Maxillary and Mandibular Incisor and Molar Dentoalveolar Heights in Untreated Subjects Presenting Class I and Class II Malocclusion

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Objective:
Class II malocclusion has been extensively studied, however there are many unanswered questions. This study analyzed the difference in incisor and molar dentoalveolar heights of untreated subjects presenting with Class I and Class II malocclusion. Dental alveolar heights are an aspect of the craniofacial complex that changes with growth and development and are manipulated by orthodontists. These changes hold important clinical implications for the development, maintenance and treatment of malocclusions.

Methods:
A sample of 96 untreated Class I and Class II subjects, with a total of 611 cephalograms was drawn from the archives of the University of Michigan Growth Study. A total of 26 Class II patients and 70 Class I patients, aged 7-17. All cephalograms were traced in 150 dpi size (converted by the software GIMP), 151 landmarks were identified via Viewbox. The identification of 10 main landmarks allowed 7 linear measurements for analysis. Data was collected and analyzed in SPSS utilizing an unpaired t-test for each variable, with equal variances assumed, as well as method error for landmarks according to the Dahlberg formula.

Results:
Statistical comparisons showed there were no significant differences (p< 0.05) between Class I and Class II for each variable. According to Dahlberg formula, error varied from 0.22 for L1 Tip to 1.62 of L6 mesial cusp.

Conclusion:
The null hypothesis is accepted. Under these circumstances, there is no difference between Class I and Class II subjects in dental alveolar heights.
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Samantha Zavada Cardinal, D.M.D

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CHAPTER 1
INTRODUCTION

The first published works regarding the study of orthodontics was first documented in 1723 in a book entitled *The Surgeon Dentist, A Treatise on the Teeth*, by French dentist Pierre Fauchard in which he discussed placing teeth in their “natural position”. Over 150 years later, the seminal work of Edward Angle provided a definitive context for practitioners to define specific malocclusions (Asbell et al., 1990). The Angle classification system is still prevalent in modern day orthodontics. Using this classification, one is able to distinguish the difference between what is considered “normal” occlusion, Class I, and malocclusions of Class I, Class II and Class III. Class I is defined as the mesial-buccal cusp of the upper first permanent molar, lying directly in the mesial-buccal groove of the lower first permanent molar. When the maxillary molar mesial-buccal cusp falls anterior, or mesial, to the groove on the mandibular tooth, it is considered Class II malocclusion, whereas when the maxillary cusp falls posterior, or distal, to the groove on the mandibular tooth, it is considered class III. Angle believed that the positioning of these teeth was a constant relative to the jaws and the corresponding interlocking of the teeth is corresponds to the position of the maxilla and mandible in the sagittal plane (Angle et al., 1907). This lead to the extensively studied theory that the various malocclusions of the teeth are associated with distinctive craniofacial skeletal patterns.

Since the definition of varying malocclusions, exhaustive research has been performed to distinguish prevalence, etiology, defining characteristics, and treatment modalities of these malocclusions. Data from the third National Health and Nutrition
Examination Survey shows that 20% of the US population has a deviation from the ideal bite relationship. It was found that 14.7% presented with a Class II malocclusion. This prevalence was found to be more profound in children than adults, with a 5mm or more overjet, corresponding to Class II, decreasing from over 20% in children aged 8-11 years old to 16% in adolescents aged 12-17 years old, to 13% in adults aged 18-50 years old (Proffit 1998). While the prevalence of Class II malocclusion can conclusively be defined, the exact etiology for each individual may vary and this is a contentious subject in the field of Orthodontics.

Why is it important to address these disharmonies? Many times, patients present to the orthodontist due to concerns with esthetics, whether it be crooked teeth, the look of their profile or that something is just “not right”. Many patients present with occlusal and skeletal disharmonies. It is not only an esthetic concern to address these matters. Many malocclusions also come with functional deficits. Issues with mastication and airway are common outcomes of malocclusion. The effects of retruded mandibles on the airway located just behind the lower jaw is a heavily studied topic in the medical field with Obstructive Sleep Apnea. It has also been shown that many Class II subjects show significantly narrower maxillary width than Class I counterparts, which may also affect the nasal passage airways (Baccetti et al., 1997). Even when patients do not recognize their dental-skeletal discrepancies, they are still important to address from a health and stability standpoint. It has been shown that Class I molar occlusion is the most stable relationship (Harris et al., 1988). Teeth are not designed to be in constant traumatic states, which is why occlusal relationships typically fall into tightly intercuspated positions and maintain them. The periodontal ligaments surrounding teeth, the alveolar bone and all of
the other tissues and fibers that make up the housing for the teeth can only withstand so much distress before deteriorating. It is important to find answers to what driving forces may be behind the skeletal and dental disharmonies so that clinicians are better able to address and alleviate the perceived and unperceived problems in their patient populations and help the teeth find stable positions.

Class II malocclusion has been extensively studied, however, there are still many unanswered questions. Adolescents undergoing pubertal growth spurts also undergo dramatic changes in all dimensions of the maxillary and mandibular complexes. The reduction in prevalence of class II malocclusion as the population ages, points to the craniofacial growth and maturation as a means of the reduction of Class II malocclusion with age. Part of change and remodeling during the pubertal growth spurt includes the changes in the dentoalveolar heights. These changes hold important clinical implications for developing, maintaining and treating patients presenting with Class II malocclusion as the sagittal and vertical components of the craniofacial dental complex and intimately integrated and due to greater vertical growth potential, dentoalveolar heights of adolescents can be possibly manipulated and corrected (Buschang et al., 2008). The topic of varying aspects of growth, particularly in dentoalveolar heights, in Class II is relevant and has clinical implications, due to interest in optimizing treatment timing and planning dentofacial orthopedics (Stahl et al., 2008). Vertical dentoalveolar height is something the orthodontic mechanics can attempt to control or modify for desired treatment outcomes. The purpose of this study was to analyze the difference in incisor and molar dentoalveolar heights of untreated subjects that present with Class I and Class II malocclusions.
CHAPTER 2
LITERATURE REVIEW

Class II Malocclusion

Class II malocclusion is a divergence in the craniofacial development from Class I that is seen in 22.6% of adolescents and 13.4% of adults (Proffit 1998). As with any deviation from “normal”, Class II malocclusions can be categorized based on characteristics of severity. The initial definition of Class II malocclusion by Edward Angle is: “Lower arch distal to normal in its relation to the upper arch – bilaterally distal, protruding upper incisors,” (Angle 1907).

Historically, this “distocclusion” has been distinguished by retrognathism of the mandible and/or prognathism of the maxilla with the dentition compensating for the skeletal discrepancy (Angle 1907, McNamara et al., 1981, Stahl et al., 2008, Baccetti et al., 2009 and Jacob et al., 2014). The reality is much more complex than this. A minimum of 4 units are involved – the maxillary skeletal base, the mandibular skeletal base, the maxillary dentoalveolar unit, and the mandibular dentoalveolar unit. This leads to several variations of the positioning of the two dentoalveolar units within the dentofacial complex that may lead to the classification of Class II malocclusion. (Fisk et al., 1953).

When it comes to a Class II subject, its useful to determine what is the major driving force for this presentation of disharmony. Is it just the teeth? Is it one or both of the dentoalveolar arches (sagittally or vertically)? Is it one or both of jaw bones? Is it the relationship of the jaw bones to the cranial base? Was it always like this or did it grow into this? These are aspects that will be further discussed in this literature review.
Etiology of Class II Malocclusion

The etiology of Class II malocclusion is something still open to debate today. It has been demonstrated to be the result of the interplay of both genetics as well as the environment.

In 1980 Solow et al., introduced work regarding the “Dentoalveolar Compensatory Mechanism” which essentially discusses the idea that the development of both the dental and alveolar aspects of the arches is controlled by a process involving the intercuspation of teeth as well as the adaptation to the basal jaw bones. The mechanism’s job is to maintain normal inter-arch relationships with varying skeletal jaw relationships. This system when functioning as its supposed to, may prevent sagittal malocclusion, while simultaneously inducing another type, such as crowding. When the system is inoperative, any change in jaw relationship will be reflected in the relationship between arches. This is typically seen in more severe jaw discrepancy relationships. The dentoalveolar units as a whole can be carried forward or backwards depending on the underlying skeletal structures and the flexure of the cranial base. The skeletal component will be discussed further later in this paper. Solow’s findings demonstrated indirect evidence that interdigitation of the maxillary and mandibular teeth may maintain sagittal relationships – a beneficial theory for Class 1 occlusion and a detrimental limiting theory for Class II malocclusion. This idea has been introduced before by Lager et al., in 1967, who demonstrated untreated Class II mandibular growth driving the maxilla and its dental arch forward, which could be interrupted by “unlocking” of the dental arches tight intercuspation and allowing the mandible to grow freely, bypassing the upper. This idea
was indirectly supported by Helm et al., work in 1979 which found a significant reduction in the prevalence of Class II malocclusion in the modern and medieval Danish population with heavy occlusal wear and therefore no locking interdigititation of the teeth. They looked at skeletal remains of 278 medieval and 1258 modern Danes and their corresponding dental maladies including pronounced dental attrition.

A natural question on this topic was to determine at which point in time the Class II malocclusion begins to appear. A common theme that will be discussed is the differences in Class I and Class II both male and female growth timing, patterns and velocities. In the first three years of life, boys reach a given mandibular length before girls, and have the emergence of the deciduous teeth generally at a chronologically younger age than girls (Tanguay et al., 1986 Buschang et al.,1986), however there are similar mandibular lengths at the time of emergence of deciduous teeth (Tanguay et al., 1986). In the childhood years, the same pattern continues with significant sexual dimorphism in mandibular growth velocity, size and corpus length. Buschang et al., 1986 documented approximately a 1.2mm larger mandibular length in boys than girls aged 6-10. When the deciduous teeth emerge, if there are already on a smaller or more distal mandible, does this doom these children to transition to permanent Class II dentition?

At the time of eruption of the deciduous molars, there are three clinically distinct scenarios of the relationship of upper to lower deciduous molar. In terms of the upper mesiobuccal cusp relation to the lower mesiobuccal groove, the flush terminal plane is analogous to permanent Class I, the distal step is analogous to permanent Class II and the mesial step is analogous to permanent Class III. In 1988 Bishara et al., studied how these instances transitioned to the permanent dentition in 55 subjects. Records were taken
before permanent molars erupted, after the initial eruption of permanent molars, and after the complete eruption of the permanent dentition, excluding third molars. Of those presenting with flush terminal plane in the deciduous dentition, 56% proceeded to Class I, and 34% proceeded into Class II molar relationships. Of those presenting with a distal step in the deciduous dentition, all cases progressed to Class II tendency or a full Class II permanent molar relationship. This study concluded that a more favorable relationship in the deciduous dentition will lower the chance of developing Class II permanent dentition relationship, as well as concluding no ability of a distal step to self-correct if that’s how growth started, that is how it will continue.

Harris and Behrents 1988 reported on the intrinsic stability of the molar Class I relationship, and why Class II presenting patients always seem to stay in their Class II state. Harris et al., followed untreated patients longitudinally from 20-55 years of age. It was found that the Class I relationship to be the most stable with none of those cases changing classification. It was found that the Class II occlusions became significantly “more” Class II with an average increase in 0.8mm in severity. These findings led to the conclusions that molar mal-relationships do not self-correct and can and will become more severe if left untreated over time.

Tsourakis et al., 2014 provided a more in-depth conclusion as to how the transitional period from deciduous flush terminal plane to permanent Class I occlusal scheme works. Essentially this came down to the Leeway space and its role. The Leeway space is “the difference in the mesio-distal size of the primary buccal segments and their permanent successors in the transition from flush terminal plane to Class I subjects” (Moyers et al., 1973). The conclusion is the mandibular molars drift more forward than
the maxillary molars to using the Leeway space to achieve Class I. Tsourakis et al., 2014
also concluded that there is a physical relationship between molar movement and
differential growth that provides an explanation regarding the stability of the fully
intercuspated dental occlusions, similar to a dentoalveolar compensatory mechanism
(Solow et al., 1980).

Influence of Growth on the Development of Malocclusion

In order to imply growth as a culprit to development of malocclusion, there must
be an understanding of cranio-facial growth. It has been well documented that there is
general trends of the adolescent growth spurt in regards to timing, duration and intensity,
along with an understood sexual dimorphism (Buschang et al., 1988). During the pubertal
growth spurt, the adolescent craniofacial complex also goes through a period of growth.
The craniofacial growth is a complex differentiation and simultaneous enlargement of
hard and soft tissues. The maxilla and mandible have an earlier age of onset, later age of
peak velocity, and a later age of the cessation of growth when compared to the cranial
base length. The cranial base length has a large proportion of its total growth before
adolescence (Nahhas et al., 2014). It is not only the genetic factors of growth, but
additionally the environmental factor as well that contribute to variation in size and shape
of dental structures and the corresponding craniofacial skeleton in both the vertical as
well as the horizontal direction. Dentoalveolar growth has a fundamental role in the
development of the vertical dimension of the face and mandibular rotation. These factors
correlate to the resulting occlusal scheme of the growing adolescent, as well as
implications regarding orthodontic timing of intervention.
To further the understanding of craniofacial growth in 1968 there was a longitudinal study by Bjork et al., 1972 that used metallic pins implanted into children to assess growth changes over a period of time. This study concluded that in the mandible, growth in the length occurred mostly at the condyles. The direction of growth at the condyles determined the shape of the basal arch and mandibular angle. There was no appreciable growth on the anterior aspect of the chin. As for the maxilla, growth in length is sutural towards the palatine bone and is simultaneous with apposition at the maxillary tuberosity. The average growth displacement of the maxillary bones is downwards and forwards at an average angle of $50^\circ$ to the nasion-sella line. There was no apposition on the anterior surface of the maxilla. Growth in height was due to maxillary apposition on lower border of alveolar process. The nasal floor and the anterior nasal spine are lowered through resorptive remodeling. It was found that the overall pubertal growth spurt occurred either at the same time as or slightly preceded the growth of the condyles and facial sutures, peaking around ages 12.5 and 14 years in girls and boys respectively. The growth of the sutures ended about two years before the end of growth of body height, and the condylar growth ceased slightly after, on average ages 17 and 19 in boys and girls respectively. The cessation of growth in the maxilla occurred around average ages of 15 and 17 in girls and boys respectively.

**Growth in the Sagittal Dimension**

In 1995, Nanda et al., published a longitudinal research study following 86 subjects with serial cephalometric radiographs to analyze sagittal growth changes in the maxilla and mandible. These measurements taken at 6, 12, 18 and 24 years of age looked
at point A, B, and Pogonion with the pterygoid vertical as a reference plane. Their findings were that growth is not linear, and there are periods of bother higher and lower growth patterns. Females showed less growth in all measurements comparatively to males. The one exception being the 6-12 year increments which is due to the fact that females begin their pubertal growth spurt earlier (around years 11-12) than males.

There has been many thoughts, speculations, theories and research poured into whether people can grow out of Class II malocclusion or if the adage “once a Class II always a Class II” is accurate. In 1988 Buschang et al., looked into exactly this with their longitudinal study of mandibular growth in untreated children presenting with normal and Class II occlusions from ages 6-15. They found small but significant differences in the yearly growth velocity between normal subjects and Class II subjects, with Class II subjects having 0.2-0.4mm/yr less in growth compared to normal occlusion counterparts. The Class II subjects maintained their Class II status and having even less overall mandibular growth and were not able to overcome the discrepancy, getting “more” Class II. These variations is growth velocity were not significant in the years 11-14, suggesting that the differences had occurred already at earlier ages. They also found a tendency for children with malocclusion to show a more vertically oriented growth direction, which would tend to only amplify the sagittal discrepancy.

Another longitudinal study examining growth trends in Class I vs Class II subjects by Bisahara et al., 1997, reported that from a cross-sectional standpoint, Class II subjects had a significantly smaller mandibular length in earlier stages of development, pre-pubertal. Longitudinally the growth profiles (direction of change) were similar in Class I and Class II, however the growth magnitudes (amount of change) were different. In the
Class II subjects, more skeletal and soft tissue convexities were found with more retruded position of the mandible. This led to the conclusion being that while growth trends are essentially the same between Class I and Class II subjects, when Class II subjects start out with a shorter mandibular length, there is no major chance of correction without intervention.

An additional longitudinal study of growth changes in untreated Class II subjects by Stahl et al., 2008, also found similar growth patterns in Class I and Class II subjects, with the exception of smaller increases in mandibular length at the growth spurt and throughout the period of observation. This smaller overall increase in mandibular length in Class II differed from Class I subjects by 2-3mm. These findings are similar to other studies by Ngan et al., & Kerr et al.,.

Comparing the literature, Stahl et al., 2008, Buschang et al., 1988, Baccetti et al., 1997, Ngan et al., 1998 and Varrela et al., 1998 all came to the conclusions that in childhood and adolescence, Class II subjects have significantly shorter mandibular lengths, and smaller increases during the growth spurt than Class I subjects. However, Bishara et al., 1997 and Bishara et al., 1998 did not find differences in mandibular growth between untreated Class I and Class II patients. This may be attributed to the fact that these studies observational periods ended around 12 years old which is before the pubertal growth spurt. Therefore it may be cautiously concluded that differences in craniofacial measures and dento- skeletal disharmony are found to be established early in life, with growth trends being fairly similar in Class I and Class II subjects, but the disharmonies established pre-pubertal are maintained through circumpubertal ages.
Growth in the Vertical Dimension

The Class II jaw discrepancy, as mentioned previously, can be due to many different factors. The sagittal and vertical components of the craniofacial dental complex and intimately integrated. The interaction between maxillary components such as the palate, teeth, and sutures with the mandibular components such as the condyles, coronoid processes, angle, corpus, symphysis, and teeth, all respond to developmental stimuli and can influence the development of Class II malocclusion when presenting in different proportions.

Schudy et al., 1968 investigated the control of vertical dimensions in orthodontics. They reported on how the vertical dimensions of the bite are heavily influenced by the vertical growth of both molar and incisor teeth in addition to the growth of the mandibular condyles. The maxillary dentoalveolar vertical growth is important because through occlusal contact effects the mandible by pushing it downward and backward, which is how the maxillary posterior alveolar process is the primary cause of increase in anterior face height. Schudy reported, “the maxilla is more responsible than the mandible for chin position vertically and to a considerable extent anteroposterior”. This is seen when the molar height is increased it causes the chin to fluctuate downward and backward creating a steeper mandibular plane and while decreasing the facial angle. Clinically, by varying the molar height is how orthodontics can control the vertical and anteroposterior position of the chin, to an extent.

While Schudy concluded that down growth of the upper molars exceeds the upper incisors by a 2:1 ratio and that this down growth of the maxillary molar is the most important factor in reducing the amount of vertical overbite, they also touched on why
the incisor teeth play a key role in vertical dimensions. There is a symbiotic relationship between the depth of the vertical overbite with the size of the interincisal angle. A more ideal interincisal angle would be around 135 degrees, as anything larger can cause excessive overbite by pushing the mandibular incisor crowns lingually and the apices of the maxillary incisors labially. They concluded that the mandibular incisor is the primary bite closer, and the maxillary molar is the main bite opener in natural growth. If there is an open overbite, the ideal thing to do is move the mandibular incisor and prevent increase/occlusal movement of posterior molars.

Braun and Legan et al., 1997 studied the importance of the cant of the occlusal plane and how it affects occlusion relationships. In this study using, Down’s occlusal plane, which is a plane “extending from the midpoint of a line connecting the anterior cusp tip of the mandibular first molar to the anterior cusp tip of the maxillary first molar, posteriorly to the midpoint of a line connecting the incisal tip of the mandibular central incisor to the incisal tip of the maxillary central incisor, anteriorly”, precise measurements were determined on how the rotation affects molar relationships. The authors reported that there is “approximately 0.5mm change in the occlusal relationship for each degree of occlusal plane rotation in either direction”. Confirming previous studies (Simmons et al., 1973) in which if the occlusal plane steepens, by rotating down and back, a Class II relationship will approach a Class I relationship, and the opposite flattening of the plane, a Class III will approach a Class I. Braun and Legan’s conclusions were that if a patient presented in an end-on Class II molar relationship, 7.2 degrees of steepening will result in Class I molar relationship. This is a similar finding to Riolo et al., 1974 in which they found that when Down’s occlusal plane is flattened by up and
forward rotation 6.15 degrees there is a mean dental occlusal relationship change of 3.0mm towards a Class II relationship.

In the vertical dimension of growth and the complex interplay of craniofacial structures, it was important to determining how specifically these changes in the growth of craniofacial complex were effecting the dental relationships. Buschang et al., 2002 reported that if there is lowering/vertical growth of the posterior maxillary complex, this will correlate with displacement of the anterior mandible. There will be a rotational aspect of the mandible if the lowering of posterior and anterior parts are not equal. This can lead to a retruded mandibular appearance concurrent with a convex facial type typically associated with Class II malocclusion. Both forwards growth rotation and backwards growth rotations can contain compensatory dental segment remodeling as discussed earlier by Solow et al., 1980. Therefore, if the maxillary complex is lowered via vertical growth, the anterior dentoalveolar portion of the mandible will displace. If there is lowering of the articular fossae and condylar growth, then the posterior dentoalveolar portion of the mandible will displace. Both of these scenarios leads to varying effects of the occlusal plane and resulting implications on Class II relationships.

Importantly, if there is a large increase in the poster height or growth of the molar teeth, it could prevent the forward positioning of the chin which would make the correction of Class II correction a much more difficult task. (Schudy et al., 1968)

Growth of the mandible is not straightforward, both physically and metaphorically. “Any vector of condylar growth is accompanied by a displacement of the mandible relative to the articular fossae of the same magnitude but in the opposite direction” (Solow et al., 1980). As discussed earlier, the mandible is not rigidly attached
and is instead suspended under the cranium so that any displacement of the mandible with growth depends not just on the growth of the condyles but additionally depends on the articular fossae relative to the cranial base, the body of the maxilla, the posterior alveolar processes of the mandible and maxilla and their vertical growth as well as the vertical growth of the incisors.

Headgear is still a utilized and effective tool in treating certain Class II patients during their adolescent growth in attempts to control the growth of the maxilla and its orientation. Baumrind et al., 1981 investigated how cervical and high pull headgear affected the facial dimensions and how the vectors of force pull can either intrude of extrude the maxillary molars which has a resulting effect on the cant of the occlusal plane and rotation of the mandible, as discussed earlier. They found that the cervical pull group showed larger rates of increase in the anterior facial height. Thus implying that cervical pull headgear use should be used conservatively in patients whom facial elongation is undesirable. Their study showed the resulting vertical effect of treating Class II patients and how treatment can project changes in the clinical observation of facial height.

The soft tissues have even been implicated in this vertical interchange of skeletal and dental variables and not always just a passive byproduct. McNamara et al., 1981 reported in conjunction with Solow et al., 1980 that lowering of the mandible, due to either vertical growth of the maxillary complex or other factors can induce stretching of the facial soft tissues which inhibits forward movement of the mandible itself.

Cranial base angulation can influence the overall craniofacial patterns patients present with. Bishara et al., 1997 reported similar directions of cranial base growth in Class I and Class II patients. Stahl et al., 2008 reported more in depth findings regarding
the cranial base. They found more obtuse cranial base angles present in Class II subjects. This is due to a more distal articulation point of the mandible to the cranium resulting in a distal skeletal relationship of mandible to maxilla (Kerr et al., 1987 & Stahl et al., 2008). This is of large importance to the treatment of orthodontic patients. Orthodontic treatment alone cannot change the cranial base angulation. Therefore if there is a patient presenting with Class II malocclusion and with further examination, the main cause of the Class II relationship is due an obtuse cranial base angulation leading to a retruded mandible, the most likely course of treatment is various modalities of camouflage which would not address the underlying problem.

With so many variables and factors affecting the development of the presentation of a Class II malocclusion, it is important to have general characteristics determined to be found in these patients. It has been noted that around 75% of Class II dental malocclusions also presented with a Class II skeletal disharmony (Jacob & Buschang et al., 2014, Beresford et al., 1969, Milacic et al., 83). Jacob & Buschang et al., 2014 reported comparisons between 77 Class I and 53 Class II untreated subjects based on eight landmarks in a longitudinal study. The findings were that there were no significant differences in the SNA angles, however the Class II subjects showed more retrognathic mandibles and a resulting larger ANB value. This was of importance due to conflicting studies reporting Class II patients disharmony being largely a result of a prognathic maxilla (Tsourakis et al., 2014).
CHAPTER 3
MATERIALS AND METHODS

Hypothesis to be Tested

The null hypothesis to be tested is that there is no difference between Class I and Class II subjects in dental alveolar heights.

Sample

This study is exempted from review by the IRB of Marquette University (Protocol #4060) since the data was collected a long time ago, it is public, and the subjects are not identified. Data is structured according to STROBE guidelines for longitudinal studies (von Elm et al., 2007).

This sample was drawn from the archives of the University of Michigan Growth Study. A total of 611 cephalograms of 96 untreated Class I and Class II subjects, stratified in the following manner: 57 male subjects and 39 female subjects; 70 Class I and 26 Class II malocclusion subjects, from 07-17 years of age, were generously provided by the AAOF Craniofacial Growth Legacy Collection (CGLC). White-Caucasian subjects were pooled from only one geographical region (elementary schools in Ann Arbor, Michigan) between the 1950s and the 1970s.

The inclusion criteria were: 1) to have Angle Class I or Class II malocclusion; 2) cephalograms of sufficient quality for landmark identification; 3) cephalograms that present permanent molars full erupted at T1; 4) no prior orthodontic treatment; 5) no evident craniofacial anomaly. Additionally, as technical exclusion criteria: 1) evident
open mouth and/or protruded mandible, and 2) evident double imaging at the mandibular base.

**Data Collection**

The author has traced all 96 of the cephalograms in 150 dpi size (converted by the software GIMP, open source, http:www.gimp.org) with the software Viewbox 4 (Kifissia, Greece). For each cephalogram, 151 landmarks were identified, following Viewbox 4 templates. Identification of ten landmarks (Table 1), according to standard definitions (Riolo et al., 1974), and enhanced by magnification and gamma changes, allowed seven linear measurements (Table 2).

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Table 1. Landmarks identified on all cephalometric radiographs.

Table 2. Linear measurements identified on all cephalometric radiographs.
Figure 1. Cephalometric landmarks correlating to Table 1.
Figure 2. Linear measurements corresponding to Table 2.

**Calculation of Dentoalveolar Height**

The protocol and dimensions that Buschang 2008 used when comparing dentoalveolar heights in males and females age 10-15 in French-Canadians was used. Reproduced here is as follows: “Maxillary dentoalveolar heights were defined as the perpendicular distances of the incisor tip and first molar mesial cusp tip to the palatal plane (ANS-
PNS). The mandibular dentoalveolar heights were calculated based on the perpendicular distances of the lower incisor tip and lower first molar mesial cusp tip to the mandibular plane (Go-Me).

**Statistical Analyses**

Data was primarily collected on the Excel 365 software (Microsoft, Redmond, WA) and transferred to IBM SPSS Statistics 28.0 (IBM, Armonk, NY). Descriptive statistics were presented as means, standard deviations, and standard error means (Table 3). Equality of means and their significance (T-tests) compared malocclusions (Class I and Class II) at confidence interval of p<0.05.

**Reliability**

Method error for landmarks identification was calculated using 15 cephalograms, randomly sorted, retraced after four weeks by the same examiner. The Dahlberg formula was used to quantify error of measurement. The Dahlberg formula is a useful and simplistic which “corresponds to the estimated error by regression analysis, when there is no systematic error” (Galvao et al., 2017).
CHAPTER 4
RESULTS

The linear measurements were recorded for all traced cephalogram and used to perform an unpaired t-test for each variable, with equal variances assumed. Statistical comparisons showed there were no significant differences (p<0.05) between Class I and Class II for each variable. The average values for each variable are shown in Table 3, with the primary outcomes of the study in Table 4 and the secondary outcomes in Table 5. According to Dahlberg formula, error varied from 0.22 for L1 Tip to 1.62 of L6 mesial cusp.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Malocclusion</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Mean Error</th>
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</table>

Table 3. Descriptive statistics of the 7 linear measurements, with the first 3 the secondary outcomes and the last 4 the primary outcomes.
<table>
<thead>
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<th>Variables</th>
<th>T-Test (p-value)</th>
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<td>U6PP</td>
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Table 4. Primary outcomes unpaired t-test between Class I and Class II groups, equal variances assumed, considering p<0.05

<table>
<thead>
<tr>
<th>Variables</th>
<th>T-Test (p-value)</th>
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</thead>
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<td>N-Me</td>
<td>0.539</td>
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<tr>
<td>ANS-Me</td>
<td>0.470</td>
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Table 5. Secondary outcomes unpaired t-test, equal variances assumed.
At timepoint T1, there is no difference between Class I and Class II dentoalveolar heights. The primary outcome measurements were the linear direct tooth-alveolar bone relation. The secondary outcome measurements were the linear measurements that also showed vertical dimensions of the jaw relationships but were not directly tooth-alveolar bone specific. In this study there were more than double the amount of Class I subjects than Class II subjects, which could account for the lack of distinct statistically significant differences in dentoalveolar heights, it would have been best to have more equal sample sizes, however the data set used did not contain more Class II subjects and, so what was used was what was available. Additional samples could be used, however the samples would need to be calibrated so that all radiographs are of equal size and quality to be compared.

Even without a statistically significant difference between dentoalveolar heights of Class I and Class II subjects, variation is significant. There are diverse degrees of Class II’s, from eight varying dental relationships to severe skeletal dysplasias. Orthodontists should be aware of the importance of dentoalveolar height as “fine tuning” of vertical craniofacial development and applying the best therapeutic approaches to correct or minimize its vertical facial outcomes.

Orthodontists can manipulate the vertical dimensions during treatment, which is why this study viewed anterior and posterior facial height as secondary outcomes. Baumrind et al., 1981 showed how critical this vertical control of treating Class II patients can be. Affecting the vertical dimensions of dentoalveolar height will affect the patients
facial heights. In patients presenting with longer faces, it would be unwise to use cervical pull headgear, which has been shown to lead to increased facial heights and visual elongation.

When patients present clinically with an open bite, it has been concluded that one of the ways to address this is via the mandibular incisor as the primary bite closer. When patients present with a deep bite the maxillary molar has been shown to be the main bite opener during natural growth (Schudy et al., 1968). These are the things that need to be taken into consideration during treatment of all patients as this is what the orthodontist can manipulate via dentoalveolar heights for each patient. This can be done through various mechanics such as changing the curve of Spee, reversing the curve of Spee and utilizing proven intrusion or extrusion arches. It is also of importance to consider the age of the patient, as the natural growth can either be working for or against your treatment and objectives in adolescents, or in adults there is minimal to no growth to help or hinder treatment.

This study did not control for sex and therefore cannot report if there is sexual dimorphism between Class I and Class II dentoalveolar heights. However, Buschang et al., 1986, Buschang et al., 1988, Buschang et al., 2002 and Buschang et al., 2008, found sexual dimorphism in subjects at multiple age time points in the mandibular growth and dentoalveolar heights. Buschang et al., 1986 reported sex differences in subjects age 6-10 in respect to growth velocities, corpus length and in size generally, with males having more growth in all respective dimensions when compared to females. This sex difference only increased with age due to the greater growth velocity of boys. Buschang et al., 1988 reported sex differences in subjects aged 6-15 in both Class I and Class II occlusions.
They found not only decreased growth velocities in females when compared to males, but additionally in Class II when compared to Class I. The only points in which growth velocity differences between males and females were not significant was ages 11-14, this was suggested to be due to the different timings of the pubertal growth spurt, occurring earlier in females around age 11, at which boys growth velocity has not yet reached its peak increases as it does during the pubertal growth spurt. Buschang et al., 2002 evaluated subjects aged 10-15 and found significantly more overall mandibular skeletal growth and modelling in males than females. This was seen in the ramus, the corpus and the condyles. Buschang et al., 2008 evaluated maxillary and mandibular dentoalveolar heights of French Canadians 10-15 years of age and found sexual dimorphism except in the years 12-13. The reasoning of the lack of differences is similar as mentioned earlier with this being the peak of the female pubertal growth spurt and before the male growth spurt has begun.

The measurements that the current study identified and analyzed were just at a cross-section in time. Future studies should investigate dentoalveolar heights at varying time points to identify if there are other ages in which dentoalveolar heights do indeed differ between Class I and Class II subjects.

What can be taken away from the present study is that at this specific snapshot of time, in the subjects of the University of Michigan Growth Study, there were no differences in dentoalveolar height between Class I and Class II untreated subjects. What cannot be extrapolated from this study is patterns of growth, or growth velocities as a longitudinal methodology would be needed. However it does align with multiple studies that have reported similar growth patterns of Class II subjects as Class I subjects. Stahl et
al., 2008 reported longitudinal growth changes comparing Class I and Class II subjects finding that both classifications of subjects had equal growth trends, Class II subjects just started from a smaller standpoint, leading to the continued disparities in sizes observed in Class II subjects.

A common theme seen throughout the literature is the conclusion of the smaller sagittal sizes of mandibles, specifically mandibular length, found in Class II subjects when compared to Class I subjects. (Stahl et al., 2009, Buschaang et al., 1988, Baccetti et al., 1997, Ngan et al., 1998, Varrela et al., 1998). What does not have as much clarity and devoted findings is the vertical aspect of the maxilla and mandible dentoalveolar arches between Class I and Class II subjects. One of closest studied variables is the vertical growth of the mandibular condyle, but that is due to the fact that the vertical growth of the condyle affects the sagittal position of the mandible – Class II subjects have been shown to have less vertical condylion growth which results in shorter overall mandibular lengths (Jacob et al., 2014). The “true” vertical dimensional differences between Class I and Class II subjects have been studied, but with no direct relation to the occlusion.

The effects of varying patterns of vertical growth on the occlusal scheme has been well demonstrated. In 1997 Braun and Legan demonstrated how the cant of the occlusal plane can affect the resulting occlusal scheme. It was shown that changing the occlusal plane rotation by 1.0 degrees could have a 0.5mm effect on the occlusal relationship - which if a Class II occlusal plane is steepened at least 7 degrees, then the occlusion would approach a more Class I relationship. Later in 2002, Buschang et al., reported how vertical growth of the posterior maxillary complex could lead to a rotational change in the mandible with the effect being a clockwise rotation of the mandible leaving a retruded
mandibular appearance, effectively worsening class II presentation. Schudy et al., 1968 summarized it well by reporting that, “as the molar height increases, the chin swings down and back, the mandibular plane becomes steeper, the gonion angle moves posteriorly and the facial angle decreases. Thus by varying the molar height we are able to change the facial angle and ramus incline. Molar height not only controls the vertical position of the chin but also to a considerable amount the anteroposterior position”.

It can be concluded that the correction or worsening of a Class II malocclusion is related to the complex interplay of the teeth, the supporting alveolar growth as well as height and the underlying skeletal growth. The soft tissues have even been implicated in this interchange of variables sometimes found to hinder the mandible moving forward when the soft tissues are already stretched. (McNamara et al., Solow et al., 1980)

Excessive growth or changes of any of these factors can have varying effects on the occlusal scheme relationship.

The dentoalveolar heights are a crucial component of the vertical aspects of occlusion and therefore the resulting occlusal scheme in the sagittal plane as they are closely intertwined. Orthodontists can and do alter the dentoalveolar heights in patients. It is of value to know before treatment that there are no statistically significant differences in the dentoalveolar heights of untreated Class II patients so that when treatment modalities are considered, proper and informed decisions can be made. If it was shown that dentoalveolar heights varied in untreated Class II subjects as compared to Class I subjects, then that may lead to choosing a specific treatment modality over others. As that is not the outcome, every patient’s treatment must be carefully chosen and modified to match their clinical presentation along with how their complex interplay of skeletal,
dental and soft tissues is presenting at that point in time, while also keeping known
growth patterns in mind.
The null hypothesis is accepted. Within the limits of the current study, there is no difference between Class I and Class II subjects in dental alveolar height.

This cross-sectional study aimed to differentiate dentoalveolar heights in Class I and Class II patients so that the patient population can be treated most efficiently and effectively.
REFERENCES


