Changes in buccolingual inclination of maxillary canines and mandibular first molars after orthodontic therapy in Class II patients treated with intermaxillary elastics.

by

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DEDICATION

This thesis is dedicated to my father, mother, sister, husband, and grandparents. I am incredibly grateful for your unconditional love, support, and encouragement without which I could not have achieved or even attempted to pursue my goals and dreams. Thank you for not only teaching me the value of hard work and tenacity, but also the worth of a soft heart. I would also like to give thanks to my late father-in-law whose gentle spirit demonstrated the impact of true kindness on the lives he touched.

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REVIEW OF THE LITERATURE

Cone beam computed tomography (CBCT) was implemented in dentistry in the early 2000's and provides a three dimensional volumetric image of the subject. This technology can record measurements that are impossible to obtain on a two-dimensional lateral headfilm. The dental measurements from CBCT volumes have been shown to be accurate to the anatomic structures they represent and can be collected reliably (Baumgartel, 2009). One of these measurements that are now accessible using the CBCT data is the buccolingual inclination of teeth in the transverse dimension.

The inclination of teeth in buccolingual dimension has been of interest to orthodontists for many years. Dr. Lawrence F. Andrews described it in his landmark article *The Six Keys to a Normal Occlusion*, in 1972. Andrews studied 120 sets of models from subjects who had not undergone orthodontic treatment and displayed a proper alignment of teeth and occlusion. From these models he looked for common patterns and characteristics that made the occlusion "normal". The commonalities he observed in the stone models led him to the conclusion that there

were six characteristics in a normal occlusion. His six keys were molar relationship, crown angulation, crown inclination, rotations, spaces and occlusal plane. Andrews proposed that a lack of any one of the six characteristics identified would be predictive of an incomplete and unsatisfactory outcome in treated orthodontic cases.

Andrews' third key, "crown inclination", is defined as "the angle formed by a line which bears 90 degrees to the occlusal plane and a line that is tangent to the bracket site". Using this reference system he described a normal occlusion as having lingual crown inclination of the upper posterior teeth with increasing lingual crown tip from the canine back to the second molar. Andrews stated that the pattern of increasing lingual crown tip was also consistent in mandibular posterior teeth. Andrews also pointed out that this key to the occlusion was clinically relevant as a variation in buccolingual inclination of the teeth affects the arch size and therefore is an important factor in achieving normal intra and inter-arch relationships (Andrews, 1972).

Andrews was not alone in thinking that crown inclination was an important element in establishing a

proper occlusion. The American Board of Orthodontics recognizes buccolingual inclination as one of the criteria that should be used to grade finished orthodontic cases. The board states that buccolingual inclination is important in order to "establish proper occlusion in maximum intercuspation and avoid balancing interferences"(ABO, 1998). In other words, a finished orthodontic case that meets board standards should not have a "significant difference between the heights of the buccal and lingual cusps of maxillary and mandibular molars and premolars." The measurement is made using the final casts and extending a flat plane across the occlusal surfaces of right and left posterior teeth. An acceptable buccolingual crown position would leave the buccal and lingual crowns with no more than a 1mm height difference when measured in this manner (ABO, 1998).

Similar measurement methods have attempted to describe the changes in buccolingual inclination during eruption and growth. Marshall et al. studied dental casts taken from the Iowa Facial Growth Study. The investigators examined casts from subjects aged 7 to 30, had a Class I occlusion, no extracted permanent teeth, and no excessive enamel wear or restoration of dental

cusps. Based on these inclusion and exclusion criteria, the study was limited to 36 subjects (18 women and 18 men). Similar to the ABO methods, a flat plane was placed transversely across the casts and the difference between buccal and lingual cusp heights was recorded at the different time points. The major findings from this study suggest that maxillary molars erupt buccally and tip lingually over time. Mandibular molars were found to erupt lingually and upright buccally with age. The authors suggest that buccolingual movements in both the maxillary and mandibular arches work towards establishing a flatter occlusal plane in the transverse dimension (Marshall, 2003). These findings seem to support the ABO's guidelines and suggest that uprighting and leveling posterior teeth during orthodontic treatment is justified.

Other studies have looked to find a correlation between buccolingual inclination and facial pattern and vertical growth. Again using dental casts and occlusal plane to determine buccolingual inclination, Ross et al. investigated the claims that people with higher mandibular plane angles had a tendency towards high, narrow palates. They hypothesized that this feature would tend to produce buccally inclined maxillary molars.

Conversely, they hypothesized that those subjects with low mandibular plane angles and wider palates would have lingually inclined maxillary molars. The study concluded that there were no statistical differences in buccolingual inclinations between the different groups of mandibular plane angles. The standard deviations, however, were large, indicating a large variability among individuals (Ross, 1990). In a follow-up study using the same methodology as Ross et al., the author notes that the measurement of the crowns only represents buccolingual inclination as an occlusal surface inclination and cautions that measurements from the crown cannot be extrapolated to the true long axis of the tooth.

Occlusal surface inclination has not been the only method used to attempt to characterize buccolingual inclination. Other studies have tried to characterize ideal buccolingual inclination based on the facial surface (Vardimon, 1986). These studies were used in part to determine the proper angulation prescriptions for the pre-adjusted brackets used in the straight-wire appliance. It was also shown that the relationship between the buccal crown surfaces and the actual long axis of the crowns, however, were subject to biologic

variation. Germane et al. reported that standard deviations ranged from 4.3° to 5.2° when comparing the buccal surface of molars to their long axes (Germane, 1989).

It is apparent that measuring buccolingual inclination using the methods mentioned in the previous studies has some inherent limitations. Buccolingual inclination measurements are inaccurate for any subjects with wear of cusp tips, broken dental casts, abnormal dental anatomy or restorations placed on teeth to be measured. This can limit sample size of a study or leave a clinician unable to evaluate a case properly. Inconsistency in the current methods of measurement suggests that there may be a need for a more accurate and reliable method to evaluate the long axis buccolingual inclination of teeth.

An initial study of the transverse dimension using CT technology by Podesser et al., proposed a method for measurement of maxillary structures and assessed the reliability of this method. The study sample consisted of only 10 individuals who received a CT scan. Two slices in the coronal plane were used for quantitation,

one that was defined by transecting the palatal root of the maxillary first molar and one that transected the root of the maxillary canines. Among other measurements, buccolingual crown inclination was recorded. The reference plane was defined as a horizontal line tangent to the inferior nasal cavity, and for the maxillary molar the angle was measured with a line connecting the apex of the palatal root and the tip of the mesiobuccal cusp. The canine inclination was defined using the same reference plane and a line connecting the canine apex and cusp tip. In order to test the intra-observer reliability of this method, all measurements were repeated 10 days after initial data collection by a different observer. Each observer recorded all points two separate times, and the investigators concluded that although not shown to be statistically significant, there were large inter-observer differences, up to 7.7 degrees for angular measurements. It was determined that this initial variation in reliability suggests that a larger sample should be studied to give significance to the quantitative findings and caution should be used when comparing individual results using this method (Podesser, 2004).

A limitation in these studies was relatively small samples of CBCT images. Recent publications have started to establish methods of measuring buccolingual inclination using larger sample sizes (Shewinvanakitkul, 2011;Karamitsou, 2010). A study by Shewinvanakitkul et al., aimed to create a method to measure the inclination of mandibular canines and first molars. The subjects in the sample studied were growing adolescent orthodontic patients between the ages of 11 and 14 years old who had fully erupted mandibular first molars and canines with no deciduous teeth present, no previous orthodontic treatment, no extracted or missing mandibular teeth, and no restorations on the cusps of measured teeth.

Buccolingual inclinations of right and left first molars and canines were recorded using the lower border of the mandible in the coronal view as a horizontal reference plane. For first molars, the buccolingual inclination was measured from the apex of the mesial root through the central groove. Canines were measured with the same horizontal reference plane and the angle measured from apex to cusp tip. The reliability of this method, assessed by the intra-class correlation coefficient, was high; $r > 0.94$ for all four teeth

measured. The means and standard deviations recorded were 98.0 ± 4.1 degrees for mandibular canines and 74.6 ± 4.7 degrees for mandibular molars with no significant difference between right and left sides. This study established a reliable method to measure buccolingual inclination.

A follow up study by Evagelinakis et al., used the previously described method and investigated the change in buccolingual inclination during orthodontic treatment. Using the same inclusion and exclusion criteria as Shewinvanakitkul et al., this study measured inclination before and after orthodontic treatment on 70 adolescent orthodontic patients. Evangelinakis found a statistically significant change ($P < 0.05$) in buccolingual inclination from before to after orthodontic treatment, as well as a significant change in intercanine width. The initial mandibular canine inclinations reported were 97.8 ± 4.6 for the left canine and 96.8 ± 3.9 degrees for the right canine.

After orthodontic treatment the mandibular canines were positioned with more lingual crown torque than initially with final values of 94.7 ± 4.8 degrees for the left and 93.9 ± 4.1 degrees for the right. Change in

intercanine width was also statistically significant, increasing during treatment an average of 1.8 mm. It was suggested by the authors that the root apex of the mandibular canines was moving buccally more than the incisal tip and had the potential to contact the buccal cortical plate. To avoid any potential periodontal problems associated with this type of movement, it was recommended that lower canine brackets have a positive torque value (Evangelinakis, 2010).

The initial buccolingual inclination of mandibular molars was 74.7 ± 5.1 for the left molar and 76.4 ± 4.5 for the right molar. Both left and right molars were uprighted during treatment with post-treatment values of 77.0 ± 4.9 for the left molar and 77.4 ± 5.0 for the right molar. The change in intermolar width was not found to be statistically significant. Overall, there was a weak correlation between the change in intermolar and intercanine widths and changes in buccolingual inclination, suggesting that these are independent variables (Evangelinakis, 2010).

Karamitsou et al. attempted to create a reliable method to measure the buccolingual inclination of molars and canines in the maxilla using CBCT. The investigators

used many of the same inclusion and exclusion criteria as Shewinvanakitkul et al. and Evangelinakis et al. Ninety seven adolescent orthodontic patients with fully erupted maxillary canines and first molars were included in the sample group. Molar inclination was measured in the coronal plane as the angle connecting a horizontal reference plane tangent to the inferior border of the superior palatal cortical plate and a line through the palatal root apex and mesiopalatal cusp tip. Canine inclination was measured using the same horizontal reference plane. The coronal plane, however, was rotated to measure the maxillary canine from a mesial to distal view, accounting for the fact that the canine lies on the curvature of the dental arc and the maximum angulation measurable will be at this orientation. Thirty five subjects were then re-measured by the same single operator three weeks later to assess reliability.

Results showed a mean inclination of maxillary left and right canines as 105.9 ± 6.5 and 103.0 ± 6.0 degrees respectively. Buccolingual inclination of maxillary first molars, the mean inclination was 101.7 ± 5.4 degrees for the left and 99.2 ± 5.3 degrees for the right side. Intraclass correlation values for all four teeth measured

were found to be greater than 0.96, indicating a high degree of reliability.

Interestingly, the mean differences in buccolingual inclination between right and left sides were found to be statistically significant. The two sides were reported separately. The sample was evaluated to determine if there was a difference in initial inclination between subjects who were treatment planned to receive rapid maxillary expansion and those who were not. No differences were found between the group slated to receive rapid maxillary expansion and the group who were not going to receive expansion as a part of their treatment plans. Similarly, no differences in angulation were found for patients starting with different molar classifications (Karamitsou, 2010).

A follow up study by Miyamoto et al., used the previously described method by Karamitsou et al. and investigated the change in buccolingual inclination of maxillary canines and first molars. Using the same inclusion and exclusion criteria as Karamitsou et al., this study measured inclination before and after orthodontic treatment on 70 adolescent orthodontic patients. Miyamoto found a statistically significant

change ($P < 0.05$) in intercanine and intermolar widths from before to after orthodontic treatment, but not for the change in buccolingual inclination.

Maxillary molars had a tendency to increase in buccolingual inclination from 101.9 ± 4.9 degrees to 103.2 ± 4.4 degrees on the right and 102.1 ± 4.9 degrees to 102.5 ± 5.1 degrees on the left. When right and left were combined, 59% of molars increased in inclination after treatment while 41% decreased in inclination. Maxillary canines tended to decrease in inclination from 106.1 ± 4.8 degrees to 104.7 ± 5.7 degrees on the right and 105.9 ± 5.6 (90.8 - 119.6) to 105.0 ± 5.7 on the left. When right and left sides were combined, 56% decreased in buccolingual inclination and 44% increased. The pre- to post-treatment change in angulation ranged 24 degrees for molars and 25.9 degrees for canines. Intraclass correlation values for all four teeth measured were found to be greater than 0.93, indicating a high degree of reliability. On average, intermolar width increased from 45.3 ± 2.6 mm to 46.5± 2.6 mm and intercanine width increased from 33.9 ± 2.7 mm to 34.9 ± 2.1 mm.

The wide ranges of change of buccolingual

inclinations in the studies by Evangelinakis et al. and Miyamoto et al. suggest there are numerous factors that can affect tooth movement including bracket prescription, archform, treatment mechanics and anatomical variation. The aim of this study is to determine the treatment mechanic effects of Class II interarch elastics on the buccolingual inclination of maxillary canines and mandibular first molars.

Class II malocclusions are a major and common challenge to orthodontists. From 1989 to 1994 the National Health and Nutrition Estimates Survey III (NHANES III) studied approximately 14,000 individuals and was statistically designed to provide estimates of approximately 150 million individuals of various racial and ethnic groups. The NHANES III data provides the best set data regarding malocclusion in children and adults in America. According to NHANES III data, Class II malocclusion (as based on overjet measurements greater than 4 mm) is present in approximately 11% of the US population and comprises approximately one-fifth of all malocclusions. Prevalence of this relationship is 10.1% in whites, 11.8% of blacks, and 6.5% of Hispanics. This data also suggests that the skeletal Class II pattern is

the most common skeletal disharmony among children and adults (Proffit, 1998).

Numerous orthodontic techniques have been introduced to treat Class II malocclusions, including intra-arch and interarch appliances, extraoral appliances, selective extraction patterns, and surgical repositioning of the jaws.

Intermaxillary Class II elastics are a typical method for treating Class II malocclusion. The effects that Class II elastics typically elicit, as examined on two-dimensional headfilms, have been well described. Ellen et al. found that Class II patients treated with Class II elastics and standard edgewise orthodontics without headgear display mesial movement of 4.1 mm and extrusion of 4.0 mm of the mandibular molars. The mandibular incisors were proclined 7.9 degrees. The maxillary incisors were extruded 3.7 mm and retroclined 1.4 degrees. A 0.8 degree clockwise rotation of the occlusal plane occurred and the lower facial height increased 6.2 mm. Pogonion and B-point moved forward 1.6 mm and 1.1 mm, respectively (Ellen, 1998).

Nelson et al. reported similar findings in a study of patients treated with Class II elastics and Begg

orthodontics. Patients experienced 1.0 mm mesial growth of the maxilla and 2.1 mm of mesial mandibular displacement. The incisal edge of the maxillary incisors moved distally 3.7 mm, while the incisal edge of the mandibular incisors moved mesially 1.0 mm. As a result, overjet decreased 5.8 mm. Maxillary molars did not experience significant movement, while mandibular molars moved mesially 2.0 mm. The resulting molar correction was 3.0 mm (Nelson,1999).

A later study by Nelson et al. again examined patients treated with Begg appliances and Class II elastics. These patients experienced 5.1 mm distal movement of the maxillary incisors and 1.4 mm of mesial movement of the lower incisors. Overjet was reduced 6.7 mm and lower face height increased 4.2 mm. The maxilla and mandible both experienced mesial movement during treatment, 1.3 mm and 1.6 mm, respectively. A 1.3 degree increase in the mandibular plane angle was also noted (Nelson, 2000).

Gianelly et al. evaluated Class II patients treated with Class II elastics and either Begg or edgewise appliances. He showed that both edgewise and Begg groups showed advancement of pogonion, 2.1mm and 1.6mm,

respectively. SNA decreased in both groups (1.5 degrees edgewise, 0.4 degrees Begg), while SNB increased 0.3 degrees in both groups. Clockwise rotation of the mandibular plane occurred in both groups (0.6 degrees edgewise, 1.3 degrees Begg). Finally, an increase in mandibular size was found in both groups (2.7 mm edgewise, 2.9 mm Begg); this was attributed to normal growth. The differences between the two groups were not statistically significant (Gianelly,1984).

Hanes examined 38 Class II subjects who had Class II elastics as the only mechanical strategy for Class II correction. He found that the majority of the skeletal correction came from posterior movements of A-point, rather than anterior movements of B-point. His subjects displayed an average 2.5 mm posterior movement of A-point and a 0.9 mm posterior movement of B-point. This posterior displacement of B-point was due to a tendency for the mandibular plane angle to increase an average of 0.8 degrees as the mandible rotated clockwise. Facial height increased an average of 4.0 mm. Hanes found that the posterior displacement of B-point was less in the group treated with maxillary elastics than in a similar group treated with cervical headgear. He concluded that,

typically, Class II elastics did not make the chin more prominent in profile (Hanes,1959).

Bien discussed the theoretical forces that interact in the dentition with the use of Class II elastics. His calculations were based on average tooth sizes, inter-arch distances, and typical elastic configurations. When the theoretical force vectors of four-ounce elastics were analyzed, there was a 2.6 ounce extrusive force on the lower molars, in addition to a 3.9 ounce mesial driving force. Furthermore, there was a tendency for distal rotation of the mandibular molar roots and mesial rotation of the maxillary molar roots, as the forces of the elastics were transmitted through these teeth (Bien, 1951).

Zingeser evaluated vertical changes associated with Class II elastic treatment and found a pronounced vertical development of the mandibular dento-alveolus and slight vertical development of the maxillary dento-alveolus. These vertical increases did not have a significant effect on the mandibular plane due to the concomitant counterclockwise rotation of the mandible that normally occurs with growth, which tended to close the mandibular plane (Zingeser, 1964).

Adams et al. experimentally studied the skeletal effects of intermaxillary elastics placed in seven *Macaca Mulata* monkeys. Cast splints were made to reduce the amount of tooth movements, and forces ranging from 75 to 250 grams were applied. Metallic bone markers and histological markers were used to track the skeletal effects. Among the changes noted was a backward and downward rotation of the maxilla. The maxillary dentition, including the second molars, which were not included in the splint, moved distally. Areas of compression were found between the maxillary tuberosity and the pterygoid process. The mandible moved forward and rotated clockwise. These changes served to rotate the occlusal plane clockwise. Animals in the mixed dentition showed increased bone apposition in the posterior aspect of the mandibular condyle. Minimal or no changes were seen in the condyles of the adult animals, although one adult experienced pathologic resorption in the articular eminence of the temporal bone, due to continuous compression of the joint (Adams,1972).

The effectiveness and success of treatment with Class II elastics is highly dependent upon patient compliance. Skidmore et al. isolated nine factors that accounted for

38% of the variation in treatment duration. Of these factors, three were related to patient compliance. One of the factors that significantly contributed to increased treatment duration was poor elastic wear (Skidmore, 2006).

The vertical and sagittal effects of Class II elastics on the dentition and skeleton have been well documented. Evaluations and measurements in these studies were made from two-dimensional radiographs because this was the technology available at the time the studies were conducted. With the advent of cone beam computed tomography, it is now possible to investigate the dental effects of treatment with Class II elastics in the coronal plane of space. Previous studies have elucidated that orthodontic treatment, in general, results in a wide range of buccolingual inclination changes of canines and first molars. The purpose of this study is to investigate the change in buccolingual inclination of maxillary canines and mandibular first molars that occurs as a result of orthodontic treatment with Class II intermaxillary elastics.

STATEMENT OF THESIS

The purpose of the study was to determine the range, mean and standard deviation for the buccolingual inclination of maxillary canines and mandibular first molars in Class II patients before and after orthodontic treatment with intermaxillary Class II elastics. Specific aims of this study were to measure and report the effect of Class II elastics on: 1) the buccolingual inclination of maxillary canines and mandibular molars, 2) the intermolar and intercanine widths, 3) changes in buccolingual inclination, intermolar with and intercanine width, 4) changes in buccolingual inclination, intermolar with and intercanine width in relation to the explanatory variables tested.

Null hypotheses: 1) There is no difference in the buccolingual inclination of maxillary canines before and after orthodontic treatment with Class II elastics, 2) There is no difference in the intercanine width of maxillary canines before and after orthodontic treatment with Class II elastics, 3) There is no difference in the buccolingual inclination of mandibular first molars before and after orthodontic treatment with Class II elastics, 4) There is no difference in the intermolar

width of mandibular first molars before and after orthodontic treatment with Class II elastics, 5) There is no relationship between post-treatment changes in intercanine width and buccolingual inclination of maxillary canines, 6) There is no relationship between post-treatment changes in intermolar width and buccolingual inclination of mandibular first molars.

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Changes in buccolingual inclination of maxillary canines and mandibular first molars after orthodontic therapy in Class II patients treated with intermaxillary elastics.

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Abstract

Objectives: To determine the effects of orthodontic treatment with Class II elastics on buccolingual inclination of the maxillary canines and mandibular first molars.

Setting and Sample Population: Pre and post-treatment Cone beam CT scans of 39 bilateral molar and canine Class II patients treated at an accredited graduate orthodontic program in the US were selected. Patients were between the ages of 10 and 17 years of age at T_0 and were treated with preadjusted appliances and Class II elastics in an average of 24 months. All cases were finished with bilateral Class I occlusions.

Material & Methods: Buccolingual inclinations of maxillary canines and mandibular first molars, intermolar widths, and intercanine widths were measured from the cone beam CT DICOM data using the commercially available software program On Demand 3D software (version 1.0.1.8407, CyberMed, Seoul, Korea). Long axis buccolingual maxillary canine inclinations were measured in the coronal view, using a horizontal reference established by a line tangent the to the internal border of the superior palatal cortical plate. Long axis buccolingual mandibular first molar inclinations were measured in the coronal view, using a horizontal reference established by a line tangent to the inferior border of the mandible. Buccolingual inclinations as well as intermolar and intercanine distances were measured both before and after orthodontic treatment.

Results: Buccolingual measurements of all four teeth were judged to be reliable, each with an intraclass correlation coefficient above 0.86. Mean buccolingual inclinations prior to treatment with Class II elastics were 103.5 ± 6.6 and 102.7 ± 6.2 for maxillary left and right canines, respectively, and 75.7 ± 4.0 and 74.4 ± 4.2 degrees for mandibular left and right first molars, respectively. Post treatment inclinations of maxillary left and right canines decreased to 102.1 ± 5.5. Post treatment inclinations of left and right first molars significantly increased to 77.4 ± 4.1 and 76.4 ± 4.6 degrees.

Conclusions: Orthodontic treatment with Class II elastics tended to increase inclination of mandibular first molars and decrease inclination of maxillary canines. The lingual force vector applied by Class II elastics on maxillary canines in combination with negative torque bracket prescriptions resulted in the decrease in inclination. The change in canine inclinations may also be related to altered archforms that resulted from changes in intercanine widths.

Keywords*: Buccolingual inclination, Class II elastics, Cone beam computed tomography (CBCT)*

INTRODUCTION

Cone beam computed tomography (CBCT) was implemented in dentistry in the early 2000's and provides a three dimensional volumetric image of the patient. This technology can record measurements that are impossible to obtain on a two-dimensional lateral head film. The dental measurements from CBCT volumes have been shown to be accurate to the anatomic structures they represent and can be collected reliably.[1] One of these measurements that are now accessible using CBCT data is the buccolingual inclination of teeth in the transverse dimension.

The inclination of teeth in buccolingual dimension has been of interest to orthodontists for many years. Dr. Lawrence F. Andrews described it as the third key to normal occlusion in his landmark article *The Six Keys to Normal Occlusion* in 1972.[2] In addition, the American Board of Orthodontics recognizes buccolingual inclination as one of the criteria that should be used to grade finished orthodontic cases.[3]

Studies at Case Western Reserve University have established methods to reliably measure buccolingual inclination of maxillary canines, maxillary first molars, mandibular canines, and mandibular first molars using CBCT technology. [4,5] A follow-up study by Evangelinakis et al. aimed to determine the effects of orthodontic treatment on the buccolingual inclination of mandibular canines and first molars. After orthodontic treatment, mandibular canines were positioned with more lingual crown torque and mandibular molars were positioned with more buccal crown torque. [6] These changes in angulations were found to be significant. In 2011, Miyamoto et al.

found orthodontic treatment positioned maxillary first molars with more buccal crown torque and maxillary canines with more lingual crown torque; however, these changes were not significant. [7]

There were wide ranges of change of buccolingual inclinations in the studies by Evangelanikas and Miyamoto. This suggests there are numerous factors that can affect tooth movement including bracket prescription, arch form, treatment mechanics and anatomical variation. The aim of this study was to determine the treatment mechanic effects of Class II interarch elastics on the buccolingual inclination of maxillary canines and mandibular first molars.

Intermaxillary Class II elastics are a typical method for treating Class II malocclusion. The effects that Class II elastics typically elicit, as described on two-dimensional head film, have been well documented. Studies have shown mesial movement of mandibular molars, buccal movement and tipping of mandibular incisors, extrusion of mandibular molars and maxillary incisors, retroclination of maxillary incisors, and clockwise rotation of the mandibular and occlusal planes. [8,9] However, the effectiveness of Class II elastics is heavily dependent upon patient compliance. A study by Skidmore found that one of the factors that significantly contributed to increased treatment duration was poor elastic wear. [10]

The vertical and sagittal evaluations and measurements in the aforementioned studies were made from two-dimensional radiographs because this was the technology available at the time the studies were conducted. Ross suggested in 1990 that transverse dental inclinations might be associated with facial form and

dentofacial skeletal anatomy just as sagittal dental inclinations are associated with anterior-posterior skeletal relationships. [11] However, the study was limited by the use of dental casts to extrapolate dental inclinations. With the advent of cone beam computed tomography, it is now possible to investigate the dental effects of treatment with Class II elastics in the coronal plane of space.

Previous studies have elucidated that orthodontic treatment, in general, results in a wide range of buccolingual inclination changes of maxillary canines and mandibular first molars. The purpose of this study was to investigate the change in buccolingual inclination of maxillary canines and mandibular first molars that occurs as a result of orthodontic treatment with Class II intermaxillary elastics.

MATERIALS AND METHODS

The Case Western Reserve University International Review Board (IRB) approved the experimental protocol in February of 2012. Subjects were selected from a sample of patients presenting to the dental school for comprehensive orthodontic treatment in the graduate clinic. Data were derived from existing pre-treatment and post-treatment Cone Beam Computed Tomography scans (CB MercuRay^{TM}, Hitachi Medical Systems America Co. – Twinsburg, OH). All scans were taken in the Craniofacial Imaging Center at Case School of Dental Medicine between 2007-2009 using the 2mA setting and the largest field of view (0.38 voxel size). A commercially available software program (OnDemand by Cybermed Inc – Seoul, Korea) was used to reconstruct and analyze the CBCT data.

Pretreatment patient records consisting of CBCT scans, study models, photographs and medical history forms were available. Sample size calculations using an estimated mean standardized effect size of 3 degrees with an alpha of 0.05 and beta of 0.20 indicated the sample should include at least 32 subjects. Out of the patients who had scans and began treatment between 2007-2009 and whose records were readily available, 39 subjects met the following inclusion criteria:

1. Patients were between the ages of 10 and 17 years old at the time of initial orthodontic records.
2. Full records were available, including pre and post treatment photographs, study models, CBCT scans, dental and medical history, and complete treatment notes.
3. No previous orthodontic treatment based on dental history form.
4. No patients with craniofacial anomalies or syndromes.
5. Fully erupted maxillary canines and mandibular first molars at the time of initial records.
6. At least end-on Class II bilateral canine and molar relationships as determined from pretreatment study models and photographs.
7. Class I canine and molar relationships at the completion of treatment as determined from post treatment study models and photographs.

8. Treatment plans that only included Class II elastics to correct the Class II malocclusion. Patients who wore triangle elastics were not included in the study.
9. No patients that were treated with rapid palatal expansion.
10. No patients whose treatment plan included extractions of permanent dentition.
11. No restoration of dental cusps used for measurement.
12. No severe rotations (> 90°) of maxillary canines or mandibular first molars.
13. Landmarks (root apices and cusp tips) clearly visible on CBCT scans.

Data were collected by a single operator. Measurements were made of the right and left maxillary canines and mandibular first molars. Buccolingual inclination was measured through the long axes of the teeth using the methods described by Shewinvanakitkul et al. and by Karamitsou et al. (Figures 1-7). Each slice was stored as a jpeg (.jpg) image, and was labeled using a patient identifier. Slice thickness was fixed at 0.38 mm (as a function of the standard voxel height). Measurements were based on slices of the left and right maxillary canines, and the left and right mandibular first molars. Measurements were repeated after a three-week interval on 32 maxillary canines and 32 mandibular molars. Patient demographic information, length of time Class II elastics were prescribed, bracket prescription, archwire size, archwire alloy, the amount of time the largest dimensional archwire was in place, whether or not the bracket slot was "filled", and treatment duration were collected

from the patients' charts. For the bracket slot to be defined as "filled" in an .022 prescription, the archwire had to be at least .019 x .025 inches in dimension. In an .018 prescription, the archwire had to be at least .017 x .025 inches in dimension.

Inclination and Arch Width Measurements (Figures 1-7)

All intermolar and intercanine widths were measured on the CBCT volumes. Intercanine width was defined as the distance between the two cusp tips of the canines, and intermolar width was defined as the distance between the central fossae of contralateral mandibular first molars. Mandibular first molar inclination (degrees) was defined as the angle between a line passing through the long axis of the molar (central groove to mesial root apex), and a line tangent to the inferior border of the mandible apical to the molars.[4] Maxillary canine inclination was defined as the angle between a line passing through the long axis of the canine (cusp tip to root apex), and a line tangent to the inferior border of the nasal cavity.[5]

Statistical Analyses

Means and standard deviations were calculated for each variable. Paired sample t-test compared inclinations and widths before and after orthodontic treatment. Independent sample t-tests and analysis of variance (ANOVA) were used to compare the outcomes for the potential explanatory variables. Pearson Correlation examined relationships among continuous explanatory variables and the outcome. Measurements were repeated after a 3-week interval on 8 randomly selected subjects and reliability was estimated using intraclass correlation (r^2). All statistics were

calculated using the Statistical Package for the Social Sciences (SPSS 17.0, Inc. – Chicago, IL).

RESULTS

Demographics

The study sample consisted of 13 male and 26 female subjects for a total of 39 subjects with at least bilateral end-on Class II occlusion. The average age at the start of treatment was 162.62 ± 16.06 months with a range of 129-208 months. Most subjects were Caucasoid (n=35) with two African American subjects and two subjects whose anthropological background was unknown due to insufficient completion of medical histories. Patients were treated by 13 residents under the supervision of 16 instructors. One resident and one instructor were assigned to each patient. A descriptive summary of explanatory variables is found in Table 1. Class II elastics were prescribed, on average, 307.92 days, and treatment length on average was 24.93 months. The largest dimensional maxillary archwire was in place for an average of 215.49 days, and the largest dimensional mandibular archwire was in place for an average of 215.79 days.

Inclination and width changes for maxillary canines and mandibular first molars

Variables tested were distributed normally, as determined by the Shapiro-Wilk test. Data for right and left maxillary canines and mandibular first molars were collected separately. For maxillary left canines, the mean initial inclination was 103.5 ± 6.6 degrees and the mean final inclination was 102.1 ± 5.5 indicating a mean

decrease in inclination of 1.5 ± 6.3 degrees. The maxillary right canines decreased, on average, 1.2 ± 5.1 degrees from 102.7 ± 6.2 to 101.5 ± 5.9 degrees. Mean intercanine width increased from 34.3 ± 2.5mm 35.7 ± 2.2mm. The final mean intercanine width was 35.7 ± 2.2mm. There was a mean change in intercanine width of 1.4 ± 2.5mm (Table 2).

For mandibular right and left first molars, the mean initial inclinations were 74.4 ± 4.2 degrees and 75.7 ± 4.0, respectively. The mean initial intermolar width was 40.9 ± 2.2mm. The final right and left mean molar inclinations were 76.4 ± 4.6 and 77.4 ± 4.1 degrees indicating mean changes in inclination of 2.0 ± 3.3 and 1.7 ± 3.2 degrees. The final mean intermolar width was 41.0 ± 2.2mm. There was a mean change in intermolar width of .19 ± 1.2mm (Table 2).

Differences among groups

Comparisons between initial and final inclinations and widths were made using paired t-tests. There were statistically significant differences in inclination for the right and left mandibular first molars, as well as intercanine width, when pre-treatment values were compared to post treatment values. The change in inclination of right and left maxillary canines and intermolar widths were not significant (Table 2). However, after a paired t-test was performed on the initial and final right and left maxillary canine inclinations, no significant difference was found between right and left cuspids. Therefore, right and left canine data were combined, and as the sample size was increased, a significant difference was found before and after treatment with

Class II elastics. Intraclass correlation coefficient (r^2) of buccolingual inclination and arch widths was greater than 0.86 for both molars and canines (Table 2).

When differences among independent variables were explored, there was no statistically significant difference between males and females for the change in inclination or widths during treatment with Class II elastics for maxillary canines or mandibular first molars. There were also no statistically significant differences among the various anthropological groups compared.

Maxillary canines

When the changes in inclinations and widths of maxillary canines were examined, significant differences were not found among various torque prescriptions (Table 3). When right and left cuspid data were combined, significant differences were found among torque prescriptions. The bracket prescriptions with negative torque values resulted in more of a lingual change in inclination compared to zero degree torque prescription (Table 4). When rectangular archwires were used in the maxillary arch, there were no differences in the changes of angulations or widths when various rectangular dimensions were compared. When various archwire alloys were compared, there was no significant difference in change in canine angulation, but there was a significant difference in change in intercanine width. Intercanine width increased the most when the largest dimensional archwire was made of stainless steel. Change in canine angulation was significantly negatively correlated with the length of time Class II elastics were prescribed and significantly negatively correlated with the amount of time the largest maxillary archwire was in place.

Change in intercanine width was also significantly negatively correlated with the length of time Class II elastics were prescribed. There was also a significant positive correlation between change in canine angulation and change in intercanine width (Table 5).

Mandibular first molars

When the changes in mandibular first molar inclinations and widths were examined, there were no significant differences found when different torque prescriptions and various archwire alloys were compared. There was no relationship between the change in mandibular molar angulations or width with the amount of time Class II elastics were prescribed or with the amount of time the largest dimensional archwire was present in the mandibular arch. When the bracket slot was filled in the mandibular arch, there was no significant difference in molar angulation compared to when the bracket slot was not filled. The change in intermolar width and molar angulation were not significantly related (Table 5).

Discussion

After orthodontic treatment with Class II elastics, there was a change in angulation of maxillary canines and mandibular first molars as well as intercanine width. The minimal mean change in canine and molar inclinations may not have clinical significance, but the wide range found amongst individual subjects could be clinically significant in regards to treatment planning.

When Miyamoto investigated the effects of orthodontic treatment in a general sample of all orthodontic patients, no significant difference was found in the change

in canine angulation after orthodontic therapy.[7] When a subset of Class I subjects were extrapolated from the general sample, maxillary right canine inclination changed -0.18 ± 4.6 degrees and the maxillary left canine changed -0.19 ± 3.9 degrees. The current investigation of Class II subjects treated with intermaxillary Class II elastics found, like Miyamoto, canine inclination change to be lingual (-1.5 ± 6.3 degrees and -1.2 ± 5.1), but this change was greater than the difference found in Miyamoto's Class I subset of patients. The difference may be related to the lingual vector of force applied to the canine during Class II elastic wear. To further support this theory, a significant correlation was found when the relationship between the number of days Class II elastics were prescribed and the change in canine inclination was investigated. The longer the Class II elastics were prescribed, the more lingual the change in canine inclination.

It could be possible that the combined effects of the lingual crown torque of the preadjusted brackets with the lingual force vector of the Class II elastics resulted in the mean lingual change in inclination. In Miyamoto's study, no significant difference in inclination change was found when various torque prescriptions were compared. In fact, his study found that even when torque prescriptions for maxillary canines had a negative value, the mean inclination change was actually buccal. Conversely, in the current study, it was found that the more lingual the torque prescription, the more lingual the change in angulation.

The increase in intercanine width pre- to post-orthodontic therapy with Class II elastics was also significant. There was a significant positive correlation between

the change in canine angulation and intercanine width. Since archform is dictated by facial form, perhaps the transverse effect of orthodontic biomechanics is a function the patient's underlying skeletal form.[11] In patients whose canine inclination changes were buccal, the intercanine widths tended to increase, and it was also found that these patients were more likely to have rectangular stainless steel archwires engaged as the largest dimensional archwire during treatment. There were 29 out of 39 patients whose intercanine width increased during treatment. Out of these 29, there were 10 patients whose right and left canine inclinations changed buccally. Therefore, the subjects who demonstrated increases in canine inclination during treatment may have had changes in their archforms as a result of archwire expansion with stainless steel wires. There were 9 patients whose intercanine width decreased, and, of these, 7 patients had bilateral lingual inclination changes, demonstrating the change in archform may be contributing to the change in cuspid inclination.

There were 11 patients whose canine crown inclinations became more lingual while intercanine width increased, indicating the root of the cuspid translated closer to the buccal cortical plate. This combination of movements may invade the physiologic boundaries of tooth movement. If the root of a tooth is tipped to an extreme, the perforation of the buccal cortical plate may occur. This then leads to bony dehiscence and fenestrations and may eventually cause attachment loss and gingival recession.[12, 13]

As Evangelinakis found in his general sample of orthodontic patients, the current investigation also revealed a significant increase in mandibular first molar

angulation after orthodontic therapy with Class II elastics.[6] In a Class I subset from his sample, Evangelinakis found the mandibular right molar to upright 1.1 ± 3.6 degrees and the left molar to upright 2.6 ± 4.3 degrees, values that are similar to the change observed in Class II patients treated with Class II elastics (2.0 ± 3.3 degrees and 1.7 ± 3.2 degrees). Unlike the significant positive relationship of length of time of Class II elastic wear to change in canine angulation, the change in molar angulation was not correlated to the number of days Class II elastics were prescribed. The buccal vector of force from the Class II elastics on the mandibular molars seemed to have less of an effect than the force on the maxillary canine perhaps due to the fact that the molar is larger in dimension. Or, it may be due to the reasoning that Class II elastics are not always connected to the mandibular first molars. Sometimes, they are attached to other posterior teeth, so the true effect on the first molars may not have been realized in this study. There was also no significant difference among the various torque prescriptions or archwire dimensions on the change in molar inclination.

The lack of orthodontic treatment effect on the mandibular first molars may be due the increased axial loading forces on the posterior dentition as opposed to the anterior dentition. The increased muscular forces transmitted to posterior teeth during functioning may override the movements attempted by orthodontic biomechanics. The results of this study may indicate that orthodontists have more control over the movements of anterior than posterior teeth.

Although the mean change in molar inclination was statistically significant, it is not deemed clinically significant. Evangelinakis also found about a two degree mean increase in buccal inclination in Class I patients after orthodontic treatment, so the change in molar inclination found in this study is not attributable to the effect of Class II elastics.[6] The increase in buccal inclination along with an insignificant increase in intermolar width is congruent with appropriate dental changes during development. Marshall reported in 2003 that during development, mandibular molars erupt with lingual inclination and upright buccally in the absence of orthodontic therapy.[14] From this study's findings, orthodontic therapy with Class II elastics is not obstructing normal development or negatively influencing stability of the mandibular first molars.

The clinical significance of the current study's findings relates not to the small mean changes in canine and molar inclinations but to individualizing treatment plans for patients with Class II malocclusions. The wide range of initial canine (88.3-116.5 degrees) and molar (61.8-89.5 degrees) inclinations, as well as the wide range of change in canine (-15.1-15.3 degrees) and molar (-6.4-12.6 degrees) inclinations demonstrates this clinical significance. In those patients with increased pretreatment lingual canine inclinations (more than one standard deviation from the norm 103.9 ± 5.0 degrees) and those with thin biotypes who may be predisposed to gingival recession, perhaps positive torque prescriptions or zero degree torque, such as in the MBT or Damon prescriptions, or increased buccal crown torque of the archwire should be used to counter balance the lingual tipping effects of Class II elastics.

These treatment modifications should also be considered in patients with increased initial canine inclination who simultaneously require an increased intercanine width with archwire expansion. As canine inclination becomes more lingual during treatment and intercanine width increases, the roots are translating closer to the buccal cortical plate. It may be preferable to limit the amount of lingual crown inclination change in these circumstances.

The choice of Class II corrector may also be affected by the initial inclination of maxillary canines. The Forsus appliance may be a better choice in individuals who require less lingual crown inclination changes since there may be less of a lingual force vector applied to them during treatment. This is a hypothesis that could be tested further.

If achieving an ideal and stable occlusion is the goal of orthodontic treatment and buccolingual inclination contributes to intra- and inter-arch relationships, the management of inclination in the transverse dimension should be a part of the orthodontic treatment plan. It should be recognized that the large range of initial inclinations, even in a selected group of Class II malocclusions, indicates many factors are responsible for not only initial transverse angulations, but also the changes of those angulations during treatment, and these factors should be considered during individualized treatment planning. For example, perhaps the combination of Class II elastics with preadjusted, negatively torqued prescription maxillary canine brackets should be more carefully considered in those patients with thin biotypes whose initial canine inclinations are more lingual than normal.

CBCT allows orthodontists to evaluate dental positions in the transverse dimension, and, hopefully, this knowledge will compel practitioners to include a transverse analysis when diagnosing and treatment planning. In addition, during active treatment, this new information may aid orthodontists in keeping the teeth in a more physiologically healthy position, reducing the possibility of fenestration and dehiscence of the root and consequent periodontal problems. Proper angulations could also contribute to increased long axis directed chewing forces and canine guidance during working movements, resulting in more efficient function and, possibly, more stable result.

CONCLUSION

1) Maxillary canine torque decreases with Class II elastic treatment, and this change is related to length of time of Class II elastic wear and to the torque prescription in the preadjusted canine bracket; 2) There was a significant positive correlation between the change in canine angulation and change in intercanine width; 3) A significant change in buccolingual inclination of mandibular first molars was observed with orthodontic treatment using Class II elastics; 4) Mandibular first molar torque increases with Class II elastic treatment while intermolar width does not significantly change.

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Table 1: Descriptive summary of demographics, bracket prescription, maxillary canine torque prescription, mandibular first molar torque prescription, slot filled maxillary arch, slot filled mandibular arch.

Variable	Group	Total (N=39)	Percent
Gender	Male	13	33.3
	Female	26	66.7
Race	Caucasian	35	89.7
	African American	2	5.1
	Asian/Other	2	5.1
Bracket prescription	MBT .022	25	64.1
	Roth .018	4	10.3
	Roth .022	5	12.8
	Damon	4	10.5
	Alexander	1	2.6
Torque maxillary canine	0°	28	78.1
	-2°	4	10.3
	-3°	6	15.4
	-7°	1	2.6
Torque mandibular first molar	-20°	20	51.3
	-25°	14	35.9
	-28°	4	10.3
	-14°	1	2.6
Bracket slot filled maxillary arch	Yes	18	46.2
	No	21	53.8
Bracket slot filled mandibular arch	Yes	11	28.2
	No	28	71.8

Table 2: Means, Standard Deviations and Ranges of Maxillary Canine and Mandibular First Molar Inclinations and Arch Widths before and after treatment with Class II elastics.

Variable (N=39)	Initial		Final		Change		Intraclass correlation r^2
	Mean±SD	Range	Mean±SD	Range	Mean±SD	Range	
Maxillary left canine inclination (°)	103.5± 6.6	90.4-116.1	102.1±5.5	92.1-113.2	-1.5±6.3	-15.1-15.3	.991
Maxillary right canine inclination (°)	102.7± 6.2	88.3-116.0	101.5±5.9	82.7-112.3	-1.2±5.1	-11.3-9.1	.996
Mandibular left first molar inclination (°)	75.7 ± 4.0	65.0-83.7	77.4 ± 4.1	67.3-86.1	1.7±3.2*	-6.5-11.5	.861
Mandibular right first molar inclination (°)	74.4 ± 4.2	62.0-83.9	76.4 ± 4.6	63.0-84.1	2.0±3.3**	-6.2-12.6	.967
Maxillary intercanine width (mm)	34.3±2.5	28.8-39.0	35.7±2.2	30.8-39.6	1.4±2.5*	-3.4-6.5	.998
Mandibular intermolar width (mm)	40.9±2.2	36.8-46.0	41.0±2.2	36.9-45.5	0.18±1.2	-3.2-3.2	.998

*P≤0.05; **P≤0.001

Table 3: One way ANOVA comparing Buccolingual Inclination and Arch Width changes after treatment with Class II elastics between torque prescriptions.

Variable	Torque	Mean	SD	Range	Sig (p-value)
Maxillary left canine inclination change (°) (N=39)	0° (28) -2° (4) -3° (6) -7° (1)	.10 -3.8 -5.9 -9.2	6.2 2.9 5.6 0	-12.8-15.3 -6.2-.40 -15.1- -.60 -9.2	.073
Maxillary right canine inclination change (°) (N=39)	0° (28) -2° (4) -3° (6) -7° (1)	-.22 -5.6 -1.4 -9.5	5.2 2.2 3.4 0	-11.3-9.1 -6.8- -2.3 -6.4-1.8 -9.5	.077
Mandibular left first molar inclination change (°) (N=39)	-20° (20) -25° (14) -28° (4) -14° (1)	1.6 2.1 .95 .70	4.1 1.9 2.1 0	-6.4-11.5 -2.1-4.8 -1.1-3.7 .70	.420
Mandibular right first molar inclination change (°) (N=39)	-20° (20) -25° (14) -28° (4) -14° (1)	2.1 2.6 .75 -2.4	3.9 2.6 2.7 0	-6.2-12.6 -.90-6.4 -2.8-3.0 -2.4	.889
Maxillary intercanine width change (mm)	0° (28) -2° (4) -3° (6) -7° (1)	1.6 1.2 .85 .80	2.7 2.9 1.6 0E-7	-3.4-6.5 -2.4-5.3 -1.3-2.4	.792
Mandibular intermolar width change (mm)	-20° (20) -25° (14) -28° (4) -14° (1)	.44 .12 -.58 -.70	1.4 .73 1.6 0E-7	-3.2-3.2 -0.9-1.4 -2.2-1.4	.120

Table 4: Independent Sample T-test comparing buccolingual canine inclinations and arch width changes after treatment with Class II elastics between negative canine bracket torque prescriptions and zero degree torque prescription.
*P≤ 0.05

Variable	Torque (°)	Mean	SD	Range	Sig (p-value)
Maxillary left canine inclination change (°) (N=39)	Negative (N=11)	-5.3	4.7	-15.1-0.4	.014*
	Zero (N=28)	0.11	6.2	-12.8-15.3	
Maxillary right canine inclination change (°) (N=39)	Negative (N=11)	-3.7	3.9	-9.5-1.8	.036*
	Zero (N=28)	-0.3	5.3	-11.3-9.1	
Maxillary intercanine width change (mm)	Negative (N=11)	.98	2.1	-1.3-5.3	.451
	Zero (N=28)	1.6	2.7	-3.4-6.5	

Table 5: Correlations among changes in inclinations and changes in arch widths (N=39).

	Change in Intercanine Width		Change in Intermolar Width	
	Pearson Correlation	Significance	Pearson Correlation	Significance
Change in Left Canine Inclination	.517	.001**	-	-
Change in Right Canine Inclination	.402	.011*		
Change in Left Molar Inclination	-	-	.234	.152
Change in Right Molar Inclination	-	-	.246	.131

*P≤0.05; **P≤0.001

Figure 1: In the axial view position the line representing the sagittal plane tangent to the most buccal point on the canine along the dental arch.



Figure 2: Locate the cusp tip of the canine in the sagittal view.

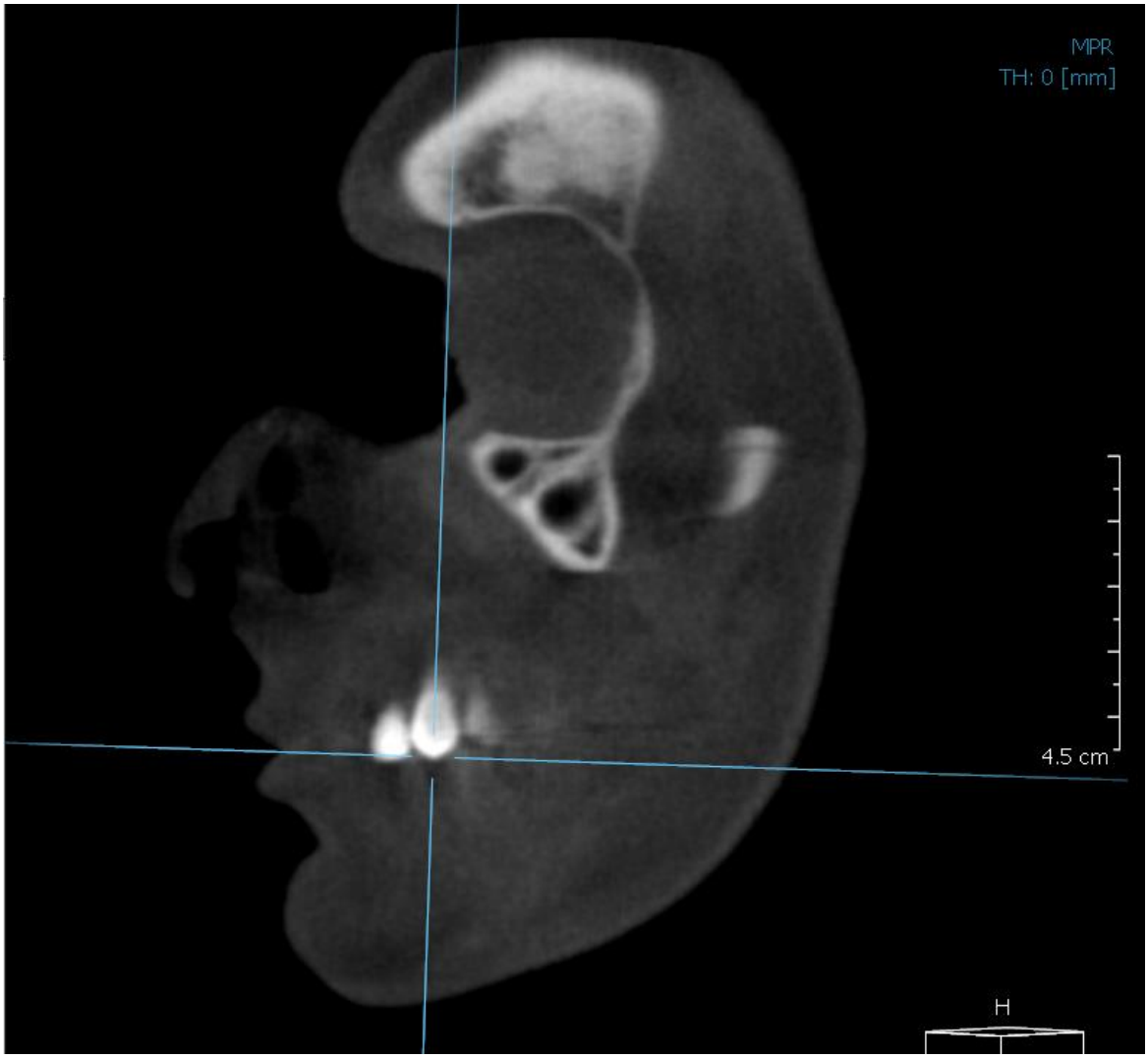


Figure 3: Locate the apex of the canine and move the coronal plane so that it passes through the apex and cusp tip, representing the long axis.

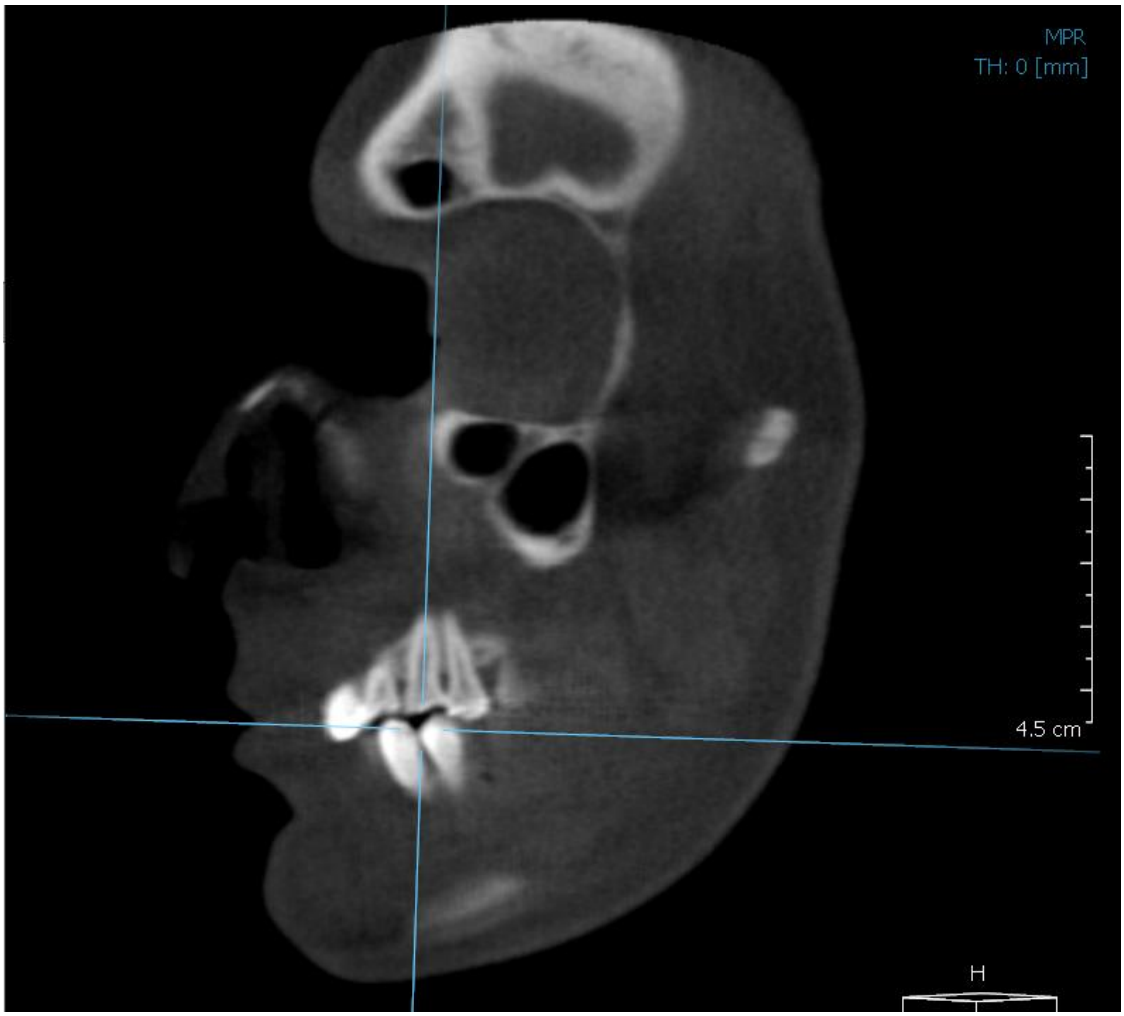


Figure 4: In the coronal view, measure the angle formed by the horizontal reference plane and the long axis of the canine.

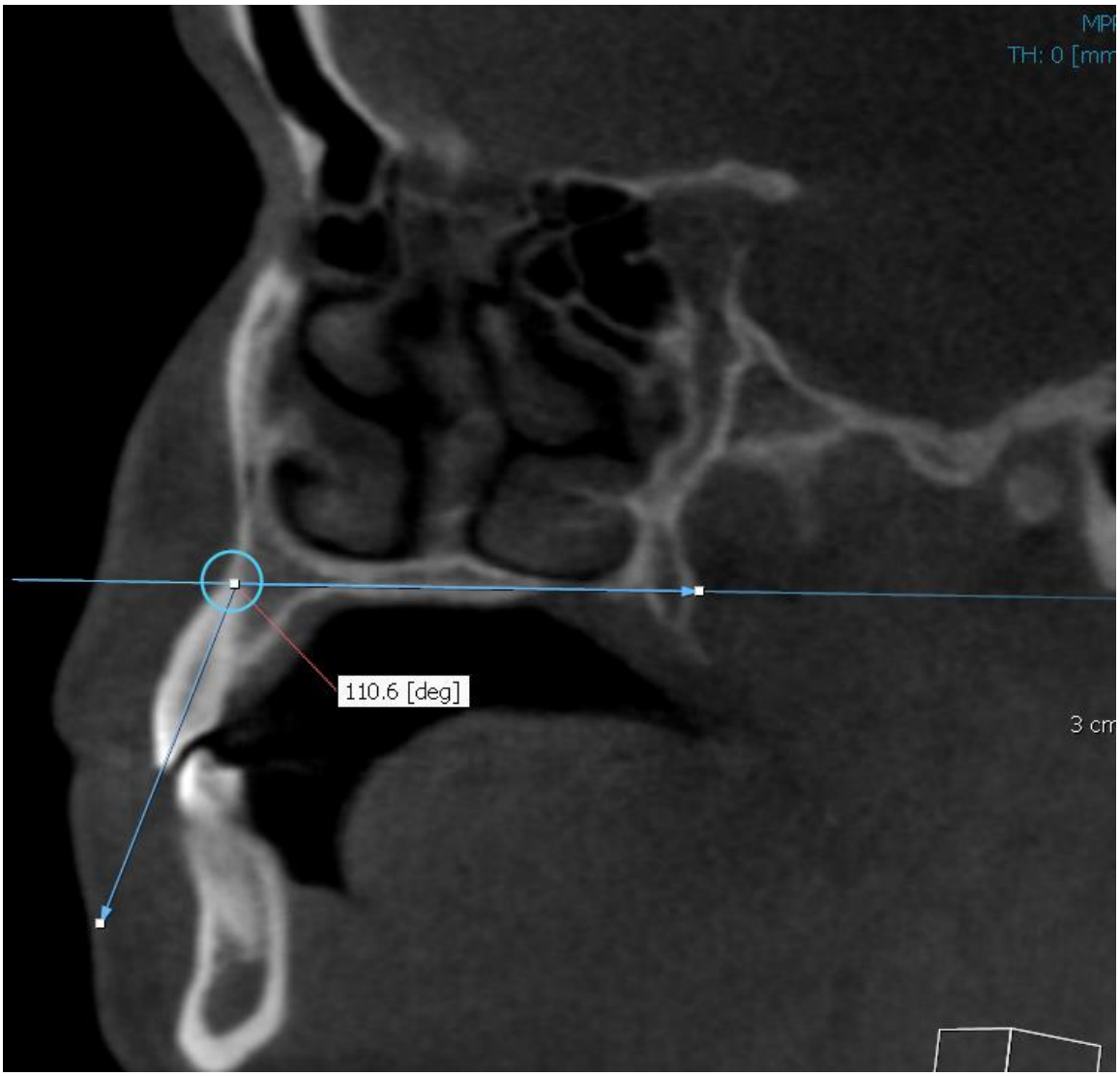


Figure 5: Locate molar in the axial view, the point at which the root is longest in the sagittal view.

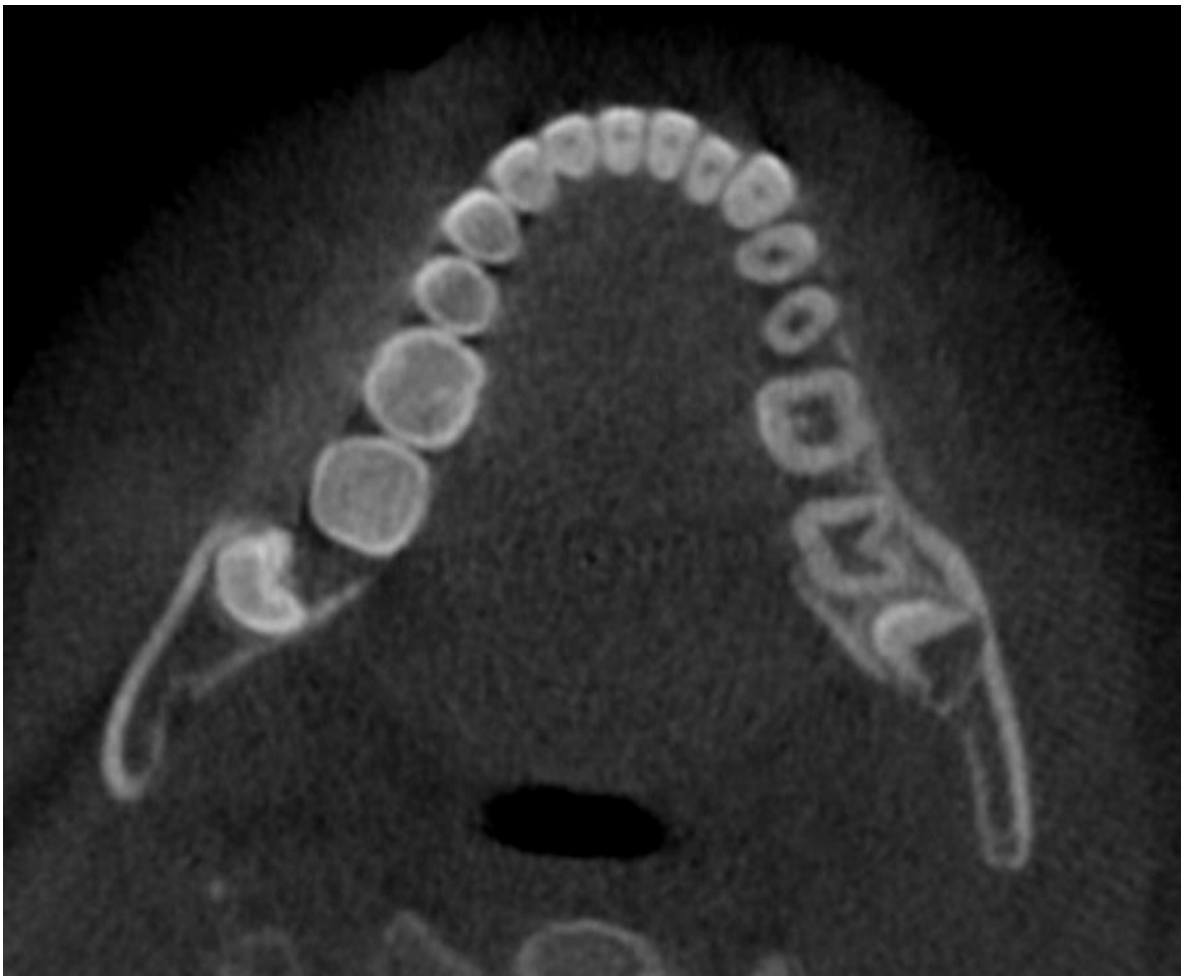
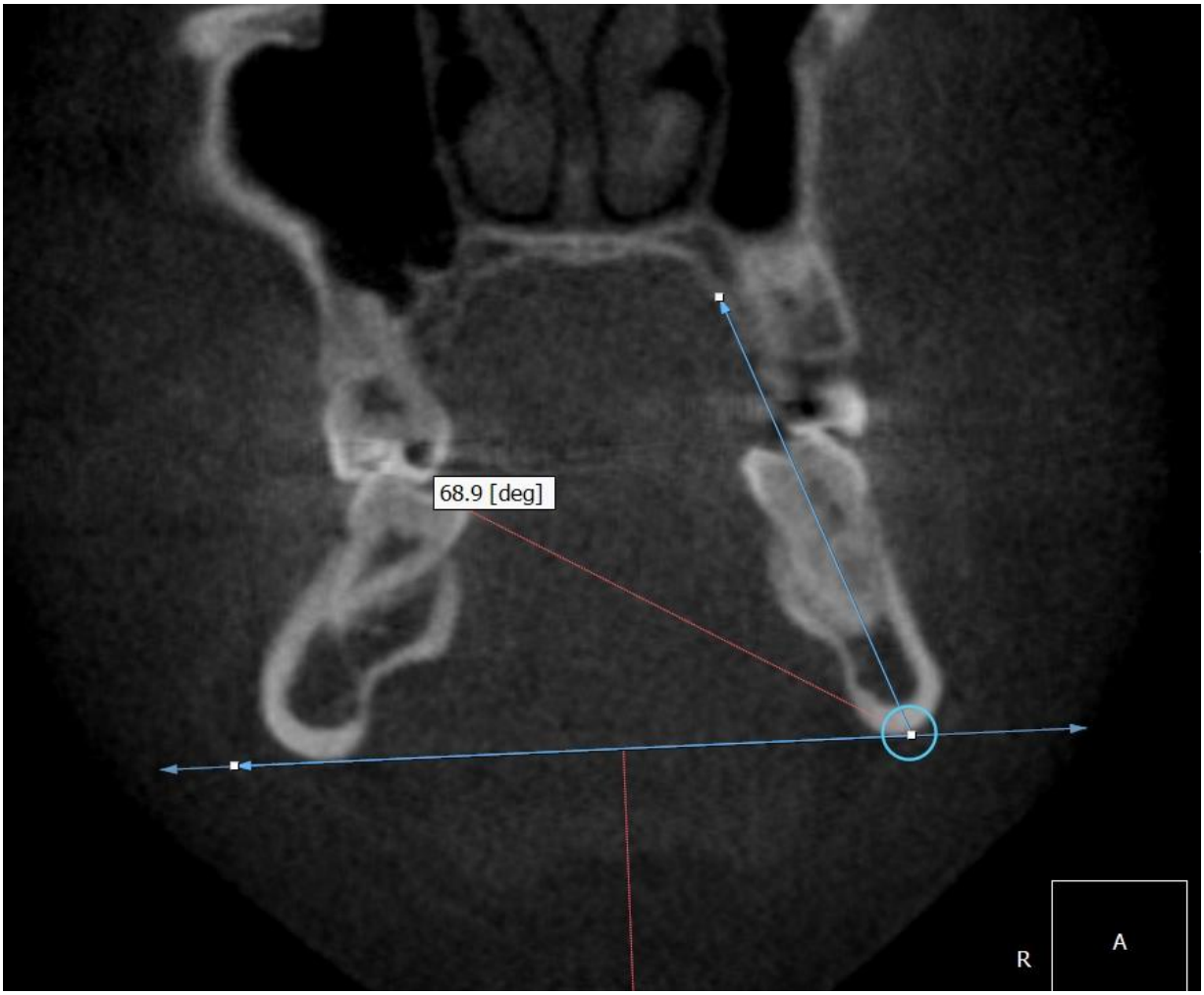


Figure 6: In the sagittal view, position the line representing the coronal slice along the plane of the mesial cusp tip and the mesial root apex.



Figure 7: In the coronal view, draw the reference line tangent to the base of mandible and measure the inclination through the long axis of the molar (line between the central groove and root apex).



Appendix I

IRB Approval

Case Western Reserve University
Institutional Review Board

NOTICE OF EXEMPTION (#4)

Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available or if the information is recorded by the investigator in such a manner that subjects cannot be identified, directly or through identifiers linked to the subjects.

This protocol is exempt under the #4 category because this involves existing retrospective de-identified data. Please note that this only applies to existing data.

Prospective data is NOT included in this exemption – i.e., De-identified pre-existing data to be collected on 02/24/2012 and after are NOT covered by this exemption.

Responsible Investigator: **J. Martin Palomo**
Department: **Dental Orthodontics**
IRB Protocol Number: **2012118**
Title: ***Changes in Buccolingual Inclination of Maxillary Canines and Mandibular First Molars After Orthodontic Treatment in Class II Patients Treated with Intermaxillary Elastics***
Co-Investigator: **Lyndsey McCaskey**

Exemption Date: **February 23, 2012**

APPENDIX II

Tables

Table: Descriptive statistics of maxillary and mandibular archwire alloy during Class II elastic wear.

Variable	Group	Total (N=39)	Percent
Archwire alloy maxillary arch	Nickel Titanium Stainless Steel TMA	5 25 9	12.8 64.1 23.1
Archwire alloy mandibular arch	Nickel Titanium Stainless Steel TMA	2 30 7	5.1 76.9 17.9

Table: Descriptive summary of maxillary and mandibular archwire dimensions during Class II elastic wear.

Variable	Group	Total (N=39 per arch)	Percent
Maxillary archwire dimension (round)	.016 .018 .020	1 0 1	2.6 0 2.6
Mandibular archwire dimension (round)	.016 .018 .020	1 5 4	2.6 12.8 10.3
Maxillary archwire dimension (rectangular)	16x22 17x25 18x25 19x25 21x25	3 13 4 16 1	7.7 33.3 10.3 41.0 2.6
Mandibular archwire dimension (rectangular)	16x22 17x25 18x25 19x25 21x25	3 12 4 9 1	7.7 30.8 10.3 23.1 2.6

Table: Descriptive summary of patient age at start of treatment, treatment length, length of time Class II elastics were prescribed, and length of time largest dimension archwire was in place.

Variable	Minimum	Maximum	Mean	Standard Deviation
Age (months)	129	208	162.6	15.9
Treatment length (months)	14	38	24.9	4.6

Class II elastics (days)	28	672	307.9	176.2
Maxillary archwire (days)	27	672	215.5	161.7
Mandibular archwire (days)	27	648	215.8	150.1

Table: Gender differences in Maxillary Canine and Mandibular First Molar Inclinations and Arch Widths before and after treatment with Class II elastics.

Variable	Group (N=39)	Mean	SD	Sig (p-value)
Maxillary left canine inclination change (°)	Male (13) Female (26)	1.6 -2.9	6.4 5.7	.041
Maxillary right canine inclination change (°)	Male (13) Female (26)	-.45 -1.6	6.3 4.5	.579
Mandibular left first molar inclination change (°)	Male (13) Female (26)	1.3 1.9	2.9 3.3	.561
Mandibular right first molar inclination change (°)	Male (13) Female (26)	1.1 2.5	2.8 3.5	.209
Maxillary intercanine width change (mm)	Male (13) Female (26)	2.1 1.1	2.7 2.5	.110
Mandibular intermolar width change (mm)	Male (13) Female (26)	.26 .15	1.1 1.3	.703

Table: One way ANOVA comparing Buccolingual Inclination and Arch Width changes after treatment with Class II elastics between rectangular archwires used.

Variable	Archwire dimension	Mean	SD	Sig (p-value)
Maxillary left canine inclination change (°) (N=39)	16x22 (6) 17x25 (26) 18x25 (8) 19x25 (36) 21x25 (2)	-3.3 -1.8 -5.0 .55 -6.7	2.5 6.9 6.5 5.0 0	.459
Maxillary right canine inclination change (°) (N=39)	16x22 (6) 17x25 (26) 18x25 (8) 19x25 (36) 21x25 (2)	.33 -1.1 -3.0 -.62 -6.7	.32 6.3 6.4 4.6	.753
Mandibular left first molar inclination change (°) (N=39)	16x22 (3) 17x25 (12) 18x25 (4) 19x25 (9) 21x25 (1)	1.3 2.1 1.2 2.9 3.3	2.4 2.2 2.2 4.5 0	.877
Mandibular right first molar inclination change (°) (N=39)	16x22 (3) 17x25 (12) 18x25 (4) 19x25 (9) 21x25 (1)	1.4 2.0 2.2 3.7 -.90	1.6 2.9 1.7 3.9 0	.522
Maxillary intercanine width change (mm)	16x22 (3) 17x25 (13) 18x25 (4) 19x25 (18) 21x25 (1)	1.5 1.4 .80 1.8 -2.8	1.3 2.8 .73 2.8 0	.172
Mandibular intermolar width change (mm)	16x22 (3) 17x25 (12) 18x25 (4) 19x25 (9) 21x25 (1)	-.13 .35 .58 .38 -.80	1.3 1.5 .73 1.4 0	.674

Table: Differences in Maxillary Canine and Mandibular First Molar Inclinations and Arch Widths before and after treatment with Class II elastics when the bracket slot was filled vs. not filled.

Variable	Slot filled	Mean	SD	Sig (p-value)
Maxillary left canine inclination change (°) (N=39)	Yes (18) No (21)	-.41 -2.4	5.9 6.6	.335
Maxillary right canine inclination change (°) (N=39)	Yes (18) No (21)	-1.2 -1.2	4.7 5.5	.994
Mandibular left first molar	Yes (11) No (28)	2.8 1.2	4.1 2.7	.239

inclination change (°) (N=39)				
Mandibular right first molar inclination change (°) (N=39)	Yes (11) No (28)	3.3 1.5	3.8 3.1	.174
Maxillary intercanine width change (mm)	Yes (18) No (21)	1.4 1.4	2.8 2.3	.979
Mandibular intermolar width change (mm)	Yes (11) No (28)	.27 .16	1.3 1.2	.726

Table: One way ANOVA comparing Buccolingual Inclination and Arch Width changes after treatment with Class II elastics between archwire alloys used.

Variable	Alloy	Mean	SD	Sig (p-value)
Maxillary left canine inclination change (°) (N=39)	Nickel Titanium (5) Stainless Steel (25) TMA (9)	.34 -1.1 -3.4	7.1 6.7 4.5	.527
Maxillary right canine inclination change (°) (N=39)	Nickel Titanium (5) Stainless Steel (25) TMA (9)	-1.7 -.92 -1.6	7.2 5.1 4.1	.911
Mandibular left first molar inclination change (°) (N=39)	Nickel Titanium (2) Stainless Steel (30) TMA (7)	1.8 1.6 1.9	2.8 3.4 2.5	.985
Mandibular right first molar inclination change (°) (N=39)	Nickel Titanium (2) Stainless Steel (30) TMA (7)	1.6 1.6 4.1	2.1 2.9 4.7	.181
Maxillary intercanine width change (mm)	Nickel Titanium (5) Stainless Steel (25) TMA (9)	1.1 2.3 -.80	2.3 2.3 1.9	.005
Mandibular intermolar width change (mm)	Nickel Titanium (2) Stainless Steel (30) TMA (7)	.85 .09 .43	.64 1.2 1.3	.360

Table: Correlations among Change in Maxillary Canine and Mandibular First Molar Inclination and Arch Width with the Length of time Class II Elastics were prescribed, Length of time Maxillary Archwire was in place, and Length of time Mandibular Archwire was in place (N=39).

	Length of time Class II Elastics (days)		Length of time Maxillary AW (days)		Length of time Mandibular AW (days)	
	Pearson Correlation	Significance	Pearson Correlation	Significance	Pearson Correlation	Significance
Change in Left Canine Inclination	-.577	.000**	-.221	.177	-	-
Change in Right Canine Inclination	-.426	.007*	-.309	.056	-	-
Change in Left Molar Inclination	-.004	.981	-	-	.196	.231
Change in Right Molar Inclination	.024	.886	-	-	-.118	.476
Change in Intercanine Width	-.347	.030*	-.085	.606	-	-
Change in Intermolar Width	-.071	.666	-	-	.082	.619

*P≤0.05; **P≤0.001

Table: Comparison of mean changes of maxillary canine and mandibular molar inclinations and widths of Class II patients treated with Class II elastics to changes in Class I orthodontic patients.

Variable (N=39)	Class II elastics (N=39)		Miyamoto Class I Maxillary Canine (N=38)		Evangelinakis Class I Mandibular Molar (N=29)	
	Mean±SD	Range	Mean±SD	Range	Mean±SD	Range
Maxillary left canine inclination (°)	-1.5 ± 6.3	-15.1-15.3	-0.19 ± 3.9	-9.3-8.3		
Maxillary right canine inclination (°)	-1.2 ± 5.1	-11.0-9.1	-0.18 ± 4.6	-9.6-8.7		
Mandibular left first molar inclination (°)	1.7 ± 3.2	-6.4-11.5			2.6 ± 4.3	-6.1-13.2
Mandibular right first molar inclination (°)	2.0 ± 3.3	-6.2-12.6			1.1 ± 3.6	-6.7-7.4
Maxillary intercanine width (mm)	1.4 ± 2.5	-3.4-6.5	1.2 ± 1.6	-0.9 - 5.1		
Mandibular intermolar width (mm)	0.19 ± 1.2	-3.2-3.2			0.39 ± 1.6	-3.9-3.2

Appendix III

Raw Data

Patient ID	Resident	IL3	FL3	CL3	IR3	FR3	CR3
1	1	98	101.4	3.4	97.9	101.3	3.4
2	2	111.3	104.3	-7	116.5	105.2	-11.3
3	3	100.7	102.2	1.5	94.6	94.5	-0.1
4	4	96.9	100.6	3.7	101.1	103.5	2.4
5	5	107.5	98.3	-9.2	103.2	93.7	-9.5
6	6	103.3	96.6	-6.7	102.9	96.2	-6.7
7	1	102.1	96.8	-5.3	104.2	101.9	-2.3
8	7	97.4	104.5	7.1	99.2	106.4	7.2
9	1	98.2	93.8	-4.4	89.5	82.7	-6.8
10	8	109.7	103.7	-6	102.5	102.7	0.2
11	6	111.9	103.5	-8.4	101.8	94.5	-7.3
12	9	95.4	100.3	4.9	103.8	96.6	-7.2
13	12	106.9	94.2	-12.7	101.2	98.7	-2.5
14	1	96.7	96.3	-0.4	100.5	98	-2.5
15	1	96.6	95.4	-1.2	88.3	90.7	2.4
16	6	99.4	101.6	2.2	95.1	104.2	9.1
17	3	111.5	106.8	-4.7	114.3	108.2	-6.1
18	10	104.4	105.1	0.7	97.7	103.1	5.4
19	8	104.6	102.4	-2.2	103.7	104.4	0.7
20	6	110.5	104.3	-6.2	113.8	107.1	-6.7
21	11	96.5	95.1	-1.4	92.7	96.1	3.4
22	6	107.4	94.6	-12.8	100.1	95.7	-4.4
23	10	98.6	102.8	4.2	99.7	101.8	2.1
24	6	108	104.8	-3.2	100.8	107.3	6.5
25	6	107.2	111.5	4.3	108.7	102.1	-6.6
26	8	94.4	99.7	5.3	106.3	108.2	1.9
27	7	95.6	96	0.4	108.7	102.2	-6.5
28	2	102.2	105.2	3	104.7	104.3	-0.4
29	2	103.9	110	6.1	108.5	112.3	3.8
30	10	101.5	92.1	-9.4	101.5	96.6	-4.9
31	6	111.4	113.2	1.8	105.2	105.6	0.4
32	10	116.1	101	-15.1	104.2	97.8	-6.4
33	8	90.4	105.7	15.3	101.7	100.8	-0.9
34	8	99.9	105.8	5.9	100.6	108.8	8.2
35	1	97.7	97.1	-0.6	97.6	99.4	1.8
36	12	111.5	111.2	-0.3	109.6	105	-4.6

37	13	105.4	102.6	-2.8	103.3	103.3	0
38	13	112.9	111.1	-1.8	110.5	110.6	0.1
39	1	115.2	110.6	-4.6	109	106.1	-2.9

Patient ID	IL6	FL6	CL6	IR6	FR6	CR6	IIC	FIC	CIC
1	73.8	76.1	2.3	76.2	70	-6.2	30.9	36.6	5.7
2	73.2	74.9	1.7	76.1	72.7	-3.4	38.6	39.4	0.8
3	78.3	77.4	-0.9	72.7	69.8	-2.9	30.5	35.7	5.2
4	75.9	77.3	1.4	76.6	73.8	-2.8	34.4	36.6	2.2
5	83.6	84.3	0.7	82.8	80.4	-2.4	34	34.8	0.8
6	72.6	75.9	3.3	69.7	68.8	-0.9	33.6	30.8	-2.8
7	76	79.5	3.5	77	76.1	-0.9	34.3	35.3	1
8	73.8	72.9	-0.9	74.2	73.3	-0.9	34	39.6	5.6
9	68.6	70.9	2.3	73.5	72.8	-0.7	36.7	34.3	-2.4
10	79.6	80.8	1.2	83.9	83.5	-0.4	35.3	37.7	2.4
11	73.3	77	3.7	80.2	80.3	0.1	32.8	32.5	-0.3
12	78	78	0	78.9	79.4	0.5	32.8	33	0.2
13	64.6	69.5	4.9	61.8	62.7	0.9	37.5	34.1	-3.4
14	72.2	83.7	11.5	74.7	75.7	1	34.9	37.7	2.8
15	70.4	70.4	0	70.8	72	1.2	31.5	31.3	-0.2
16	77.2	79.4	2.2	72.4	73.9	1.5	30.1	35.5	5.4
17	76.4	82.2	5.8	77.4	79.2	1.8	34.9	34	-0.9
18	79.1	80.7	1.6	75.3	77.1	1.8	34.7	36.6	1.9
19	69.3	73	3.7	67.2	69.1	1.9	32.6	35	2.4
20	78.9	79.8	0.9	77.4	79.6	2.2	33.2	38.5	5.3
21	82.8	76.4	-6.4	76.7	79.1	2.4	34.7	38.3	3.6
22	77.4	76.3	-1.1	73.1	75.8	2.7	32.6	33.8	1.2
23	79.1	80	0.9	73.7	76.5	2.8	37	37.9	0.9
24	70.9	67.3	-3.6	71.7	74.6	2.9	33.8	34.6	0.8
25	74.9	74.7	-0.2	78.4	81.4	3	34.6	36.1	1.5
26	71.9	74.5	2.6	75.7	78.9	3.2	31.2	37.5	6.3
27	76.3	81.1	4.8	73.3	76.8	3.5	37.8	38.8	1
28	77.2	76.1	-1.1	72.9	76.6	3.7	32.3	35.4	3.1
29	79.2	77.7	-1.5	74.6	78.4	3.8	36.2	35.9	-0.3
30	83.7	86.1	2.4	79.6	83.5	3.9	34.1	33.8	-0.3
31	76.5	74.4	-2.1	71.1	75.1	4	35.3	36.3	1
32	75.7	78.5	2.8	70.8	74.9	4.1	33.9	32.6	-1.3
33	76.8	85.6	8.8	77.3	81.6	4.3	28.8	35.3	6.5
34	78.3	78.6	0.3	77.5	82.9	5.4	37.2	36.6	-0.6

35	79.3	78.5	-0.8	72.1	77.6	5.5	30.9	33	2.1
36	72.9	77.5	4.6	72.3	78.4	6.1	38.8	35.8	-3
37	71.5	75.5	4	66.6	72.7	6.1	33.8	34.5	0.7
38	77.1	79.5	2.4	72.8	79.2	6.4	38.6	38.4	-0.2
39	77.3	76.7	-0.6	71.5	84.1	12.6	37.4	38	0.6

Patient ID	IIM	FIM	CIM	Length of time for elastics	Gender	Age Start	Age Finish	Tx Length	Bracket Prescription
1	41	40	-1	142	2	143	163	20	1
2	45.5	45.2	-0.3	438	2	154	187	33	1
3	40.5	41.4	0.9	242	1	172	198	26	1
4	43.1	40.9	-2.2	89	1	176	190	14	5
5	40.9	40.2	-0.7	245	1	208	232	24	1
6	43.3	42.5	-0.8	607	2	177	214	37	1
7	41.1	40.4	-0.7	648	2	164	186	22	3
8	38.8	40	1.2	254	1	161	199	38	1
9	42.4	43.8	1.4	378	1	157	180	23	3
10	41.4	42.5	1.1	502	2	178	202	24	2
11	40.6	40.9	0.3	317	2	161	182	21	5
12	41.2	41.8	0.6	672	1	160	190	30	1
13	37.8	36.6	-1.2	497	2	184	209	25	1
14	40.7	42	1.3	342	2	145	179	34	1
15	43.2	40	-3.2	300	2	162	185	23	1
16	37.8	37.4	-0.4	224	2	161	182	21	1
17	40.9	44.1	3.2	187	2	161	185	24	1
18	41.2	40.3	-0.9	187	1	171	196	25	1
19	40.6	40.9	0.3	173	2	155	179	24	2
20	41.9	42.7	0.8	181	1	145	167	22	3
21	41.1	40.8	-0.3	276	2	171	195	26	1
22	39.1	37.3	-1.8	637	2	193	218	25	5
23	44.3	45.5	1.2	125	1	159	183	24	1
24	41.7	42.3	0.6	251	1	151	175	24	1
25	36.8	38.2	1.4	119	2	129	152	23	5
26	41.7	41.4	-0.3	295	2	159	183	24	1
27	43.5	43.9	0.4	219	1	158	176	18	3
28	37.7	39	1.3	405	2	165	193	28	1
29	39.6	40.7	1.1	130	2	171	195	24	1
30	39.9	40.3	0.4	473	2	148	173	25	4

31	37.6	37.3	-0.3	82	2	139	162	23	1
32	38.1	38.8	0.7	524	2	182	208	26	3
33	42	43.2	1.2	85	1	145	170	25	1
34	45.9	44.8	-1.1	28	1	172	192	20	1
35	41.4	40.6	-0.8	288	2	173	195	22	2
36	38.2	40.8	2.6	267	2	178	205	27	1
37	37	36.9	-0.1	141	2	148	173	25	1
38	42.4	42.6	0.2	528	2	171	197	26	2
39	40.6	41.7	1.1	511	2	135	162	27	1

Patient ID	Torque L6	Torque U3	AW shape max	AW dimension round max	AW dimension rectangular max	AW alloy max	AW time max	Slot filled max	AW shape mand
1	1	1	2		4	2	84	1	1
2	1	1	2		4	2	323	1	1
3	1	1	2		4	2	194	1	1
4	3	1	2		4	2	89	1	2
5	4	4	2		2	2	145	2	2
6	2	1	2		5	3	106	1	2
7	2	2	1	1		2	648	2	1
8	1	1	2		2	2	254	2	2
9	2	2	2		4	3	189	1	2
10	2	3	2		1	2	502	2	2
11	3	1	2		3	1	158	2	2
12	1	1	2		2	2	672	2	2
13	1	1	2		2	3	132	2	1
14	1	1	2		4	2	220	1	2
15	1	1	2		4	3	106	1	2
16	1	1	2		2	2	91	2	2
17	1	1	2		2	2	187	2	2
18	2	1	2		4	3	116	1	2
19	2	3	2		1	2	173	2	2
20	2	2	2		4	1	78	1	2
21	1	1	2		4	2	160	1	1
22	3	1	2		3	2	91	2	2
23	1	1	2		4	2	125	1	2

24	1	1	2		3	2	184	2	1
25	3	1	2		3	1	119	2	2
26	1	1	2		2	2	281	2	2
27	2	2	2		2	2	219	2	2
28	1	1	2		2	2	405	2	2
29	1	1	2		4	1	103	1	1
30	2	3	2		2	2	473	1	2
31	2	1	2		4	3	82	1	2
32	2	3	2		2	2	524	2	2
33	1	1	2		4	2	85	1	2
34	1	1	2		2	1	28	2	1
35	2	3	2		2	2	153	2	2
36	1	1	2		4	3	191	1	2
37	2	1	2		4	3	27	1	2
38	2	3	2		1	2	215	2	1
39	1	1	2		4	3	350	1	2

Patient ID	AW dimension round mand	AW dimension rectangular mand	AW alloy mand	AW time mand	Slot filled mand	Race	Instructor
1	3		2	142	2	1	1
2	3		2	438	2	1	2
3	3		2	194	2	1	3
4		2	2	89	2	1	4
5		2	2	145	2	1	5
6		5	3	106	1	1	6
7	1		2	648	2	1	7
8		2	2	254	2	1	8
9		4	3	189	1	1	7
10		1	2	502	2	1	9
11		3	1	158	2	1	4
12		2	2	371	2	1	8
13	2		2	260	2	1	2
14		4	2	177	1	1	3
15		4	2	232	1	1	10
16		3	2	91	2	1	8
17		2	2	93	2	1	8
18		2	3	187	2	1	6

19		1	2	173	2	1	9
20		4	2	78	1	1	11
21	2		2	276	2	3	2
22		1	2	91	2	1	12
23		4	2	125	1	1	13
24	2		2	184	2	1	14
25		3	1	119	2	3	4
26		2	2	281	2	1	8
27		2	2	219	2	1	7
28		3	2	63	2	1	8
29	3		2	130	2	1	3
30		2	2	473	1	2	15
31		4	3	82	1	1	6
32		2	2	524	2	1	8
33		4	2	524	1	1	8
34	2		2	28	2	1	8
35		2	2	141	2	1	16
36		2	3	191	2	1	8
37		4	3	27	1	1	6
38	2		2	215	2	2	16
39		4	3	196	1	1	8

Patient ID	DOB	Start Date	Debond Date
1	12/4/97	11/4/09	7/18/11
2	11/18/94	11/14/06	8/31/09
3	5/10/94	9/23/08	11/9/10
4	4/8/92	12/6/06	2/18/08
5	7/21/91	11/12/08	11/1/10
6	10/9/93	7/10/08	8/23/11
7	4/24/96	10/9/09	10/3/11
8	2/24/95	7/14/08	9/14/11
9	10/21/96	11/24/09	10/18/11
10	10/31/94	8/12/09	8/17/11
11	6/4/96	11/2/09	8/30/11
12	11/27/93	3/7/07	9/22/09
13	3/20/93	7/29/08	8/18/10
14	7/15/96	8/26/08	6/27/11
15	5/14/96	11/16/09	10/4/11

16	6/21/96	11/9/09	8/16/11
17	6/14/95	11/19/08	11/22/10
18	7/27/92	10/5/06	11/7/08
19	9/17/96	8/19/09	8/9/11
20	9/23/97	10/19/09	8/3/11
21	4/21/92	7/18/06	9/23/08
22	9/9/93	10/21/09	11/2/11
23	4/23/93	7/13/06	7/31/08
24	1/21/97	8/27/09	8/11/11
25	1/20/99	10/5/09	9/27/11
26	4/18/96	7/29/09	7/6/11
27	8/14/96	10/21/09	4/26/11
28	11/1/94	8/20/08	12/1/10
29	5/2/94	8/19/08	8/24/10
30	6/1/94	10/17/06	11/4/08
31	3/1/98	10/14/09	9/8/11
32	7/15/91	9/6/06	11/19/08
33	10/4/97	11/11/09	12/14/11
34	9/17/94	1/29/09	9/22/10
35	3/1/95	8/17/09	6/20/11
36	11/19/93	9/4/08	12/1/10
37	6/7/96	10/29/08	11/1/10
38	4/7/94	7/7/08	9/27/10
39	5/15/98	8/26/09	11/7/11

KEY FOR CATEGORICAL DATA COLLECTION

Gender 1 - Male
2 – Female

Race 1 – Caucasian
2 – Black
3 – Asian/Other

Bracket Prescription	1 – MBT .022	
	2 – Roth .018	
	3 – Roth .022	
	4 – Alexander .018	
	5 – Damon .022	
Torque Prescription L6	1 - -20	
	2 - -25	
	3 - -28	
	4 - -14	
Torque Prescription U3	1 – 0	
	2 - -2	
	3 - -3	
	4 - -7	
Archwire Shape	1 – Round	
	2 – Rectangular	
Archwire Dimension Round	1 - .016	
	2 - .018	
	3 - .020	
Archwire Dimension Rectangular	1 – 16x22	
	2 – 17x25	
	3 – 18x25	
	4 – 19x25	
	5 – 21x25	
Slot Filled	1 – yes	
	2 – no	
Archwire Alloy	1 – Nickel Titanium	
	2 – Stainless Steel	
	3 – TMA	
Resident	1 – Miyamoto	
	2 – Paulus	
	3 – Schilling	

4 – Evang
5 – Karamitsou
6 – Chitharajan
7 – Carmen
8 – Wu
9 – Zhang
10 –Vel
11 – Aus
12 – Zarka
13 – Park

Instructor 1 – White
2 – Palomo
3 – Fennel
4 – Sabat
5 – Lawrence
6 – Wenger
7 – Herberger
8 – Skorobotckyj
9 – Trouten
10 – Schmahl
11 – DeLoach
12 – Gustovich
13 – Razavi
14 – Baumgaertel
15 – Beeson
16 – Griffith

Raw Data Reliability

	IL3	IR3	IL6	IR6	IIC	IIM	FL3	FR3	FL6	FR6
1	98.1	97.3	74.7	76.3	30.8	41	101.3	100.7	74.9	71.6
39	115.2	108.5	74.2	71.7	37	40.6	112.6	107.2	76.9	83.5
15	95.7	88.5	72.5	71	31.5	43	95.7	90.3	70.4	72.1
26	95.1	106.4	71.9	75.6	31.1	41.7	100.6	107.3	74.1	79.1
10	110	103.5	81.2	81.4	35.2	41.2	101.7	102	82.6	83.7
25	107.8	108.5	73.7	77.8	34.6	36.8	111.8	102.1	77.7	79.7
11	111.2	101.8	72.8	79	32.8	40.6	104.3	94.2	77.9	80.3
17	110.6	113.1	77.5	77.7	34.9	40.9	107	108	82.9	79.9

	FIC	FIM
1	36.5	39.7
39	37.8	41.5
15	31.3	40
26	37.5	41.5
10	37.7	42.5
25	36.1	38.2
11	32.5	40.8
17	34	44.1

Shapiro-Wilk Test for Normal Distribution of Variables

	Shapiro-Wilk
	Sig.
IL3	.206
IR3	.648
IL6	.536
IR6	.556
IIC	.610
IIM	.274
FL3	.275
FR3	.188
FL6	.849
FR6	.415
FIC	.732
FIM	.354
CL3	.856
CR3	.365
CL6	.159
CR6	.252
CIC	.074
CIM	.410

Paired Sample T-test Comparing Initial and Final Right and Left Maxillary Canine and Mandibular First Molar Inclinations.

Pair	Mean	SD	Sig (p-value)
IL3-IR3	.86	6.1	.382
IL6-IL6	1.4	3.6	.024
FL3-FR3	.62	4.6	.405
FL6-FR6	1.0	4.1	.121