclusion criteria. Four participants were unable to adhere to the follow-up timeline. Two participants completed orthodontic treatment prior to the final time point. A total of 16 patients were included at the 6-month time point and a total of 12 patients were included at the final 12-month time point. There was a final total of 3 males and 9 females ranging from 13-25 years (average age of 15.6 years). The initial malocclusions ranged from class I to class II on molar and canine. On average, T1 was taken at 25.3 ± 3.5 weeks and T2 was taken 56.2 ± 2.9 weeks after T0.

Orthodontic Variables: Rotation and Incisor Inclination

The median change in rotation from T0 to T1 and T0 to T2 was -0.7° and 1.4, respectively. The tooth with the most rotation is upper left canine (10.9° ± 14.3°) and with the least is (0.1° ± 10.0°). The median value of U1-PP at T0 was 112.5° ± 14.3°, at T1 was 109.4° ± 5.9°, and at T2 was 109.8° ± 6.7°. The median value of IMPA at T0 was 95.3° ± 7.9°, at T1 was 94.0° ± 8.0°, and at T2 was 98.1° ± 8.9°. The median change of U1-PP from T2-T0 was 0.6°and IMPA was 4.7°. From T0-T2, incisor inclinations were within the range of normal and were not excessively retroclined nor proclined during treatment.

Periodontal Variables

Hard Tissue: Alveolar Housing

The median change in alveolar housing at the S1 level at 6 months and 12 months were 0mm and -0.2mm, respectively. There were 48.9% of sites decreased at S1 at 6 months and 54% of sites decreased at S1 at 12 months. Upper centrals and upper canines consistently had the most decrease of sites at S1 at both 6 months and 12 months. Lower centrals had the most increase in sites at 6 months but eventually that became more distributed across the lower anteriors at 12 months. Lower anteriors overall had more increase in sites at 12 months as compared to upper anteriors. Of all the sites at 12 months, 54.1% decreased, 43.8% increased, and 2.1% had no change in S1.

The median change in alveolar housing at the S2 level at 6 months and 12 months were -0.1mm and -0.2mm, respectively. There were 52.1% of sites decreased at S2 at 6 months and 53.5% of sites decreased at S2 at 12 months. Upper centrals had the most decrease of sites at S2 at both 6 and 12 months. Lower centrals had the most increase of sites at S2 at both 6 and 12 months. Of all the sites at 12 months, 53.5% decreased, 42.6% increased, and 4.2% had no change in S2.

The median change in alveolar housing at the S3 level at 6 months and 12 months were -0.2mm and -0.6mm, respectively. There were 61.5% of sites decreased at S3 at 6 months and 57.6% of sites decreased at S3 at 12 months. Lower canines and upper centrals had the most amount of sites with decrease at 6 months and 12 months, respectively. Upper canines had the most sites with increase at both 6 and 12 months. Of all the sites at 12 months, 57.6% decreased, 37.5% increased, and 4.9% had no change in S3.

Soft Tissue: Gingival phenotype, midfacial recession, keratinized tissue width, papilla fill, papilla width, papilla height

At 6 and 12 months, no changes in gingival phenotype were noted at 65.2% and 51.4%, respectively. At baseline, T1 and T2, thick phenotype were noted at 73.2%, 68.1%, and 75.7% of sites, respectively. Lower right lateral incisor exhibited the least amount of change and maxillary centrals had the most amount of change from thin to thick.

Midfacial recession decreased (44.4%) or remained the same (41.7%) at the final 12 months. The magnitude of recession decrease was 1mm in 77.2% and 68.8% at 6 and 12 months, respectively. The magnitude of recession increase was 1mm in 12.0% and 13.9% at 6 and 12 months, respectively. Recession was decreased the most in lower canines at 6 and 12 months, whereas recession increased the most at upper centrals at 6 months and lower centrals at 12 months. Overall, 41.7% of sites showed no changes in midfacial recession.

The average change in KTW at 6 months was 0.22mm and 0.15mm at 12 months. KTW remained the same in 37.0% of sites at 6 months and 41.7% at 12 months. Maxillary central had the least amount of KTW change. KTW decreased in 24.0% of sites at 6 months and 27.1% at 12 months. Lower laterals decreased the most in KTW. Additionally, KTW increased in 39.0% of sites at 6 months and 31.3% at 12 months. Upper canines had the most increase in KTW.

The average change in papilla fill decreased in 27.8%, increased in 4.5%, and did not change in 67.9% by 6 months. The average change in papilla fill decreased in 2.1%, increased in 9.0%, and did not change in 88.9% by 12 months. At T1, 70.1% of sites were fully filled and 29.9% were partially filled. At T2, 97.9% of sites were fully filled and 2.1% were partially filled.

The average change in papilla width decreased in 16.1%, increased in 48.2%, and did not change in 35.7% by 6 months. The average change in papilla width decreased in 21.4%, increased in 47.0%, and did not change in 31.5% by 12 months. The final amount decreased ranged from 1-3mm with 72.2% showing a 1mm increase and 27.8% showing more than 1mm decrease. The final amount increased ranged from 1-6mm with 48.1% showing a 1mm increase and 50.6% showing more than 1mm increase. Maxillary teeth showed the most increase in papilla width whereas mandibular teeth showed the most decrease in papilla width.

The average change in papilla height decreased in 15.2%, increased in 52.2%, and did not change in 32.6% by 6 months. The average change in papilla height decreased in 16.1%, increased in 54.2%, and did not change in 29.8% by 12 months. The final amount decreased ranged from 1-2mm with 92.6% showing a 1mm increase and 7.4% showing more than 1mm decrease. The final amount increased ranged from 1-4mm with 49.5% showing a 1mm increase and 50.5% showing more than 1mm increase. Papillas adjacent to mesial of canines showed the most increase in papilla height whereas mandibular teeth showed the most decrease in papilla height.

Plaque Presence

At 6 months, 9 patients increased in plaque (ranging from 16.7-75.0% increase) and 4 patients decreased in plaque (ranging from 33.3-100.0%). Of the 9 patients that increased in plaque, 6 patients had full fixed appliances and 3 had Invisalign. Of the 4 patients that decreased in plaque, 1 patient had full fixed appliances and 3 had Invisalign. At 12 months, all 12 patients increased in plaque (ranging from 8.33-100.0% increase).

Spearman's Correlations

Spearman's correlations analyses were conducted to examine any correlations that exist between the variables studied. The average change in rotation and the average change in alveolar housing width at S1 is statistically significant at both 6 months (ρ= -0.53, P= 0.034) and 12 months (ρ= -0.61, P= 0.034) following start of orthodontic treatment.

The average change in the inclination of maxillary centrals and average change in midfacial recession is statistically significant at both 6 months (ρ= -0.60, P= 0.014) and 12 months (ρ= -0.67, P= 0.016) following start of orthodontic treatment. The average change in the inclination of maxillary centrals and average change in papilla width (ρ= 0.65, P= 0.006), papilla height (ρ= 0.64, P= 0.007) is statistically significant at both 6 months, but not at 12 months. The average changes the inclination of maxillary centrals and the average change in alveolar housing width at S1 is statistically significant at 6 months (ρ= -0.50, P= 0.048), but not at 12 months. The average change of plaque and inclination of maxillary centrals (ρ= -0.66, P= 0.018) is statistically significant at 12 months only, but not at 6 months.

A significant negative correlation exists between the average change in plaque percentage at the maxillary centrals and the average change in alveolar housing width at S1 at 6 months (ρ= 0.67, P= 0.004), but not at 12 months. There is a significant correlation between the average change in KTW at the maxillary centrals and the average change in alveolar housing width at S1 at 12 months (ρ= 0.61, P= 0.033).

When comparing parameters at 6 months versus 12 months, the average alveolar housing at S3 and lower incisor is statistically significant (ρ= -2.1, P= 0.033). Statistical significance is reached when comparing the average change in rotation to average papilla width (ρ= 2.1, P= 0.034), to average alveolar housing at S1 (ρ= -2., P= 0.027), and to average alveolar housing at S3 (ρ= -2.1. P= 0.034). The average change in the proclination of maxillary centrals do not appear to alter significantly between 6 months and 12 months.

DISCUSSION

The current study found that orthodontic rotation of a tooth into proper alignment, also termed "derotation", is significantly correlated with a decrease in alveolar housing width at the level of S1. As the tooth derotates, the periodontium remodels leading to dimensional changes in the alveolar housing (Moga et al. 2023). The amount of derotation was minimal but consistently increased over time and was experienced on most teeth. There are currently no clinical studies studying the effect of rotation on the alveolar housing. A finite element study using a computer based model evaluated orthondontic movements and remodeling of periodontium by Moga et al. (2023) showed that rotational forces inflict a stronger biomechanical stress on the cervical third that is nine times higher than the maximum physiologic pressure. Thus, it is not surprising that we observed alveolar changes in the cervical third of the tooth but not at the midroot nor apical portion of alveolar housing. Furthermore, Moga et al. 2023 suggested that forces applied to this cervical region seem to display higher risks of ischemia and further resorptive processes supporting the concept that the apical third of the alveolar socket has better vascularization than the cervical third.

An increase in U1-PP was significantly correlated with a decrease in midfacial recession on upper centrals. As teeth are more proclined, less recession would be noted at the buccal because the crown is tipped more palatally. This is in agreement with Joss-Vassalli et al. 2010, that more proclined teeth may be associated with a higher tendency for developing gingival recessions. Orthodontic movement of incisors of out the osseous envelope of the alveolar process constitutes a risk that recession of the gingiva may result (Joss-Vassalli et al. 2010). Another significant confounder of maxillary centrals was an increased in plaque at the final 12 months of the study, but was not statistically significant at the half way point. Prior to orthodontic movement, poor oral hygiene, thin gingival phenotype, coupled with orthodontic proclination will lead to varying degrees gingival recession. Presence of gingival inflammation and baseline recession, a thin gingival biotype, a narrow width of keratinized gingiva or a thin symphysis were found to correlate significantly with the development or increase in gingival recession (Joss-Vassalli et al. 2010, Yared et al. 2006, Melsen et al. 2003). It is important to note that midfacial recessions can be attributed to multifactorial etiologies.

There was a singular increase in the proclination of maxillary centrals that was significantly correlated with a decrease in the alveolar housing width at the level of S1 after 6 months of beginning orthodontic treatment. This decrease at S1 became insignificant after 12 months following initiating orthodontic treatment. Thus, as the teeth proclined, the width of the bone decreased initially, but returned to baseline by or near the end of orthodontic treatment. This finding is consistent with Chaimongkol et al. (2017) when maxillary incisors were advanced labially via light force tipping and bodily movement, the alveolar bone thickness was maintained in both the treated and untreated group. Furthermore, there was no other decrease nor increase in alveolar housing width at either the maxillary centrals or mandibular centrals.

Within the first 6 months, an increase in proclination of maxillary centrals was significantly correlated with an increase in papilla width and height. At 12 months, however, papilla width and height were no longer significantly correlated with proclination. This contrasts with Kandasamy et al. (2007) where the direction of tooth angulation affected papilla height. Papilla height between anterior teeth lengthen following palatal movement of labially displaced or imbricated teeth. However, Kandasamy evaluated only the papilla height, whereas this study evaluated both papilla height and width. This study is the first to investigate the relationship between inclination of incisors and papilla width and height. It is also worthwhile to note that the presence of plaque had a significant influence on papilla. Inflammation of the gingiva would lead to swelling of the papilla, leading to a false or incorrect evaluation of papilla height and width. Papilla dimensions are affected by interproximal alveolar height and contact point location, age, tooth shape, proximal contact length, and gingival thickness. It has previously been reported that plaque accumulation increases during and after orthodontic treatment with fixed orthodontic appliances (Boke et al. 2014).

No significant correlations of increasing proclination of mandibular centrals and soft tissue (recession, KTW, papilla dimensions) parameters were noted. These findings are similar to Livia et al. (2022) in that they too found that in patients who did had non-extraction orthodontic treatment performed with controlled forces and biomechanics, does not appear to affect the development of gingival recession or the periodontal health after retention. Renkema et al. (2015) also did not find significant increase in gingival recession due to the proclination of mandibular incisors as compared to non-proclined teeth. Alzoman et al. (2021) also noted that the lower teeth showed a mix of improvement and compromised width of keratinized gingiva. The variability of KTW for the lower teeth could be attributed to variable buccal cortical plate thickness (Alzoman et al. 2021). Lack of correlation could be attributed to minimal orthodontic tooth movement leading to no clinical observations of periodontal parameters. Plaque likely also played a significant role in masking any potential soft tissue changes due to gingival inflammation.

Our study also showed a lack of significant correlation of increasing proclination of mandibular centrals and alveolar housing at all three levels. This was in contrast to a study by Zhang et al. (2001) that found an increase in horizontal labial bone thickness, especially at 6mm below the CEF in them mandibular central incisors when teeth were proclined. This difference could be explained by the difference in bone measurements.

Our study evaluated the entire thickness of bone including buccal plate, tooth root, and lingual plate. The study by Zhang et al. (2001) focused on the buccal bone plate only which likely allowed for tracking specific changes of the bone while our study focused on the entire width which could mask the buccal bone resorption and palatal bone addition leading to no overall change.

The present study has several limitations. First, this study had a small sample size, indication a possible lack of appropriate study power. Although some improvement sites were statistically significant, others were not. Therefore, future studies would include larger populations to reliably detect potential consistent associations. Furthermore, because we considered multiple cofounding factors, our results failed to clearly demonstrate a statistically significant association and differences, especially for the mandibular teeth. There is a great difficulty in controlling for confounding clinical variables in a large group practice such as differing oral hygiene instructions per provider and different treatment modalities amongst the orthodontic residents treating the patients. Future studies would be to implement regular prophylaxis at a more frequent interval to alleviate the major confounding factor of plaque presence potentially masking soft tissue changes. Additionally, there was slight variation in collecting 6 month and 12 month data due to factors beyond our control, such as patients being unable to make their set appointments due to personal reasons. One other factor that did not allow for much periodontal change observation was due to selecting cases that required minimal orthodontic movement. Future studies could include teeth that would require more alignment, rotation, or proclination in the orthodontic treatment. Additional studies could also extend the follow up time through to the completion of orthodontic treatment to confirm or deny the permanence of soft tissue changes.

CONCLUSION

Within the first 12 months of orthodontic treatment, rotation of the tooth into proper alignment is correlated with a decrease in alveolar housing width at the level of S1. Orthodontic rotation has minimal impact on the periodontium in the aesthetic anterior region. Changes in the upper centrals inclination are correlated with a decrease in midfacial recession. There is also a positive correlation with an increase in KTW at the level of S1. Future prospective, randomized clinical studies that implement stricter oral hygiene before and during treatment should be conducted to further understand the effects of orthodontic tooth movement on the periodontium.

FIGURES

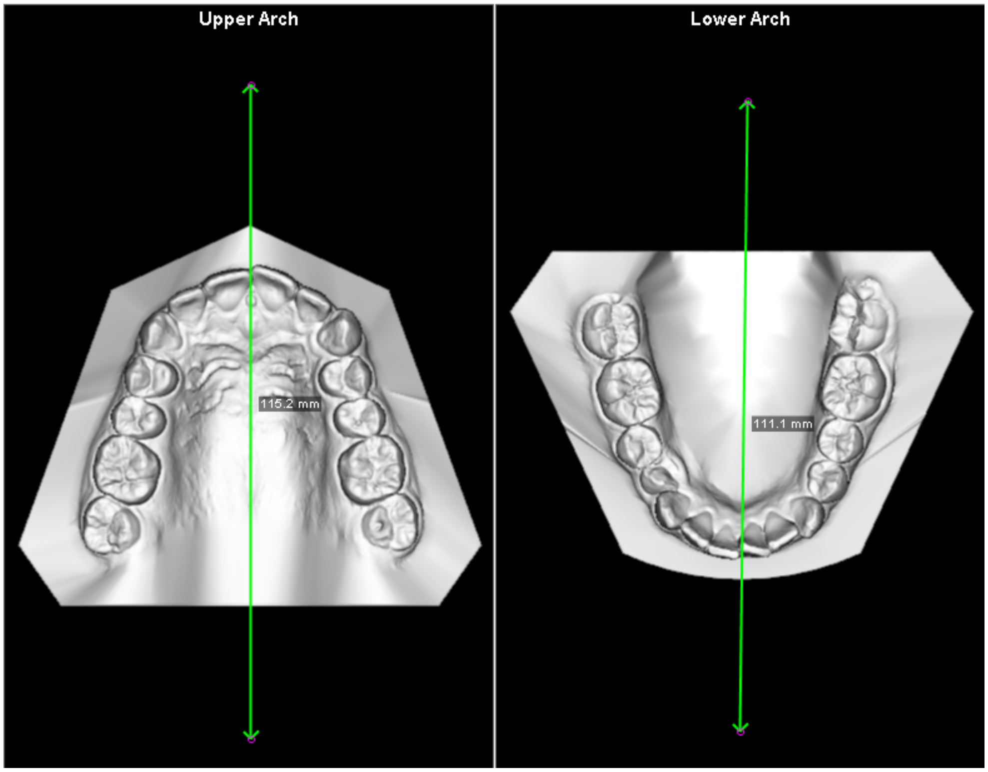

Figure 1. Rotation measurement. Degree of rotation is measured from the midline to the incisal edge of the central incisors on maxilla and mandible.

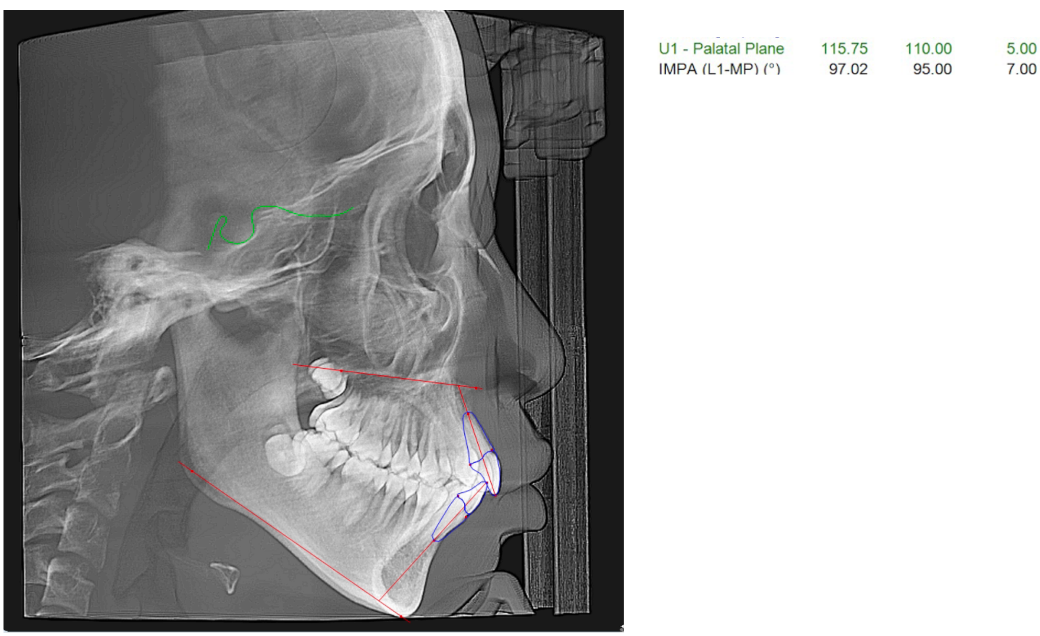

Figure 2. Incisor inclination measurement. Measurement of incisor inclination is based on the axial angle of the incisors and the palatal plane (for maxilla) or angle of mandible (for mandible).

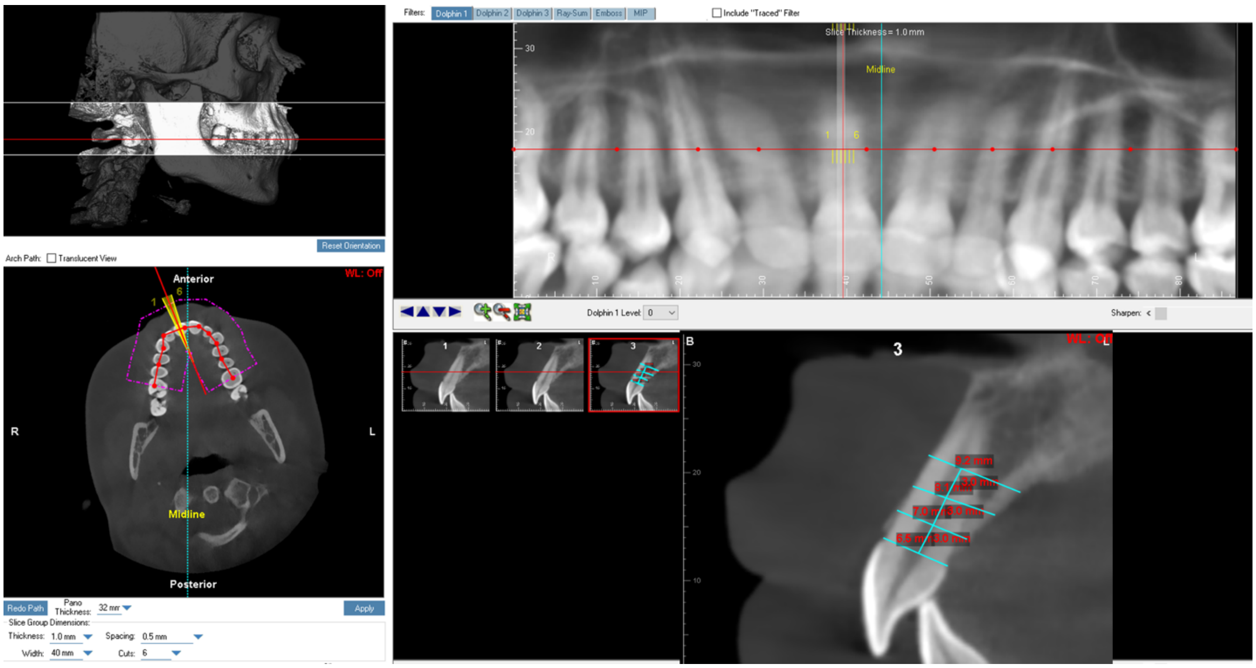

Figure 3. Alveolar housing width measurement. Alveolar housing is measured based on the width starting from 3 mm from CEJ and moving apically every 3 mm.

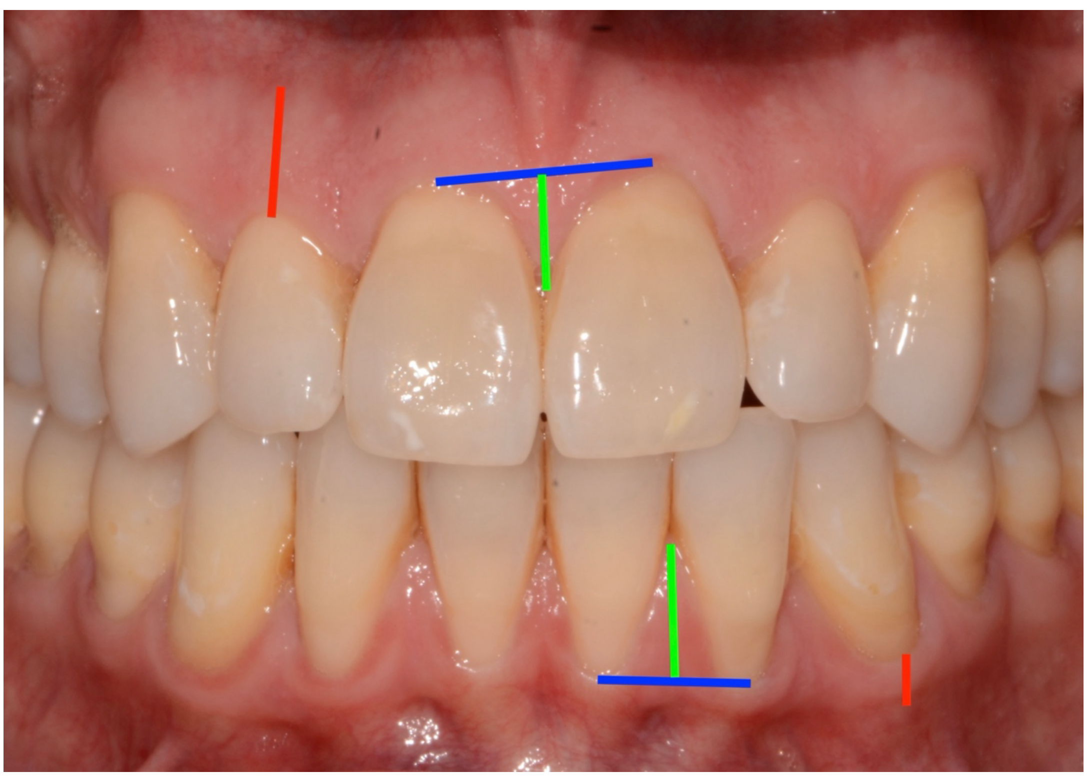
Figure 4. Periodontal soft tissue parameters. Blue denotes papilla width, green denotes papilla height, and red denotes keratinized tissue width.

Figure 5. Papilla fill. Papilla fill is based on Norland and Tarnow's classification system of normal, class I, class II, and class III.

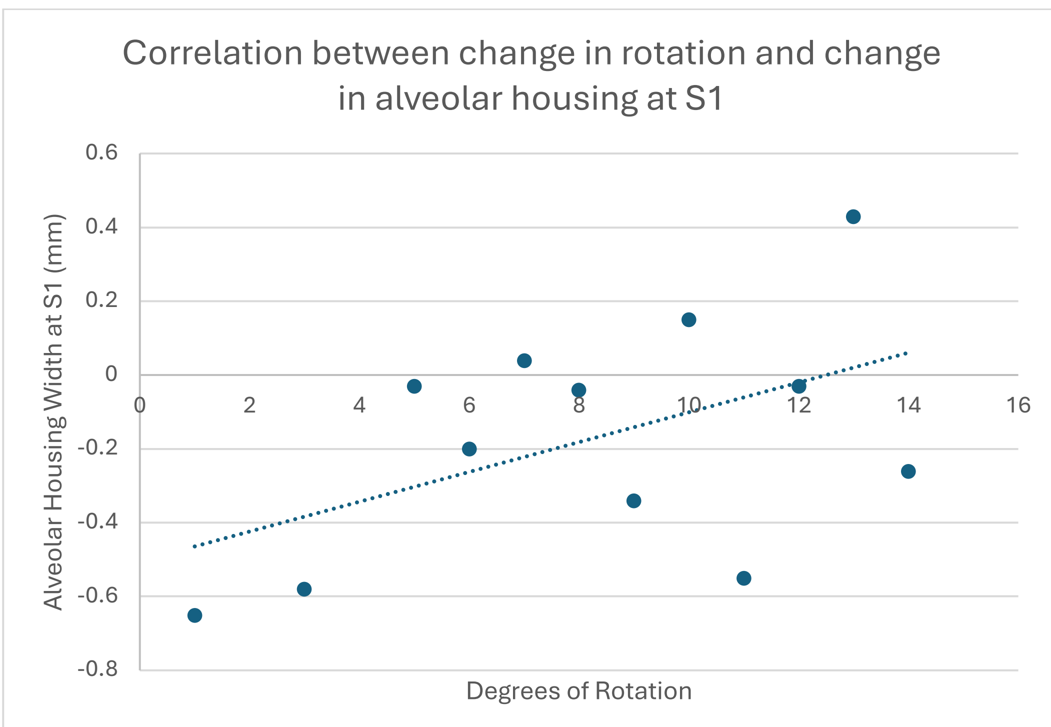

Figure 6. Correlation between change in degrees of rotation and change in alveolar housing at S1. This is at the 12 month follow up. Spearman's rho = -0.613; $p = 0.034$

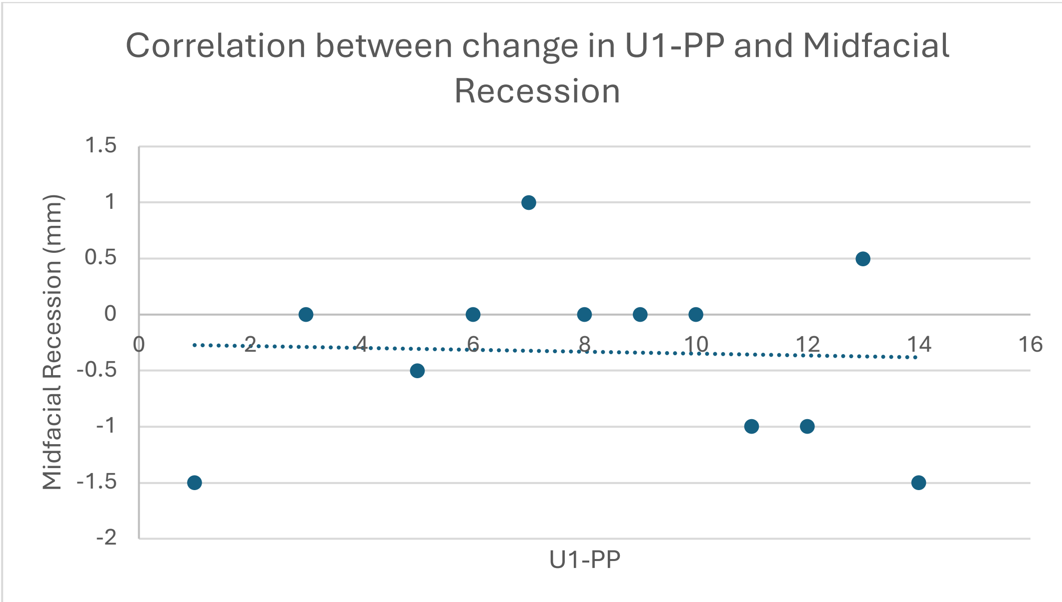

Figure 7. Correlation between change in U1-PP and midfacial recession. This is at the 12 month follow up. Spearman's rho = -0.673; $p = 0.016$

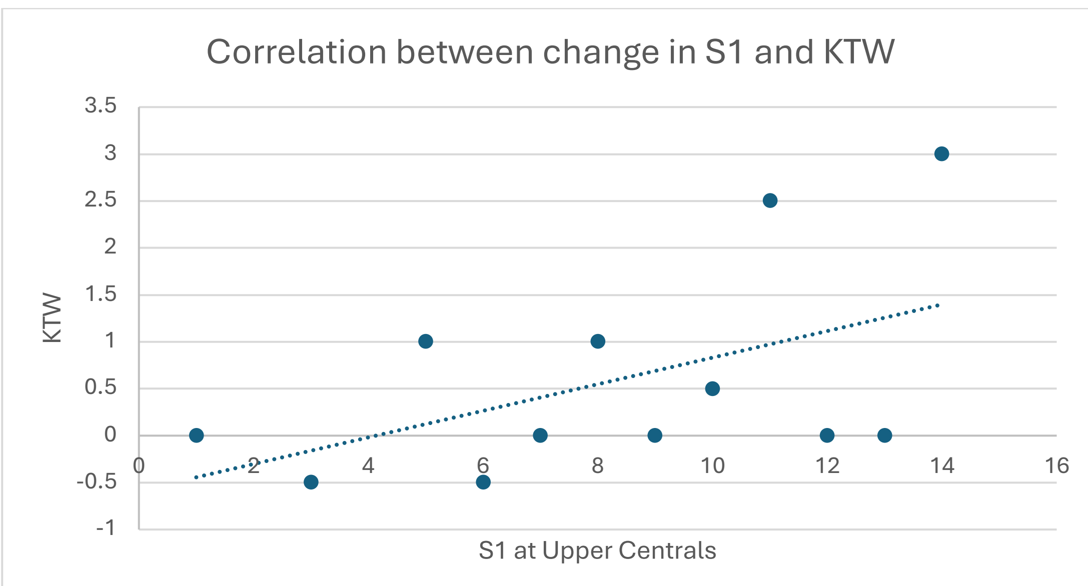

Figure 8. Correlation between change of S1 alveolar housing and change of KTW at upper centrals. This is at the 12 month follow up. Spearman's rho = -0.616; $p = 0.033$

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