Contribution of Dentoalveolar Heights on Facial Heights in Class I and Class II Untreated Subjects

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CONTRIBUTION OF DENTOALVEOLAR HEIGHTS ON FACIAL HEIGHTS IN CLASS I AND CLASS II UNTREATED SUBJECTS

by

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ABSTRACT

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Objective:

This research aims to investigate the impact of dentoalveolar heights on craniofacial growth and the development of Class I and Class II malocclusions in untreated subjects aged 6-18 years. The study seeks to establish relationships between dentoalveolar heights and anterior and posterior facial heights. The findings contribute to understanding the dynamic interplay between dentoalveolar growth, mandibular rotation, and facial height establishment, shedding light on critical aspects of craniofacial development.

Materials and Methods:

The study draws upon cephalograms from the University of Michigan Growth Study, encompassing untreated Class I and Class II subjects aged 6-18 years. A subsample of 408 cephalograms from 55 subjects, meeting specific inclusion criteria, was selected from the AAOF Craniofacial Growth Legacy Collection. The research design, approved by the Marquette University Institutional Review Board, features a mixed-longitudinal approach and excludes orthodontic interventions, allowing for a natural exploration of malocclusion development. The study explores the role of four independent variables (U6, L6, U1, L1) in three separate phases of development (phase A, phase B, and phase C) in determining anterior and posterior facial heights. Cephalograms were processed using Viewbox 4 software, and statistical analyses, including multiple linear regression models, were conducted to examine the relationships between dentoalveolar heights and facial height dynamics.

Results:

For Class I subjects, the multiple linear regression models for anterior facial height (AFH) and posterior facial height (PFH) exhibited significant goodness of fit, with the distance from the upper molar to the palatal plane (U6-PP) emerging as a crucial determinant variable. In contrast, Class II subjects showed no statistically significant role for the four independent variables except for the distance from upper incisors to the palatal plane (U1-PP) in phases B and C. The study emphasized the intricate interplay between dentoalveolar heights, mandibular rotation, and facial height establishment, revealing distinct patterns between Class I and Class II malocclusions.

Conclusion:

The research concludes that AFH is more influenced by dentoalveolar heights than PFH in Class I subjects, emphasizing the significance of the upper molar's distance to the palatal plane. The late mixed dentition period introduces challenges in assessing craniofacial growth. In Class II subjects, less consistent dentoalveolar growth may contribute to non-ideal facial heights, with the relationship between upper and lower incisors complicating the cause-and-effect relationship between mandibular rotation and molar eruption. Despite limitations, the study underscores the pivotal role of dentoalveolar heights in facial height establishment and offers valuable insights into craniofacial growth and development.

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CHAPTER 1
INTRODUCTION

Craniofacial growth, a multi-dimensional and dynamic process, has been a subject of extensive study within orthodontics, particularly concerning Class I and Class II malocclusions. While prior research has delved into the intricacies of craniofacial development, numerous questions remain, presenting an opportunity for thorough examination. The vertical dimension of the face plays a pivotal role in not only the aesthetic harmony but also the functional efficiency of the craniofacial complex. Proper vertical dimension ensures the establishment of favorable occlusal relationships, which in turn influences masticatory function, speech articulation, and overall oral health (Baumrind 1981). Deviations from the norm in vertical dimension can lead to malocclusions and dysfunctions, impacting an individual's quality of life (Baccetti 1997). Moreover, the vertical dimension is linked with the stability of orthodontic treatment outcomes, as alterations in dentoalveolar heights may influence the stability of occlusion post-treatment (Bishara 1998). Thus, understanding the contribution of dentoalveolar heights to facial heights is essential in grasping the underlying mechanisms of craniofacial growth and addressing clinical challenges associated with malocclusions, particularly in Class I and Class II untreated subjects (Bishara 1988).

The vertical dimension serves as a significant indicator of craniofacial development and maturation. Changes in vertical dimensions occur not only during growth and development but also in response to environmental factors, genetic influences, and orthodontic interventions (Bishara 1997). Variations in dentoalveolar heights can reflect underlying skeletal discrepancies and may offer insights into the etiology of malocclusions, particularly Class II discrepancies, which often exhibit vertical excess or deficiency (Baumrind 1981). Investigating the relationship between dentoalveolar and facial heights in Class I and Class II untreated subjects provides a unique opportunity to reveal the interplay between skeletal, dental, and soft tissue components in craniofacial morphology (Björk 1972). Such insights are crucial for refining treatment strategies, optimizing treatment outcomes, and advancing our understanding of craniofacial growth and development (Braun 1997).

This study undertakes a comprehensive examination, utilizing data derived from cephalograms obtained from the University of Michigan Growth Study's AAOF Craniofacial Growth Legacy Collection. Focused on untreated subjects falling within the Class I and Class II malocclusion categories, the research spans a crucial age range of 6 to 18 years, capturing the pivotal phases of craniofacial growth (Buschang 2017). A distinctive feature of this investigation lies in its mixed-longitudinal design, allowing for the exploration of developmental changes over time (Buschang 1986). Notably, the absence of orthodontic intervention in the selected sample ensures a naturalistic observation of malocclusion progression, affording insights into the dynamics of craniofacial development (Buschang 1986).

In the subsequent sections of this paper, we discuss the data collection process, detailing the methods employed for cephalogram processing and landmark identification. The statistical analyses unravel the complex relationships between dentoalveolar heights and facial height dynamics. Through consideration of multiple linear regression models, the study aims to discern the interplay between dentoalveolar heights of upper and lower molars and incisors and their impact on anterior and posterior facial heights. This research strives to contribute detailed insights into the intricate dynamics of craniofacial growth, offering a deeper understanding of the developmental processes underlying Class I and Class II malocclusions.

CHAPTER 2
LITERATURE REVIEW

Class II malocclusion, a craniofacial developmental anomaly, affects approximately 14.7% of the US population. However, its prevalence varies with age, declining from 22.6% between 8 and 11 years of age to 15.6% between 12 and 17 years of age, and further decreasing to 13.4% between 18 and 50 years of age (Proffit, 1998). Within the spectrum of developmental deviations such as malocclusions, the degree of severity is a key factor for categorization. Class II malocclusion subjects often exhibit functional deficits, primarily affecting mastication and respiration. The severity of this malocclusion is proportional to the extent of these deficits, which orthodontic therapies may help address.

Some research indicates that there is no significant difference in maxillary size between Class I and Class II subjects (Baccetti, 1997; Buschang, 1998). On the other hand, Class II subjects tend to have smaller mandibles compared to Class I subjects (Ngan, 1997; Baccetti, 1997; Stahl, 2008; Jacob, 2014), although some studies report no discernible distinctions (Bishara, 1997; Bishara, 1998; Riesmeijer, 2004). In the studies concluding smaller mandibles in class II patients (Stahl 2008), the authors suggest that Class II dentoskeletal disharmony does not have a tendency to self-correct with growth, which underscores the importance of early orthodontic intervention.

McNamara (1981) also studied the frequency of various identifiable components of Class II malocclusion and evaluated the effectiveness of existing therapeutic approaches. The researchers studied lateral cephalometric radiographs of 277 children between the ages of 8 and 10 years old and found that Class II malocclusion can result from numerous combinations of skeletal and dental components, and mandibular skeletal recession was the most common single characteristic of the sample. They also noted that while a wide variation in vertical development was observed, almost half of the sample exhibited excessive vertical development.

Differences in the rates of change of nine linear measures of mandibular and facial proportions during Phase I orthodontic treatment for the correction of Class II mixed-dentition malocclusion has also been investigated (Baumrind 1981). The analysis found statistically significant differences between treatment groups in some linear measures, including an increase in the condyle-pogonion distance in the intraoral group, and a similar increase in the cervical group.

The correlation between dental occlusion and rotations of the occlusal plane in the sagittal view has been examined as well (Braun 1997). Each degree of rotation of the occlusal plane results in a half millimeter change in the dental relationship, which can have significant effects on occlusion. Changes in the cant of the occlusal plane are sometimes unintentional during orthodontic therapy and can have implications for the developing dentition, resulting in Class II or Class III dental relationships. Differential growth factors between the maxilla and mandible, natural changes in the cant of the occlusal plane during growth and development, and leeway space are the three principal factors that determine dental occlusal relationships.

Bishara (1997) aimed to compare the changes in dentofacial structures in untreated Class II division 1 and normal individuals from deciduous to permanent dentition. Records of 65 subjects were analyzed at three stages of development. On a cross-sectional basis, mandibular length was the only significant difference between the two groups during the earlier stages, but not later. Longitudinal comparisons showed no significant differences in growth trends between the two groups, except for upper lip protrusion. Total changes from deciduous to permanent dentition indicated significant differences, including larger maxillary and mandibular lengths in normal individuals and greater skeletal and soft tissue convexities in Class II individuals. Overall, the study suggests that some "catch up" growth may occur in Class II individuals, but there are still significant differences in dentofacial structures between Class II division 1 and normal individuals.

Buschang (1986) examines sexual dimorphism in the emergence of deciduous dentition in French-Canadian children and explores the correlation between dental heights/positions and vertical dimensions. The results show that boys' teeth emerge earlier than girls but when evaluated on the length scale rather than chronological age, there are no significant sex differences in the lengths attained at the age of emergence of deciduous teeth. The study suggests that clinical standards for emergence of deciduous teeth scaled relative to length rather than chronological age are more accurate and efficient. However, the age of emergence is just one stage of a continuous process of dental maturation, and interpreting a single stage as an index of dental maturation may be misleading.

A longitudinal study (Nanda 1995) analyzed male versus female growth pattern in sagittal linear measurements at points A, B, and pogonion relative to the pterygoid vertical plane in a Class I sample. The study found that between the ages of 6 and 24 years, there was a total growth increment of 6.07, 7.53, and 11.17 mm at points A, B, and pogonion, respectively, in the female Class I sample and 9.49, 11.65, and 16.21 mm at points A, B, and pogonion, respectively, in the male sample. Thus, males showed greater vertical heights at these measurements during this timeframe compared to females.

Buschang (2002) analyzed the correlation between dental heights/positions and vertical dimensions in a sample of untreated French-Canadian adolescents (79 females and 107 males) evaluated at 10 and again at 15 years of age. The study found significant superior and posterior growth and modeling of the condyle and ramus, with males undergoing significantly greater growth and modeling than females. It was concluded that individual differences in ramus growth and modeling can be explained by mandibular rotation and displacements. Multivariate assessments revealed that superior condylar growth and ramus modelling were most closely associated with forward rotation and inferior mandibular displacement. Posterior growth and modeling were most closely correlated with anterior mandibular displacement and forward rotation. Modeling of the lower anterior border was independent of rotation and displacement. The study also found that the ramus showed the most growth, modeling and the greatest variation, and sex differences were observed with males showing greater growth and modeling changes. This study suggested that growth and modeling changes for the ramus and corpus were relatively independent and that different regions of the corpus were also relatively independent.

Specifically examining molar relationship, Harris (1988) discussed the stability of the sagittal molar relationship in orthodontically untreated individuals with full dentitions over a period of approximately 35 years from young adulthood to middle age. The study found that the Class I molar relationship is the most stable and none of the cases in this category changed. In contrast, Class II and Class III relationships became more severe with age, with the lower molar becoming more distal in Class II cases and more mesial in Class III cases. The study highlights that dental occlusion is a dynamic condition influenced by various factors, and rates of change in adulthood are not zero.

Additionally, Jacob (2014) analyzed a group of untreated French-Canadian adolescents to determine differences in mandibular growth and modeling between Class I and Class II division 1 malocclusion, as well as differences between males and females. The results showed that Class II individuals had more retrusive mandibles than Class I individuals, and Class I individuals had greater growth and modeling changes in condylion and gonion, resulting in longer mandibular lengths at 15 years of age. Additionally, boys were more prognathic than girls, had larger mandibles, and exhibited greater size increases and growth changes. Overall, the study highlights the importance of considering both class and sex differences when analyzing dental heights/positions and vertical dimensions.

Buschang (2008) aimed to establish reference data for anterior and posterior dentoalveolar heights of growing French-Canadians with untreated normal occlusions and malocclusions. The study used a mixed longitudinal sample of 227 French-Canadian adolescents, with cephalograms taken annually between 10-15 years of age. The results showed that male dentoalveolar heights were significantly greater than female heights at all ages. Dentoalveolar heights increased from 10-15 years of age, with the anterior and posterior heights showing the smallest and greatest changes, respectively. The authors remarked that male adolescents had larger dentoalveolar heights than female adolescents. The study also concluded that French-Canadian adolescents require age- and sex-specific reference data for dentoalveolar heights, with mandibular heights showing the strongest associations. This information is important for clinicians in determining appropriate treatment plans and assessing dental and facial growth in adolescents.

CHAPTER 3
METHODS AND MATERIALS

Study Design

This is a retrospective study that evaluates untreated Class II and untreated Class I subjects for dentoalveolar vertical heights and their effects on facial heights. The materials and methods were reviewed by the Marquette University Institutional Review Board MUIRB, and considered “exempt” (Protocol #4060, January of 2022).

Sample

The sample was drawn from the archives of the University of Michigan Growth Study, which includes cephalograms annually taken in untreated subjects, generously provided by the AAOF Craniofacial Growth Legacy Collection (AAOF-CGLC).

From a total sample of 604 cephalograms taken in 98 subjects, a subsample of 408 cephalograms from 55 subjects was drawn. The subsample included 40 male and 15 female subjects. 45 subjects presented Class I malocclusion (33 male and 12 female subjects) and 10 subjects presented Class II malocclusion (7 male and 3 female subjects) (**Table 1)**.

The inclusion criteria were: 1) to present Angle’s Class I or Class II malocclusion; 2) to have three cephalograms/time-points, at least one for each one of the phases A, B and C [for male subjects: phase A – 10 years old or younger, phase B – between the ages of 10 and 13 years old, and phase C – older than 13 years old; for female subjects: phase A – younger than 10 years old, phase B – between the ages of 10 and 12 years old, and phase C – older than 13 years old (**Table 2**)]; 3) the cephalograms must be of good quality for precise anatomic identification; 4) the cephalograms must present permanent molars fully erupted at the first time point (T1); 5) the subjects must not have had prior orthodontic treatment; and 6) the subjects must have no evident craniofacial anomaly.

The exclusion quality criteria were: 1) cephalograms which presented evident open-mouth and/or protruded mandible during exposure, and 2) cephalograms which presented evident double imaging of the mandibular base due to head mal-positioning during exposure.

The average measurement for each one of the 165 considered phases (A, B, C) was calculated based on three or more cephalograms/timepoints in 50% of the cases, two cephalograms/time-points in 28% of the cases, and a unique cephalogram/time-point in 22% of the cases.

	Males	Females	Total
Class I	33	12	45
Class II	7	3	10
Total	40	15	55

Table 1. Demographics of the 55 subjects included in this study categorized by gender and malocclusion.

PHASE	MALE	FEMALE
A	Age $\leq$ 10	Age $\leq$ 10
B	10 < Age $\leq$ 13	10 < Age $\leq$ 12
C	Age > 13	Age > 12

Table 2. Classification criteria outlining age groups of each phase for males vs. females from which timepoints were collected.

Data Collection

All of the cephalograms were sized to 150 dpi (converted by the software GIMP, open source, http:www.gimp.org), before being processed with the Viewbox 4 software (dHAL Software, Kifissia, Greece, www.dhal.com). All cephalograms were oriented with the SN-7° constructed line parallel to the horizontal natural plan. To help the identification of landmarks, and potentially reduce method error and increase reproducibility, the digitization of 151 points allowed the design of fifteen geometric curves, which followed the outlines of anatomical structures. Nasion (Na), Sella (S), Anterior Nasal Spine (ANS), Posterior Nasal Spine (PNS), Gonion (Go) and Menton (Me) were automatically identified by the software, according to their anatomic definition (Riolo 1974) and their best fit into the Viewbox pre-determined geometric curves.

Using the ten landmarks shown in **Table 3**, seven measurements (shown in **Table 4** and **Figure 1**) were used to analyze facial heights in all subjects across the three phases.

10 Cephalometric Landmarks
Nasion (N)
Sella (S)
ANS
PNS
U1 Tip
U6 Mesial Cusp
Gonion (Go)
Menton (Me)
L1 Tip
L6 Mesial Cusp

Table 3. Ten landmarks were identified and plotted on each cephalometric radiograph for analysis.

7 Cephalometric Measurements	
Skeletal	S-Go (mm)
	N-Me (mm)
	ANS-Me (mm)
Dentoalveolar	U1-PP (mm)
	U6-PP (mm)
	L1-MP (mm)
	L6-MP (mm)

Table 4. From the ten landmarks shown in Table 3, seven measurements were performed on each cephalometric radiograph for analysis of facial vertical dimensions. These measurements are categorized into two groups: skeletal and dental.

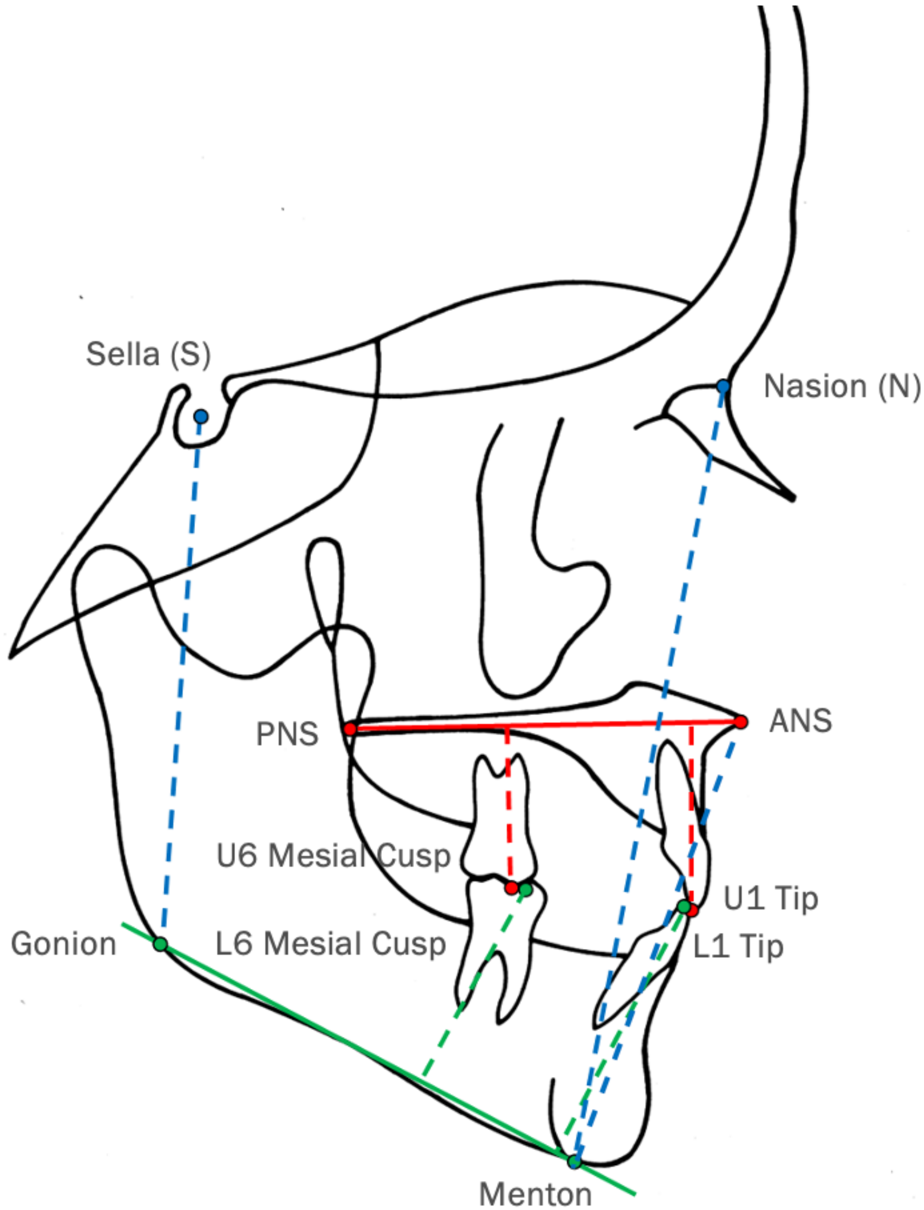

Figure 1. Cephalometric landmarks and visual representation of measurements.

Statistical Analysis

Data was exported from Viewbox 4 to the Excel 365 software (Microsoft, Redmond, WA). The statistical package GraphPad-Prism was used for calculations. Descriptive data (mean, standard deviation, and standard error of the mean) for the three variables were calculated for their X component (horizontal) measurement (mm) and their Y component (vertical) measurement (mm). The horizontal reference line was constructed based on the original S-N line minus 7 degrees. The vertical reference line was perpendicular to the horizontal reference line at Sella, establishing the (0,0) reference.

Descriptive data was collected for the dependent variables AFH and PFH, and the independent variables a) mesial cusp of the upper molar (U6), b) mesial cusp of the lower molar (L6), c) tip of the upper incisor (U1), and d) tip of the lower incisor (L1).

The Dahlberg formula (Dahlberg 1940) was used to calculate random method errors. A total of 30 cephalograms were digitized and re-digitized within a one-month interval by the same operator. The Dahlberg measurements ranged from 0.17 for the horizontal component of U1-tip to 1.63 for the horizontal component of L6-mesial cusp.

Multiple linear regression analysis (least squares type) was applied to determine the estimation of anterior facial height (AFH) and posterior facial height (PFH) based on the dentoalveolar heights of upper and lower molars and incisors. AFH and PFH were considered individually dependent variables. The independent variables of the regression models were: the distance from the mesial cusp of the upper molar to the palatal plane (U6-PP), the distance from the mesial cusp of the lower molar to the mandibular plane

(L6-GoMe), the distance from the tip of the upper incisor to the palatal plane (U1-PP) and the distance from the tip of the lower incisor to the mandibular plane (L1-GoMe), as shown in **Figure 1**.

The multiple regression models were designed by the following formulas:

AFH (Na-Me) = $ß_0 + ß_1{}^*X_1 + ß_2{}^*X_2 + ß_3{}^*X_3 + ß_4{}^*X_4$

PFH (S-Go) = $ß_0 + ß_1{}^*X_1 + ß_2{}^*X_2 + ß_3{}^*X_3 + ß_4{}^*X_4$

In the equations, AFH and PFH represent response or dependent variables. $ß_0$ represents the estimated intercept, while $ß_{1,}$ $ß_{2,}$ $ß_{3,}$ and $ß_4$ are the estimated slope coefficients. X_1, X_2, X_3 and X_4 are the U6, L6, U1, and L1 predictors. Ultimately, the goodness of fit was determined by the R-squared (R^2) value and statistical significance was considered at the level of *p<0.05; **p<0.01; ***p<0.0005; and ****p<0.0001.

CHAPTER 4
RESULTS

The mean linear measurements, standard deviations, and standard error of mean (SEM) were recorded for all cephalometric tracings to evaluate class I and class II subjects in each of the phases A, B, and C (**Tables 5a and 5b**).

Class I N=45			
Variable	Phase A	Phase B	Phase C
AFH (Na-Me)	88.23±5.02 SEM=0.75	93.47±5.53 SEM=0.82	98.96±6.93 SEM=1.03
PFH (S-Go)	54.22±3.90 SEM=0.58	58.62±4.31 SEM=0.64	63.77±5.44 SEM=0.81
U6-PP	15.31±1.62 SEM=0.24	16.82±1.73 SEM=0.26	18.84±2.05 SEM=0.31
L6-GoMe	21.41±1.74 SEM=0.26	22.51±1.98 SEM=0.30	24.22±2.28 SEM=0.40
U1-PP	21.06±2.12 SEM=0.32	22.73±2.12 SEM=0.32	23.50±2.37 SEM=0.35
L1-GoMe	28.89±2.26 SEM=0.34	30.61±2.48 SEM=0.37	32.08±3.26 SEM=0.49

Table 5a. Descriptive statistics: mean, standard deviation and standard error of mean (SEM) for the Class I group.

Class II N=10			
Variable	Phase A	Phase B	Phase C
AFH (Na-Me)	87.10±2.58 SEM=0.81	93.34±2.87 SEM=0.91	99.16±3.39 SEM=1.14
PFH (S-Go)	54.36±3.44 SEM=1.09	60.51±4.71 SEM=1.49	66.50±5.65 SEM=1.79
U6-PP	15.31±1.34 SEM=0.43	17.05±1.32 SEM=0.42	19.43±1.47 SEM=0.46
L6-GoMe	21.54±1.11 SEM=0.35	23.17±1.36 SEM=0.43	24.94±1.62 SEM=0.51
U1-PP	20.60±1.20 SEM=0.38	23.06±1.20 SEM=0.38	24.04±2.10 SEM=0.66
L1-GoMe	29.02±1.77 SEM=0.56	31.33±1.82 SEM=0.57	33.02±1.90 SEM=0.60

Table 5b. Descriptive statistics: mean, standard deviation and standard error of mean (SEM) for the Class II group.

For the Class I group of subjects, the multiple linear regression model for the AFH (Na-Me) showed meaningful goodness of fit ($R^2 = 0.81$, $R^2 = 0.81$ and $R^2 = 0.86$ for phases A, B and C, respectively), being statistically significant at the level of $P<0.0001$ (**Table 6a**). The multiple linear regression model for the PFH (S-Go) showed moderate goodness of fit ($R^2 = 0.57$, $R^2 = 0.52$ and $R^2 = 0.57$ for phases A, B and C, respectively), being statistically significant at the level of $P<0.0001$ (**Table 6a**). In the AFH regression model, U6-PP was the best estimator for phases A and C (**Table 6a**). For the PFH regression model, U6-PP was the best estimator for phases A, B and C (**Table 6a**).

Multiple Regression		Class I Group		
		Phase A	Phase B	Phase C
Dependent Variable AFH (Na-Me)	Goodness of Fit Significance	$R^2 = 0.81$ P<0.0001****	$R^2 = 0.81$ P<0.0001****	$R^2 = 0.86$ P<0.0001****
	P value of Parameter Estimates & Significance	U6-PP = 0.005** L6-GoMe = 0.018* U1-PP = 0.230 L1-GoMe = 0.134	U6-PP = 0.138 L6-GoMe = 0.146 U1-PP = 0.016* L1-GoMe = 0.062	U6-PP = 0.0004*** L6-GoMe = 0.049* U1-PP = 0.041* L1-GoMe = 0.205
Dependent Variable PFH (S-Go)	Goodness of Fit Significance	$R^2 = 0.57$ P<0.0001****	$R^2 = 0.52$ P<0.0001****	$R^2 = 0.57$ P<0.0001****
	P value of Parameter Estimates & Significance	U6-PP = 0.003** L6-GoMe = 0.182 U1-PP = 0.099 L1-GoMe = 0.174	U6-PP = 0.001*** L6-GoMe = 0.014* U1-PP = 0.022* L1-GoMe = 0.714	U6-PP = 0.002** L6-GoMe = 0.015* U1-PP = 0.114 L1-GoMe = 0.526

Table 6a. Multiple linear regression analysis for the Class I group. *p<0.05; **p<0.01; ***p<0.0005; ****p<0.0001

For the Class II group of subjects, the multiple linear regression model for the AFH (Na-Me) showed meaningful goodness of fit ($R^2 = 0.80$, $R^2 = 0.87$ and $R^2 = 0.87$ for phases A, B and C, respectively), being statistically significant at the level of $P<0.05$ for phases B and C (**Table 6b**). The multiple linear regression model for the PFH (S-Go) showed important goodness of fit ($R^2 = 0.69$, $R^2 = 0.88$ and $R^2 = 0.80$ for phases A, B and C, respectively), being statistically significant at the level of $P=0.05$ for phases B and C (**Table 6b**). In the AFH regression model, there was no statistically significant estimator (**Table 6b**). For the PFH model, U1-PP was the best estimator for phases A and C (**Table 6b**).

Multiple Regression		Class II Group		
		Phase A	Phase B	Phase C
Dependent Variable AFH (Na-Me)	Goodness of Fit Significance	R^2 = 0.80 P=0.057	R^2 = 0.87 P=0.021*	R^2 = 0.87 P=0.021*
	P value of Parameter Estimates & Significance	U6-PP =0.598 L6-GoMe = 0.907 U1-PP = 0.427 L1-GoMe = 0.072	U6-PP = 0.067 L6-GoMe = 0.466 U1-PP = 0.197 L1-GoMe = 0.068	U6-PP = 0.621 L6-GoMe = 0.453 U1-PP = 0.273 L1-GoMe = 0.3905
Dependent Variable PFH (S-Go)	Goodness of Fit Significance	R^2 = 0.69 P=0.144	R^2 = 0.88 P=0.015*	R^2 = 0.80 P=0.050*
	P value of Parameter Estimates & Significance	U6-PP = 0.567 L6-GoMe = 0.709 U1-PP = 0.279 L1-GoMe = 0.175	U6-PP = 0.306 L6-GoMe = 0.054 U1-PP = 0.027* L1-GoMe = 0.097	U6-PP = 0.222 L6-GoMe = 0.660 U1-PP = 0.030* L1-GoMe = 0.057

Table 6b. Multiple linear regression analysis for the Class II group. *p<0.05; **p<0.01; ***p<0.0005; ****p<0.0001

Visual representation of the multiple linear regression graphics for Anterior Facial Height (AFH) and Posterior Facial Height (PFH) across phases A, B, and C is displayed in **Figure 2** for the class I group and **Figure 3** for the class II group.

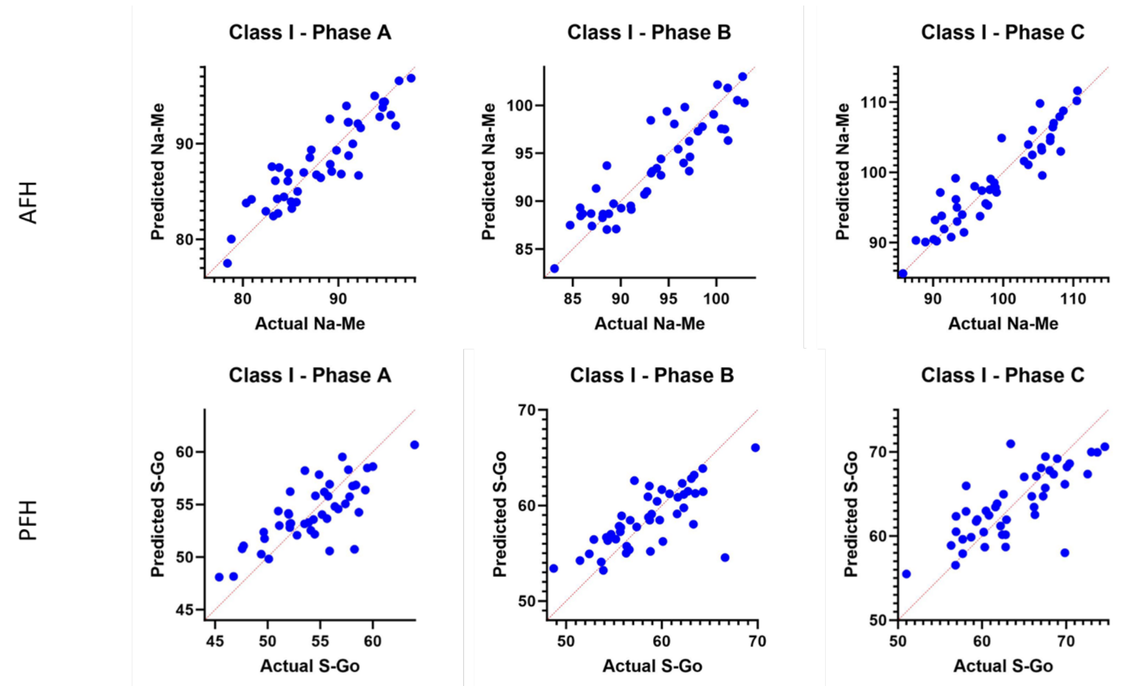

Figure 2. Multiple linear regression graphics for Anterior Facial Height (AFH) and Posterior Facial Height (PFH) for the Class I group in phases A, B and C.

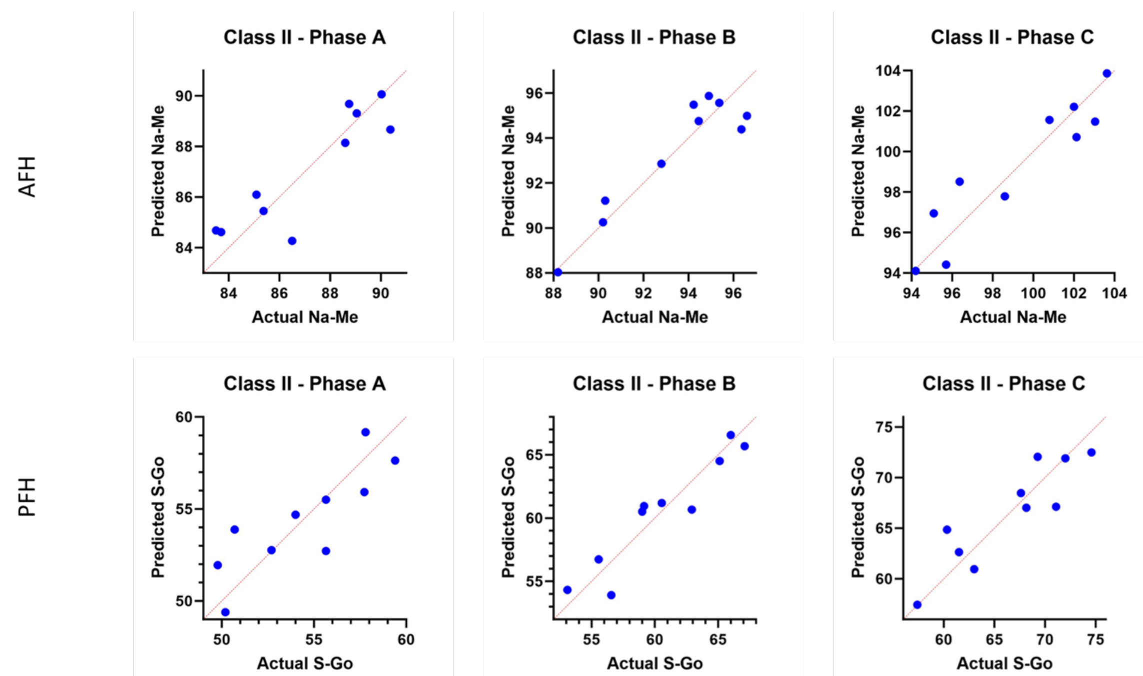

Figure 3. Multiple linear regression graphics for Anterior Facial Height (AFH) and Posterior Facial Height (PFH) for the Class II group in phases A, B and C.

CHAPTER 5
DISCUSSION

Our investigation into craniofacial growth and the impact of dentoalveolar heights, particularly in Class I and Class II malocclusions, aligns with the broader context of existing research. The prevalence of Class II malocclusion in the U.S. population, approximately 14.7%, underscores the significance of understanding the dynamics of craniofacial development (Proffit, 1998). Drawing on data from the University of Michigan Growth Study, our study contributes to this understanding, especially given the age range covered (6-18 years) and the mixed-longitudinal nature of the sample (Harris 1988).

Examining the factors influencing craniofacial growth, our results shed light on the intricate relationship between dentoalveolar heights, mandibular rotation, and the establishment of facial heights. The literature indicates that the severity of Class II malocclusion correlates with functional deficits, emphasizing the importance of early intervention (McNamara 1981; Buschang 1988; Jacob 2014). Our study extends this understanding by exploring specific variables, such as the distance from the upper molar to the palatal plane (U6-PP), as crucial determinants in phases A and C in Class I subjects (Stahl 2008).

The late mixed dentition period (phase B) introduces challenges in assessing vertical stability due to the shedding of deciduous molars without immediate eruption of premolars, leading to transitory effects on facial heights (Creekmore 1983). Our study aligns with these observations, providing further insights into the complexity of craniofacial development during this critical period. The lack of significance of the upper molar estimate for anterior facial height (AFH) during phase B in Class I subjects suggests the nuanced nature of these developmental processes (Fishman 1976).

Specifically, with Class II malocclusion, our study corroborates the variability observed in dentoalveolar growth, leading to inconsistent facial heights in this group (Nanda 1995). The lack of statistically significant roles for the four independent variables (U6, L6, U1, L1) in any of the phases, except for the distance from upper incisors to the palatal plane (U1-PP) in phases B and C, further highlights the challenges associated with consistent dentoalveolar growth in Class II individuals (Ricketts 1960). This also highlights a limitation of our study—potential sampling bias from focusing on untreated subjects, especially as severe Class II subjects may have dropped out after starting orthodontic treatment. Efforts were made to mitigate biases, but a larger Class II sample size would strengthen our findings.

Moreover, the complex relationship between upper and lower incisors in Class II division 1 subjects during late mixed and permanent dentition complicates the determination of cause and effect between mandibular rotation and molar eruption (Sassouni 1955; Schudy 1964). Our study supports the existing literature in acknowledging the difficulty in establishing a definitive cause-and-effect relationship between these factors.

Our findings underscore the importance of considering the vertical position of the upper molar (U6), influenced by direct or indirect dentoalveolar growth as a key factor in craniofacial vertical growth and development. This aligns with previous research emphasizing the role of dentoalveolar heights in shaping facial heights and the establishment of occlusion (Siriwat 1985). Our study contributes to this understanding by providing specific insights into the relevance of the upper molar (U6) vertical position, particularly in Class I subjects during phases A and C (Solow 1977).

Furthermore, our study advances the current understanding of craniofacial growth and the impact of dentoalveolar heights in Class I and Class II malocclusions. Integrating our findings with existing literature, we contribute to the nuanced discussion surrounding the complexities of these developmental processes (Subtelny 1959). The challenges in establishing definitive cause-effect relationships, particularly in Class II malocclusion, highlight the need for continued research to unravel the intricate interplay of factors influencing craniofacial development (Thilander 2001).

Additionally, the impact of orthodontic treatment on craniofacial growth patterns, particularly the concurrent development of the craniofacial complex during and after treatment, has been well documented (Weislander 1974). Changes in mandibular and maxillary growth due to altered breathing modes further emphasize the significant influence of functional habits on craniofacial morphology (Woodside 1976). Finally, the comparative effects of extraction versus non-extraction treatment on mandibular growth underscore the crucial role of dental interventions in shaping craniofacial outcomes (Williams 1997).

By synthesizing these insights, our study not only provides a deeper understanding of craniofacial growth dynamics but also stresses the importance of targeted orthodontic interventions in managing malocclusions and optimizing facial development.

CHAPTER 6
CONCLUSION

Based on the findings presented in this study, it is evident that the anterior facial height (AFH) and the posterior facial height (PFH) are both influenced by dentoalveolar heights in the Class I group. Furthermore, the study highlights the significance of the distance from the upper molar to the palatal plane (U6-PP), which emerged as the most determinant variable during phases A and C but not in phase B. The late mixed dentition period (phase B) introduces challenges in assessing vertical stability due to the shedding of deciduous molars without immediate eruption of premolars, leading to transitory effects on facial heights.

In contrast, the Class II group exhibits a different pattern, with none of the four independent variables (U6, L6, U1, L1) showing a statistically significant role in any of the phases, except for the distance from upper incisors to the palatal plane (U1-PP) in phases B and C. The lack of consistent dentoalveolar growth in the Class II group is reflected in the inconsistency of facial heights and the limitation of the sample. The relationship between upper and lower incisors in Class II subjects during the late mixed dentition may play a significant role in this lack of consistency.

Ultimately, this study sheds light on the complex relationships within craniofacial growth and provides valuable insights for future research in this field.

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