AMERICAN UNIVERSITY OF BEIRUT

EFFECT OF THE VARIATION OF POSTERIOR DENTOALVEOLAR GROWTH ON ANTERIOR CHIN PROJECTION IN THE TREATMENT OF CLASS II DIVISION 1 MALOCCLUSION

by
SARA JOSEPH KHAZAKA

A thesis
submitted in partial fulfillment of the requirements
for the degree of Master of Science
to the Department of Orthodontics and Dentofacial Orthopedics
of the Faculty of Medicine
at the American University of Beirut

Beirut, Lebanon
May 2021

AMERICAN UNIVERSITY OF BEIRUT

EFFECT OF THE VARIATION OF POSTERIOR DENTOALVEOLAR GROWTH ON ANTERIOR CHIN PROJECTION IN THE TREATMENT OF CLASS II DIVISION 1 MALOCCLUSION

by

SARA JOSEPH KHAZAKA

Approved by:

Dr. Joseph G. Ghafari, Professor and Head Orthodontics and Dentofacial Orthopedics	Advisor
Dr. Anthony T. Macari, Associate Professor Orthodontics and Dentofacial Orthopedics_	Member of Committee
Dr. Maria Saadeh, Adjunct Clinical Associate Professor Orthodontics and Dentofacial Orthopedics	Member of Committee
Dr. Naji Abou Chebel, Clinical Instructor Orthodontics and Dentofacial Orthopedics	Member of Committee

Date of thesis defense: May 4th, 2021

AMERICAN UNIVERSITY OF BEIRUT

THESIS RELEASE FORM

Student Name: Khazaka Sara Joseph

Last First Middle

I authorize the American University of Beirut, to: (a) reproduce hard or electronic copies of my thesis; (b) include such copies in the archives and digital repositories of the University; and (c) make freely available such copies to third parties for research or educational purposes:

☒ As of the date of submission

☐ One year from the date of submission of my thesis.

☐ Two years from the date of submission of my thesis.

☐ Three years from the date of submission of my thesis.

May 11, 2021

Signature Date

ACKNOWLEDGMENTS

First and foremost, I would like to thank ***God*** *Almighty for giving me the strength, knowledge, ability and opportunity to undertake this research study and to persevere and complete it satisfactorily. Without his blessings, this achievement would not have been possible*

I would like to pay my special regards to all those who helped me in this work

To all the committee members

I would like to begin by expressing my heart-felt gratitude to my advisor, *Dr. Joseph Ghafari* for his constant guidance and support without which I could not have completed this thesis. I consider myself to be extremely privileged to have been his student. I benefited enormously from his excellence as a teacher and as a researcher. I am very grateful to him for being very patient and for all his time that he spent in discussing the various subjects of this thesis

Dr. Maria Saadeh, your help was invaluable. I consider myself to be extremely fortunate to have had the opportunity to work with you. Thank you for your constant support and motivation during this research process, not forgetting the time you have dedicated to help me in the statistical analyses.

Dr. Anthony Macari, your suggestions and encouragements made a lot of difference. Thank you for being a great teacher and for your contribution to my clinical training.

Dr. Naji Abou Chebel, for kindly agreeing to be in my defense committee, I am forever grateful and honored.

To all who contributed to the success of this project

Dr Antoine Hanna and Dr. Elie Haddad your contributions in this project were extremely helpful. Thank you for your priceless effort.

I am immensely thankful to all my teachers who taught me at various stages. I particularly would like to thank *Dr. Ramzi Haddad* and *Dr. Kinan Zeno* for their excellence in education and for their time invested in our clinical training.

To my classmates, fellow residents and staff

It has been a pleasure getting to know you all. Your friendship and support in were irreplaceable.

To my family and friends

This journey wouldn't have been possible without your love and support. Thank you for always being there.

ABSTRACT
OF THE THESIS OF

Sara Joseph Khazaka for Master of Science
Major: Orthodontics

Title: Effect of the variation of posterior dentoalveolar growth on anterior chin projection in the treatment of Class II Division 1 malocclusion

Introduction

In a preliminary study, the cant of the anterior contour of the symphysis was shown to be a good predictor of forward chin projection following Class II orthopedic treatment. Given the importance of facial esthetics in determining treatment plan the relevant components should help in improving diagnosis and prediction of treatment outcome, thus projecting more reasonable treatment plans.

Aims

1- To assess if the anterior projection of the chin is associated with the control of the posterior occlusion during growth and treatment of Class II division 1 malocclusion

2- To develop predictive models of treatment response (favorable vs unfavorable) based on objective cephalometric classifications

Design

This is a retrospective study conducted on the pre and post-treatment lateral cephalograms taken on orthodontically- treated patients diagnosed with Class II division 1 malocclusion, where linear and angular measurements were performed to gauge relations among cranial base, maxilla and mandible. Each component potentially contributing to treatment outcome is quantified by its corresponding cephalometric measurement.

Methods

A total of 285 patients recruited under strict inclusion criteria of Class II division 1, and treated at the Division of Orthodontics and Dentofacial Orthopedics at AUBMC, were classified into 2 age groups (195 growing and 90 adults) based on superimposition of T1 and T2 lateral cephalograms. The growing group was further divided into 96 pre-pubertal and 99 post-pubertal subjects based on the time of initiation of treatment (T1). All patients must have reached Class I occlusion at the end of treatment (T2). Linear and angular measurements gauging relations among cranial base and both jaws were taken on pre- and post-treatment lateral cephalograms. Treatment response was defined as "favorable" or "unfavorable" following this approach. Various appropriate statistical analyses were

applied, including multivariate analyses to the cephalometric data to determine pretreatment predictors of a favorable response in Pog-N measurement.

Results

The treatment effects had different responses on the various age categories. In the sagittal discrepancy, there was more decrease in the anterior chin projection relative to N perpendicular (Pog-N) in the pre- pubertal (1.42 mm, $p<0.001$) than the post-pubertal (1.107 mm, $p<0.001$) groups compared to the adult group where there was less of change in this measurement (0.479 mm, $p<0.001$). On the other hand, the maxillary incisors were significantly retroclined (-6.71°, $p<0.001$) among the adult patients, more than in the post-pubertal group (-1°, $p<0.001$), while almost no retroclination occurred in the pre-pubertal group (-0.80°, $p=0.56$). The initially proclined mandibular incisors remained relatively stable after treatment in all age groups indicating the awareness of the orthodontists to avoid tooth proclination for periodontal and facial esthetics reasons. Pearson correlation coefficient indicates a high correlation between the angle formed between the occlusal plane and palatal plane (OP/PP) and the anterior chin projection (Pog-N) with an $r = -0.824$, $p<0.001$ in the growing group and a coefficient of $r = - 0.736$, $p<0.001$ in adult group. Based on the multivariate analyses in which one major cephalometric classifier was used (response in Pog-N), the significant predictors of treatment outcome were found in both age groups. More specifically, in the growing group predictors were Co-Go, AFH, SNB, OP/PP and U6-PP. In the adult group, predictors were Co-Go, AFH, MP/SN, and L6-MP.

Conclusion

In conclusion, the occlusal plane also translated by the vertical dentoalveolar heights of posterior teeth has a direct relation with the anterior chin projection. Vertical control of posterior teeth, resulting in a decrease of the angle OP/PP will project the anterior chin projection forward. Various predictive equations pointed to several cephalometric measurements as predictors of outcome. Among these predictors, OP/PP. U6-PP and L6-MP play a significant role in predicting the response of the anterior chin projection after treatment. Improvement of the chin projection is better seen within the pre-pubertal group followed by the post-pubertal and least seen within the adult group where growth has cessated. Future research should expand the boundaries of the methodology used in this study, by including larger samples, and panels to judge facial characteristics in relation to the underlying skeletal structures.

TABLE OF CONTENTS

ILLUSTRATIONS

TABLES

Table

ABBREVIATIONS

Class II/1	Class II, division 1
TMJ	Temporomandibular joint
NHP	Natural Head Position
FH	Frankfort Horizontal
Mm	Millimeter
Niti	Nickel Titanium
Cl	Class
Coef.	Coefficient
Tx	Treatment
FR	Favorable response
UFR	Unfavorable response

CHAPTER 1

INTRODUCTION

Individuals exhibiting Class II malocclusions constitute a large segment of the population requiring orthodontic treatment for esthetical and functional motives. Mandibular retrognathism, commonly present in Class II malocclusion, implies an orthopedic treatment to improve chin projection by stimulating a more anterior position in the face. In fact, facial esthetics has risen to a higher ranking because of personal and social demands. Among Caucasian population, convex profiles are among the least favored. Thus, the correction of retruded chin significantly increases attractiveness. The individualization of the treatment remains a challenge, particularly in malocclusions combining skeletal dysmorphology underlying the dental/occlusal irregularities. Treatment of such problems is guided by central tendencies gathered from research, including investigations at the highest level on the evidence hierarchy. The assessment of treatment outcomes has redirected research into associating modalities and timing of treatment with successful outcome in the individual patient. Dentofacial orthopedics or growth modification aims to correct or reduce the severity of dentoskeletal discrepancies in growing children. Limitations to this modality are inherent to the growth potential of each individual patient determined by his genome.

Similar to any other malocclusion, Class II division 1 malocclusion should be diagnosed on the basis of its multiple components instead of focusing on a major one, because the outcome of treatment encompasses the cumulative response of a number of components rather than a singular effect of one component (Ghafari and Macari, 2014). Prediction of craniofacial growth is a key element to a successful orthopedic treatment.

Unfortunately, despite contemporary attempts to anticipate growth, clinicians are still unable to accurately forecast the remaining amount of growth for individual malocclusions, especially at the level of the chin. The focus of the present research is to study effect of the variation of posterior dentoalveolar growth on anterior chin projection in the treatment of Class II division 1 malocclusion, and to find predictors for the improvement in the anterior chin projection in individuals with Class II division 1 malocclusion. The scope of the research includes variations in age groupings (growing and adult), the response of the anterior chin projection after the treatment as well as correlating it to the posterior dentoalveolar heights.

CHAPTER 2

LITERATURE REVIEW

2.1. Postulation of malocclusion

In 1839, John Hunter the anatomist introduced a concept of normal occlusion and irregularities between teeth and jaws. Right after, in the middle of the 19^{th} century, Georg Carabelli introduced a classification system describing abnormal relationships between dental arches including the terms “edge to edge “, “open bite”.

In 1890, Edward H. Angle,” father of modern Orthodontics’’ classified the normal occlusion in the natural dentition. He described three classes of malocclusion based on the occlusal relationships of the first permanent molars in occlusion (Fig. 2.1).

Class I: Normal relationship of the molars, but with incorrect line of occlusion because of the mispositioned teeth, rotations, or other causes.

Class II: Lower molar distally positioned in comparison to the upper molar, where the line of occlusion is not specified. He characterized two types of Class II malocclusions: Class II division 1 when the maxillary anterior teeth are proclined and a large overjet is present whereas, Class II Division 2 is when the maxillary anterior teeth are retroclined and a deep overbite exists, which was also classified into 3 sub-classes (Type A,B,or C).

Class III: Lower molar mesially positioned in comparison to the upper molar, where the line of occlusion is not specified (Angle, 1907)

This classification was quickly and widely adopted early in the twentieth century. It is incorporated within all contemporary descriptive and classification schemes. (Proffit et al, 2014).

While commonly used to this day, the Angle classification was considered incomplete because it did not represent the myriad of encountered problems. Reported deficiencies included the lack of correlation between dentition and face or profile, the prevalence of sagittal rather than 3-dimensional analysis, the absence of differentiation between dentoalveolar and skeletal discrepancies, as well as the incorporation of arch deficiencies and the complexity of the problem. Yet, Angle's classification was simple enough to remain in use worldwide. Moreover, it constituted a solid baseline for all the refinement that came afterward.

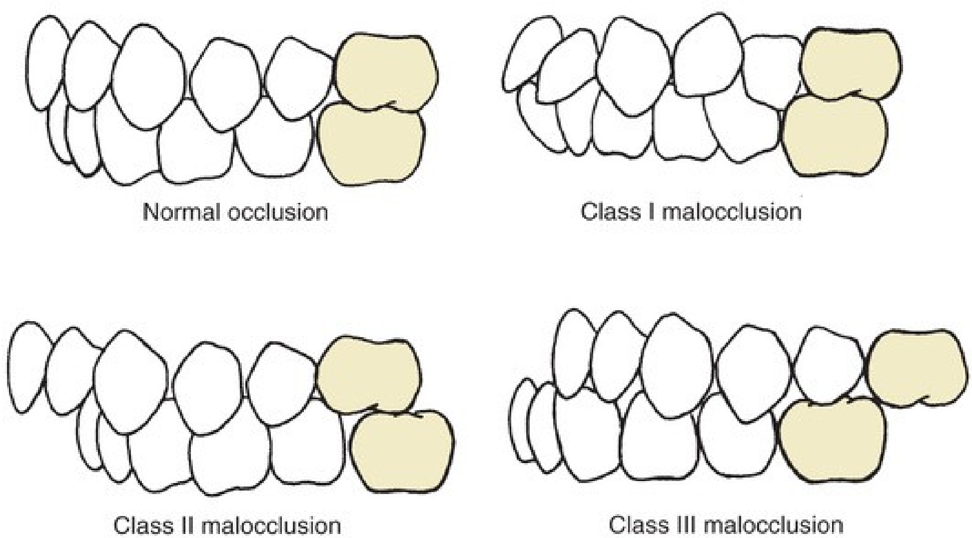


Fig. 2.1: Normal occlusion and malocclusion classes as specified by Angle. This classification was quickly and widely adopted early in the twentieth century. (Angle, 1907; illustrations adapted from Proffit et al, 2014, p. 7)

To solve the major drawbacks of Angle's classification, Ackerman and Proffit (1969) described a system of diagnosis encompassing five major characteristics of malocclusion that account for skeletal deviations in the three planes of space, crowding, protrusion, asymmetry within dental arches, and most importantly profile consideration (Fig. 2.2). The classification succeeded in classifying the different complexities of malocclusions; however it was not practical for wide use in clinical practice.

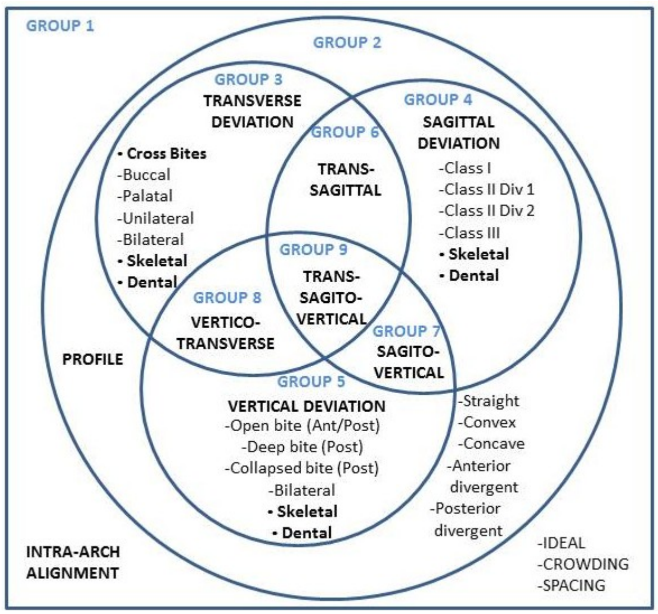


Fig. 2.2: Venn diagram of Ackermann and Proffit classification System.

Later on, Andrews defined 6 keys to normal occlusion in essence defining targets for the correction of malocclusion. These components included Angle's own Class I molar occlusion with additional definition of the contacts between the teeth, as well as more detailed dentally and occlusally related parameters.

2.2. Predominance and characteristics of the Class II, division 1 malocclusion

Class II malocclusion is the most common clinical situation in any orthodontic practice in the U.S (Proffit et al, 1997). According to NHANES III, the prevalence of malocclusion of the U.S. population is the following: 50% to 55% of the population have Class I malocclusion, which constitute the largest group, followed by the Class II malocclusion encompassing around 15% of the population and finally the Class III malocclusion which represents less than 1% of the total population (Fig. 2.3) (Proffit et al, 1997). However, the classification was based on the amount of overjet, thus Class II prevalence would be greater than 15% because dentoalveolar compensation (proclined mandibular incisors and/or retroclined maxillary incisors) might camouflage the severity of the distoclusion.

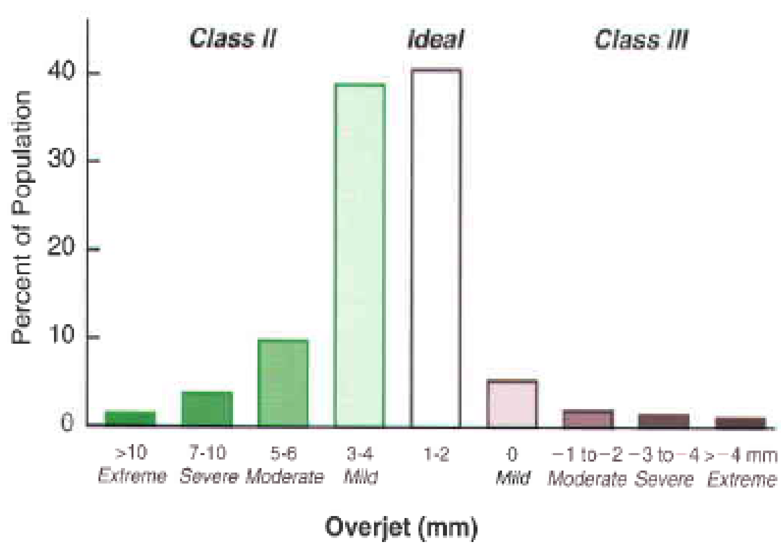
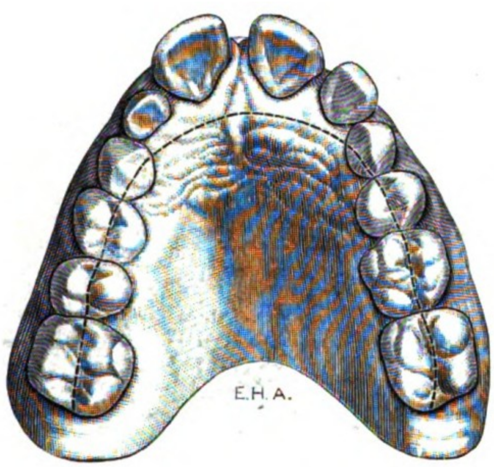


Fig. 2.3: Overjet (Class II) and reverse overjet (Class III) in the U.S. population, 1989-1994. Only one-third of the population has ideal anteroposterior incisor relationships, but overjet is only moderately increased in another one-third. Increased overjet accompanying Class II malocclusion is much more prevalent than reverse overjet accompanying Class III. (After Proffit et al, 2014, p.12).

Malocclusion in the sagittal plane might vary in different severity levels, falling between a fully interdigitated Class I or Class II malocclusions. Authors have attempted to gauge the severity in various ways: measuring half and quarter cusps in quantifying the malocclusion for research purposes and assessment of treatment results creating comprehensive indices that encompass all the occlusal anomalies possibly present in a malocclusion including the amount of overjet and overbite (Richmond et al, 1992).

Angle's definition of Class II malocclusion was based on distally positioned mandibular teeth, and a distal position of the mandible itself (usually lesser than the normal size) relative to the maxilla (Fig. 2.4). He further described the major components of Class II division 1 malocclusion: 1- abnormally lengthened and narrowed maxillary arch, 2- lengthened and protruded maxillary incisors (Fig. 2.4A),



A **B**

Fig. 2.4: A, Abnormally lengthened and narrowed maxillary arch in Class II, division 1 malocclusion. Note the protruding incisors away from the normal curve of alignment. **B,** Profile outlines typical to Class II/1 malocclusion. Notice the convexity of the face and the lip incompetency associated with mouth breathing. (From Angle, 1907, p. 47, 48).

3- deep curve of spee due to greater compensation, mainly from the overeruption of mandibular incisors, 4- lengthened lower incisors, 5- short and functionless upper lip, 6- thickened and interposed lower lip (Angle, 1907). Angle pointed out the lack of facial harmony and impairment of the profile outline associated with the Class II/1 malocclusion (Fig. 2.4B). In almost a century following these descriptions, hundreds of studies confirmed the presence of these findings.

2.3. Cephalometric elements of Class II division 1 malocclusion

After its introduction in the field of orthodontics by Hofrath and Broadbent in 1934, radiographic cephalometry has allowed orthodontists to evaluate the relationship between the major facial components (cranial base, jaws, and teeth) for diagnostic purposes with great precision. In addition, serial cephalometric radiographs taken throughout treatment can be thoroughly evaluated using superimposition methods that identify structural changes resulting from growth and treatment mechanics (except in non-growing patients) (Proffit et al, 2014). Concerning Class II division 1 malocclusion**,** the skeletal and dentoalveolar components have been delineated in much detail in major cephalometric studies. In 1981, McNamara described five principal components: mandibular skeletal position, maxillary skeletal position, maxillary dentoalveolar position, mandibular dentoalveolar position, and vertical development (anterior facial height) .More specifically, multiple morphological variations in the dentofacial complex are responsible for the development of the Class II, division 1 malocclusion (Fig.2.5):

1- Orthognathic maxilla along with anteriorly positioned maxillary dentition,

2-Small orthognathic mandible or micrognathia, 3- Prognathic maxilla along with anteriorly positioned maxillary dentition relative to the cranium,

4- Retrognathic mandible of normal size,

5- Orthognathic mandible along with posteriorly positioned mandibular dentition.

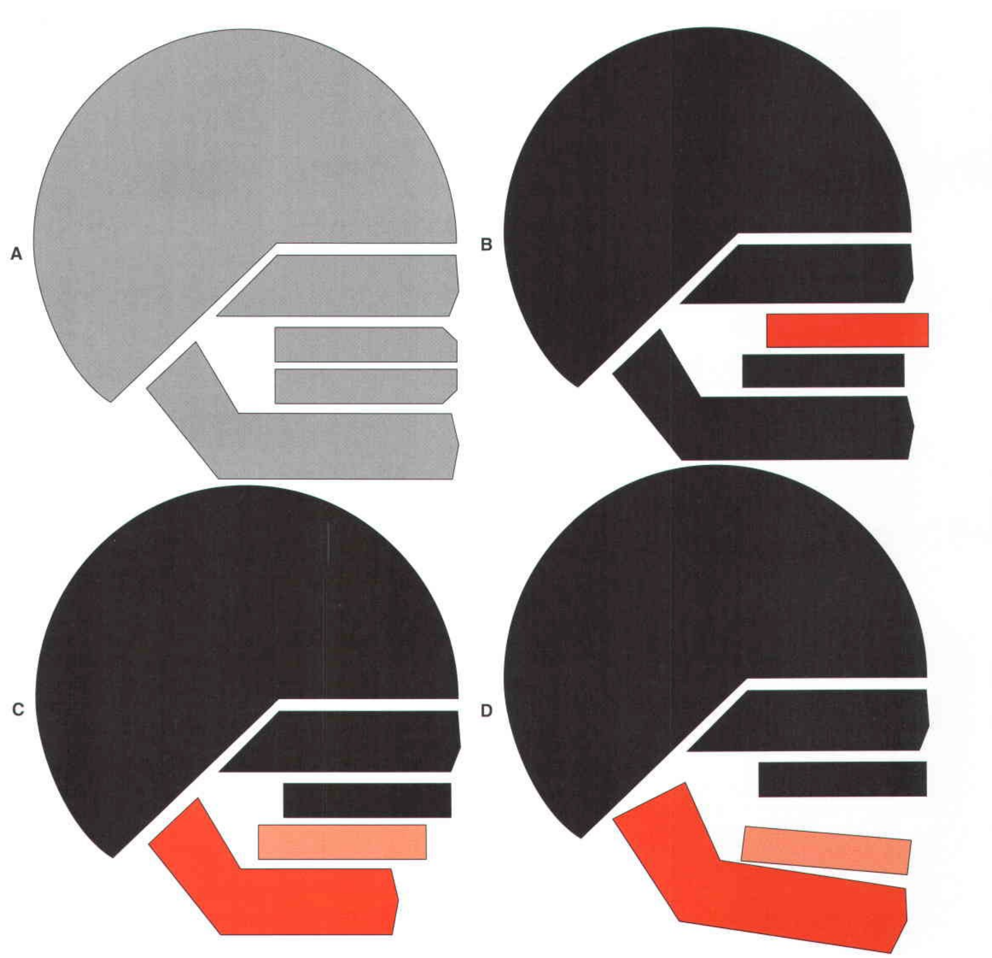


Fig. 2.5: The ideal relationships of the facial and dental components can be represented as shown in A. Cephalometric analysis clarifies the differing dental and skeletal contributions to malocclusions that present identical dental relationships. A Class II division 1 malocclusion could be produced by (B) protrusion of maxillary teeth although the jaw relationship was normal, (C) mandibular deficiency with the teeth of both arches normally related to the jaw, (D) downward-backward rotation of the mandible produced by excessive vertical growth of the maxilla, or a number of other possibilities. (After Proffit et al, 2014, p. 203).

Many other combinations could be present, entailing dentoalveolar compensation for the underlying skeletal discrepancies, which can be therapeutically challenging as much as their severity (Fisk et al, 1953).

Common findings in the literature claim that mandibular skeletal retrognathism along with maxillary dental protrusion are significant factors behind the development of Class II profiles. Despite wide variations in the vertical dimension, nearly half of Class II profiles presented excessive vertical development (McNamara, 1981).

In summary, a Class II malocclusion is the result of several variations in skeletal and dentoalveolar components; however, mandibular skeletal retrusion was shown to be the most prevalent characteristic (McNamara, 1981, Anderson, 1983; Kerr, 1987; Varella 1998). In addition, some studies associated the retruded mandibular position with short mandibular length or micrognathia (Baccetti et al, 1997). The sum of these features defines a specific phenotype where, during the diagnosis, it is important to evaluate its components to end up with a targeted treatment plan that achieves the best functional, esthetic and stable results (Ghafari & Macari, 2014).

2.4. Etiology of Class II, division 1 malocclusion

The etiology of Class II division 1 malocclusion is multifactorial. It might result of a developmental abnormality or an unfavorable position of developing jaws. As well as that, it is influenced by genetic factors and in some cases by environmental factors. Class II phenotype tend to recur; for instance, a hereditary trait from any parent or a combination of traits from both parents may generate similar or modified characteristics in the offspring. In addition, the mixing of gene pools within a population may produce new traits or may alter the expression frequency of existing traits (Graber, 1963). Based on genetic studies, 40% of common dentofacial variations in tooth malposition and malocclusion between dental arches were related to genetic factors that dictate variability between individuals (Lundstrom, 1984). However, other studies in which twin models were used to estimate genetic variability have indicated that a significant amount of concealed environmental influences might induce the development of malocclusions. The same studies failed to demonstrate significant heritability for dental overjet, indirectly eliminating the dominance of genetic over environmental factors in the establishment of some features of the Class II division 1 malocclusion (Corruccini & Potter, 1980). Therefore, a dental Class II division 1 is more likely to be the result of local environmental factors, whereas a skeletal Class II with underlying skeletal dysplasia is less likely to be influenced by these factors. In other words, inter-arch problems are due to genetic predisposition and intra-arch problems are mostly shaped by environmental factors (Shaughnessy & Shire, 1988).

While this might be true, environmental factors can influence the development of certain malocclusions. For example, patients with persistent thumb sucking habit and excessive overjet, may have the lower lip trapped behind the maxillary incisors, causing abnormal contraction of the mentalis and other perioral muscles tipping the maxillary incisors more labially (Lear, 1965). The malocclusion in this case is the cumulative result of the peri-oral musculature malfunction, which is superimposed on the original malocclusion (Graber, 1963). Therefore, persistent tongue, lip, or finger habits can either create a Class II malocclusion or accentuate an existing one (Harvold, 1963).

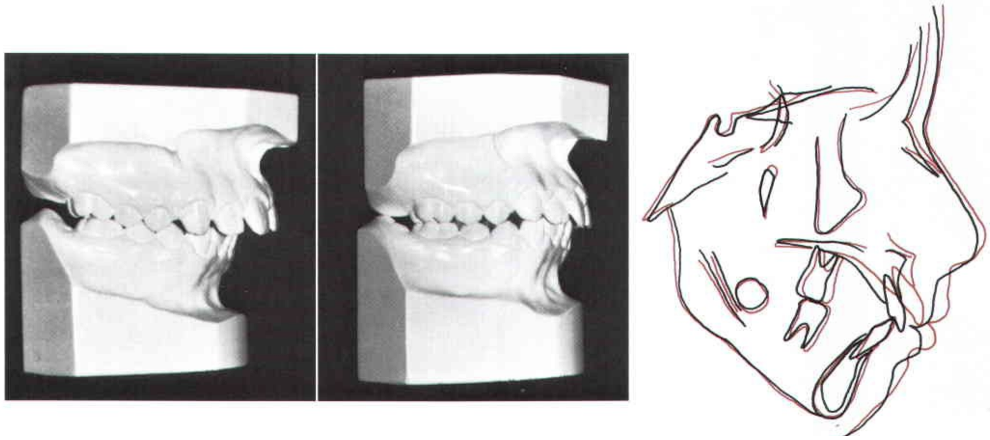


Fig. 2.6: In this pair of identical twins, one sucked her thumb up to the time of orthodontic records at age 11 while the other did not. (A), Occlusal relationships in the non-thumbsucking and (B) the thumbsucking girl. Note the increased overjet and forward displacement of the maxillary dentition in the thumbsucker.(C), Cephalometric tracings of the two girls superimposed on the cranial base for the two girls. As one would expect with identical twins, the cranial base morphology is nearly identical. Note the forward displacement of not only the maxillary dentition but also the maxilla itself. (After Proffit et al, 2014, p. 149).

As well as that, Angle stated without much of evidence that mouth breathing related to blockage of the adenoids at an early age, leads to the development of the Class II division 1 malocclusion (Angle, 1907).

Mouth breathing is known to alter the myofunctional equilibrium and leads to an increased overjet, anterior open bite and posterior crossbite without necessary inducing a Class II malocclusion. This conclusion was confirmed by Harvold's experiment of inducing obligatory mouth breathing in monkeys, which resulted in different malocclusions, comprising Class III (Harvold et al, 1981). Sustained mouth breathing would lead to changes in some skeletal and soft tissue components of the face (head, mandible and tongue posture), causing a steep mandibular plane, large gonial angles and increased anterior lower facial height (Harvold et al, 1981). In extreme situations, these manifestations will lead to the development of the long face syndrome (also known as adenoid facies), which will aggravate the phenotypic expression of a present Class II, division 1 malocclusion (Ghafari and Macari, 2014).

Nevertheless, there are no specific measures to prevent a Class II malocclusion, unless if it is affected by environmental factors such as habits and early loss of deciduous teeth (Bishara, 2006).

Moreover, mandibular deficiency plays a major role in the establishment of distocclusion. Approximately 5 to 10% of severe mandibular growth deficit and/or asymmetry were closely related to previous trauma to the temporomandibular complex and fracture at the level of the mandibular condyle (Proffit, 1980). In some instances, condylar fracture in childhood may be overlooked, leading limited mandibular motion. Partial ankylosis of the mandible impedes translational movements and restricts normal growth.

Authors evaluated the association between cranial base length and angulation with the sagittal relationship of the jaws, based on the assumption that the cant of the anterior cranial base affects the maxillary position whereas the posterior cranial base affects the position of the mandible (Dhopatkar et al, 2002). A long anterior cranial base would lead to the midface protrusion, whereas a long posterior cranial base would position the TMJ more posteriorly and lead to mandibular retrognathia (Shaughnessy & Shire, 1988). The Class II, division 1 malocclusion is also accompanied with higher linear and angular measurements of the cranial base compared to other malocclusions, which would also place the mandible in a more retruded position compared to the maxilla. (Hopkin et al, 1968; Ghafari et al, 2011; Ghafari and Macari, 2014). The cranial base angle was found to be the best discriminating variable between Class I and Class II malocclusions. In almost 73% of cases, cranial base angle at age of 5 years was a good predictor of the patient's occlusion at age of 15 years old (Kerr & Hirst, 1987).

In contrast, other authors found similarity in the growth pattern of the cranial base among both skeletal Class I and Class II subjects and no association between the cranial base angle and the type of malocclusion, contradicting the previous description of more obtuse angulation of the cranial base in skeletal Class II subjects (Wilhelm et al, 2001; Guyer et al, 1986).

2.5. Vertical growth of posterior dentoalveolar heights

Orthodontists must come to consider and appreciate the value of vertical growth as it relates to sagittal growth. They must constantly seek a deeper understanding into how the total effect of growth in these two directions produces different facial types and different amounts of vertical overbite. While it is true that growth of the dentofacial complex does not proceed strictly vertically and anteroposteriorly, perhaps it can be understood when simplified by considering it in this matter. These two factors should be considered not as allied forces but as opposing forces, each vying for the control of Pogonion Vertical growth is trying to carry Pogonion downward while anteroposterior growth is attempting to carry it forward. This battle ensues early in life ad continues until growth is complete. The interplay of growth in these two general directions is responsible for retrognathic and prognathic facial types (Schudy 1964).

Vertical and sagittal growth are intimately correlated, i.e a change in one dimension will necessarily affect the other (Ghafari, J.G. and Macari, A.T., 2013). The connector between these two dimensions is the rotation vector of the jaws during development or during orthodontic treatment; for example when the bite opens the sagittal overjet will increase , and when the incisors are being retracted the bite tends to deepen etc..The jaw relations are defined by the balance of the maxillary and the mandibular sagittal and vertical of growth. Therefore, if vertical growth exceeds sagittal growth, this will lead to a clockwise rotation of the jaws leading to an increased lower anterior facial height, retruded chin position and thinner and longer symphyseal appearance. On the other hand, when sagittal growth exceeds vertical growth this will result in a counterclockwise rotation of the jaws, resulting in a decreased lower anterior facial height, protruded chin position and shorter and thicker symphyseal appearance. Moreover, the growth at the level of the posterior dentoalveolar heights plays a role in favoring growth in one dimension than the other. Excessive growth at the posterior dentoalveolar heights will enhance more vertical growth whereas depressed or deficient growth at the level of the posterior dentoalveolar heights will favor sagittal growth. Dentoalveolar segment has the innate ability to adapt to the underlying developing or established skeletal dysplasia (Kucera, J. et al.,2011). This has been referred to as dentoalveolar compensation. Some investigators believe that the face height is genetically determined and is established early in life. On the other hand, some investigators believe that the excessive eruption of teeth during growth or even during adulthood may result in the increase of facial height. Dentoalveolar heights for the vertical and sagittal facial patterns. The dentoalveolar heights are significantly increased in hyperdivergent facial patterns as compared to hypodivergent or normodivergent facial patterns (Islam, Z.U.,et al., 2016). The evaluation of the dentoalveolar heights is an important consideration in orthodontic treatment planning to fulfill the objectives of the treatment.

2.6. Treatment modalities of Class II, division 1 malocclusion

Treatment of Class II malocclusion through various modalities aims at achieving neutroclusion within the surrounding soft tissue envelope. The ideal goal is to approach or achieve an orthognathic profile, entailing normalization of cephalometric measurements away from compensatory compromises (Ghafari & Macari, 2014). There are three ways to correct a class II malocclusion.

2.6.1. Orthopedic treatment

In other terms it is also known as enhancing differential growth of the mandible. Success in treating this malocclusion is challenging and unpredictable since it relies on the growth potential of the patients as well as that the patient's compliance. The efficiency of an orthopedic treatment in growing children has been wildly exploited and documented by several randomized clinical trials (Harrison, 2007). In Europe, ''functional jaw orthopedics'' method was developed to enhance growth changes while extra-oral force was used in the United States. Currently, functional appliances (e.g. activator, Frankel, twin block, bionator) and extra-oral appliances (headgear) are internationally used to control and modify growth of the mandible (Proffit, 2006).

The aim of the functional appliances is to stimulate mandibular growth by posturing the mandible forward in growing individuals. It must dislodge the condyles (or stimulate the patient to displace them) for a critical amount of distance and time. Nevertheless, the condylar displacement is rarely considered, because almost any functional appliance repositions the condyles effectively if it is worn enough. Animal studies have demonstrated that skeletal mandibular changes due to forward positioning of the mandible induced profound metabolic changes in the condyle and thus enhanced growth. However, the effect is controversial on human subjects, depending on the research approach, treatment protocols and sample sizes. A functional appliance postures the mandibular jaw forward and downward while muscles and soft tissues restrain maxillary growth by producing a backward upward reaction and transmitting the force to the maxilla (Fig 2.7, Fig 2.8) (Ghafari et al., 1998). Maxillary molar distalization and mandibular incisors proclination are produced with differential growth.

On the opposite side, the headgear restricts forward downward maxillary growth and allows the mandible to grow downward forward (Fig 2.9). Although the headgear and the functional appliance have different targets, these appliances have an effect on both jaws, reinforcing the concept of differential growth in young patients (Ghafari et al., 1998).

Figure 2.7 Mandibular retrognathism at rest (A), with functional appliance; bionator (B)

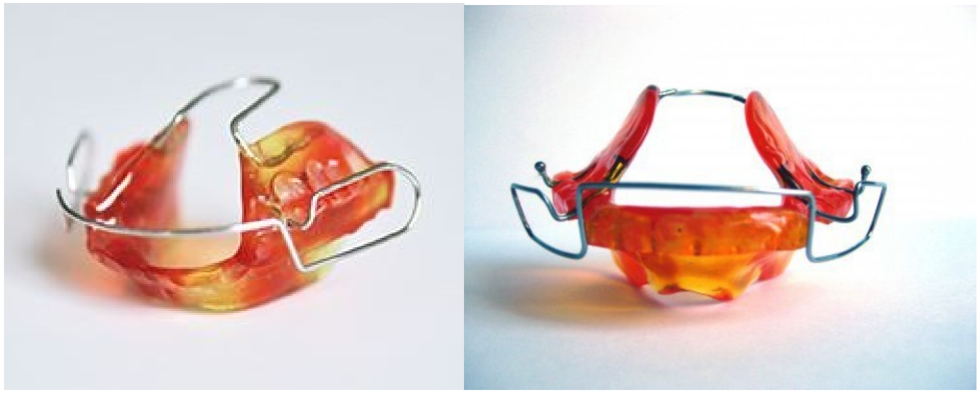


Fig 2.8 Functional appliance: Bionator.

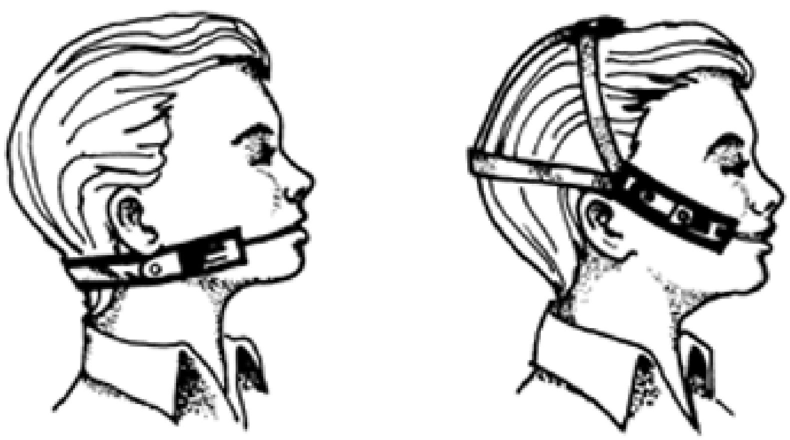


Fig. 2.9: Extraoral traction. Commonly used directions of forces are low-pull, straight-pull and high pull. **A,** Low-pull (cervical) face bow is mostly used in patients with decreased lower vertical facial heights. **B,** High-pull facebow, used in patients with increased lower vertical facial dimensions to minimize or avoid the worsening of the vertical problem. (Glauser Williams,2014).

2.6.1.1. Outcome of orthopedic treatment modalities:

Response to orthopedic treatment depends on the patient's cooperation and growth potential regardless of the type of orthopedic appliance. Patients are usually instructed to wear the appliance at least 14 hours close to 12-13 hours (headgear) or 14-16 hours (functional regulator) (Ghafari et al, 1997). Treatment success is compromised by poor compliance, favoring the use of fixed functional appliances that are assumed to be more predictable than removable appliances (O'Brien et al, 2003).

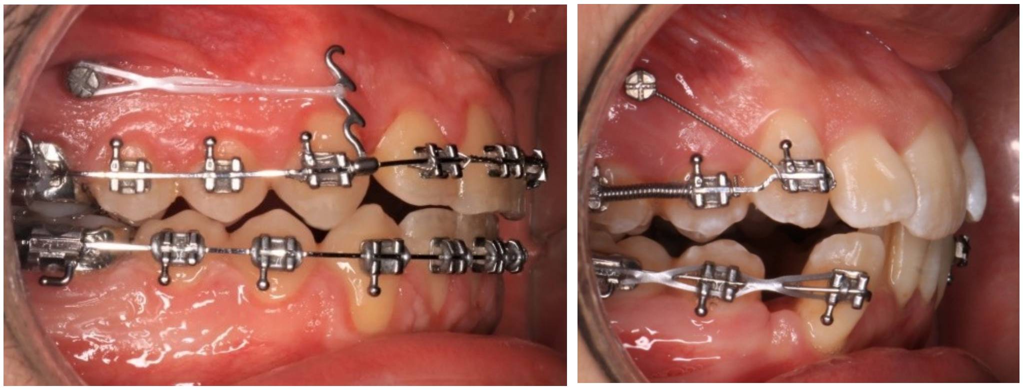
Most appliances correct the Class II by a combination of dentoalveolar and skeletal changes summarized by key outcomes: restriction of maxillary forward translation, retroclination of maxillary incisors along with distal movement of maxillary buccal segments, proclination of mandibular incisors along with mesial movement of mandibular buccal segments and finally clockwise rotation of the occlusal plane (Ruf & Pancherz, 1999; Heinig & Goz, 2001; Franchi, 2011). Other investigators have shown unfavorable clockwise rotation of the mandible after treatment with headgear (Baumrind et al, 1983).

Individual differences exist in the amount of skeletal and dentoalveolar response to treatment inherent to each jaw, whereby mandibular growth is reported to be unpredictable and most of the correction related to maxillary changes (West, 1957). It has been suggested that mandibular growth can be accelerated with functional appliances but its predetermined final size cannot be increased (Ghafari et al, 1998; Tulloch, 2004).

While adult comprehensive orthodontic treatment focuses on resolving the Class II malocclusion by dentoalveolar movements, early treatment aims to redirect growth of the jaws using either headgear or functional appliances. Modalities of orthopedic treatment have been the topic of multiple randomized clinical trials (Ghafari et al, 1998; Keeling et al, 1998; O’Brien et al, 2003; Tulloch et al, 2004). All the various modalities could yield optimal overjet and overbite; however, not all corrections were related to favorable differential growth (Ghafari et al, 1998). Comparisons between the headgear and function regulator showed similar results of enhancing differential growth. The headgear targets mainly the maxilla by restraining its forward growth and functional appliances target the mandible by repositioning it in a forward direction; however, each appliance has an indirect effect on the other jaw (Ghafari et al, 1998). Moreover, no significant differences were shown in the treatment outcome of Class II, division 1, whether treated with fixed or removable functional appliances followed by a second phase of fixed appliances (Lima, 2013).

2.6.2. Orthodontic treatment

In class II malocclusion, the orthodontic treatment consists of camouflaging the skeletal discrepancy by proclining the mandibular incisors and distalizing the maxillary teeth to reach a class I malocclusion. The goal is to make teeth fit even in the absence of jaws alignment. The use of distalizing appliances, mini-implants, class II elastics and extracting teeth are beneficiary in this case.



A B

Fig 2.10:A.Direct anchorage modality for distalization of maxillary dentition with the use of power-arm for bodily movement. **B**. Indirect anchorage modality applied for the distalization of the posterior segment Note the compressed Niti open coil between first second premolar while the canine is ligated to the miniscrew

2.6.3. Orthodontic-surgical treatment

In severe skeletal discrepancy, where orthopedic treatment is no longer successful and where camouflage orthodontic treatment is not a valid option: orthognathic surgery is the optimal treatment option. It is a combination of orthodontics normalization of the teeth into the bone structures and a displacement of the jaws into the correct position in the three dimensions space.

Fig. 2.11: Pre and postsurgical photographs of a patient with severe Class II division 1 malocclusion

2.7. Optimal timing for treatment of Class II, division 1 malocclusion

In order to achieve optimal results of treatment of Class II division 1 malocclusion, an orthodontist should know when to target the malocclusion. Thus emerges the concept and practice of early treatment in the primary but mostly mixed dentition to normalize the natural forces and if possible rectify alterations with muscle equilibrium (Ghafari, 1997). Delaying treatment until the permanent dentition may shorten active treatment duration but earlier intervention may help avoid the extraction of permanent teeth and better benefit from growth, particularly in girls whose growth spurt coincides with the late mixed dentition (about age 11.5 years) (Ghafari & Macari, 2014).

Several randomized clinical trials have shown that early treatment followed by a second phase has no advantages over a 1 phase of orthodontic treatment (Tulloch, 2004; O'Brien, 2009). On the contrary, treatment duration is lengthened and the burden of treatment weighs more on the patient. In addition, comparison of Class II treatment outcomes between pre- and post-pubertal interventions showed no difference in the overall dentoskeletal components at the completion of growth (Chhibber et al, 2013). From the various prospective and retrospective studies in the past 20 years, an evidence-supported consensus emerged regarding the optimal timing of early or phase 1 treatment: during the late childhood or late mixed dentition phase (Gianelly, 1994), running into phase 2 without a retention period. This working hypothesis would cover nearly 60% of malocclusions (Ghafari et al, 1995). However, in some specific conditions, the Class II division 1 malocclusion would need intervention in the early or mid- mixed dentition when one of the following conditions is present: severe overjet that would also expose the maxillary incisors to serious risks of trauma, psychological problems (also related to increased overjet), functional posterior crossbite, risk of developing a skeletal deviation, other developmental conditions such as early dental development relative to normal skeletal development. When an earlier intervention is needed the two phases of treatment are necessarily distant, and retention of phase 1 results may be needed (Ghafari, 1998).

2.8. Facial esthetics in Class II, division 1 malocclusion

The major chief complaints of patients seeking an orthodontic treatment are facial disharmony and altered function. Orthodontists are capable of changing moderately some of lower face third components, whereas the middle and upper thirds are mainly affected by maxillofacial and plastic surgery (Herzberg, 1952). An attractive and balanced face has been related to an average chin size that is neither too strong nor too retruded, both lips with average thickness and not protruded, nor a mental sulcus that is not deep nor absent, unaffected by a strain of the mentalis muscles (Herzberg, 1952).

Perception of facial beauty is indirectly affected by the morphology of the teeth and their underlying skeletal tissues (Kerns et al, 1997).In adult treatment, correcting a severe dentoskeletal deviation by orthodontic compensation might worsen facial esthetics; therefore, adjunctive orthognathic surgery is the ideal treatment option if facial esthetics needs improvement (Proffit et al, 2014). Otherwise, if camouflage treatment is implemented, dental compensation should be limited, maintaining a residual overjet but an acceptable facial appearance (Ghafari & Macari, 2014). In addition, differential thickness between the lips may represent a constitutional limitation that might dictate compromised treatment outcome, where leaving slight proclination of maxillary incisors will be the ideal treatment option not to create a step between both upper and lower lips, impairing facial harmony (Ghafari & Macari, 2014).

2.9. Development of the chin

In 1975, Blumenbach identified the chin as being the most fundamental features in the craniofacial complex that he considered uniquely "human" (Fig.2.12).

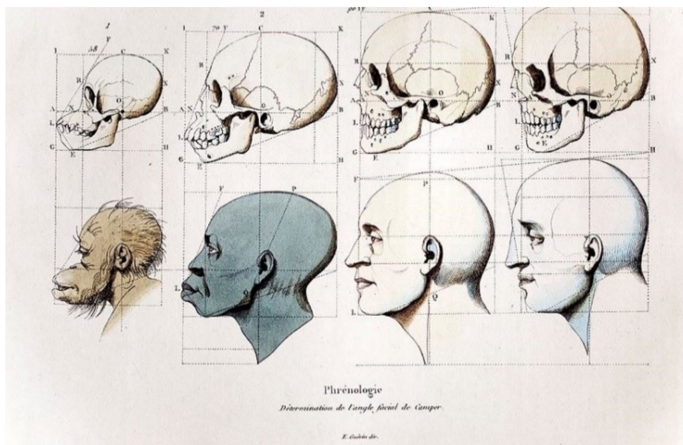


Fig. 2.12: Evolution of the chin throughout the human lineage from homo habilis to homo sapien sapien (Blumenbach 1975)

There is a wide range of chin morphology seen throughout the world. There is a link between facial profile and attractiveness. This profile can be greatly affected by chin prominence. The chin can be altered slightly by orthodontics alone, but greatly in combination with surgery. The shape of chin can have a significant effect on the patient's facial appearance and profile, with the height, projection of its basal symphysis and the lower face height ultimately influencing the position of the adjacent soft tissues and lower third of the facial skeleton (Park et al.,1989) .While thinking of a treatment plan, the orthodontist should consider both the hard and soft tissues in terms of stable results and esthetic benefits of the patient. The chin being a critical zone in determining the esthetics of the lower face the same depends primarily on the chin height, particularly in the zones of the lower and total anterior face height (Marshall S. et al.,2011). Even though the lower facial height can be altered during the orthodontic therapy, the main reason for seeking and receiving orthodontic surgical treatment has been the vertical discrepancy. When dealing with such cases with a vertical discrepancy, the main areas of interest have been the relationship between the sagittal, vertical and transverse changes with their concomitant effect on facial attractiveness (Varlık S et al.,2010).

Executing an ideal treatment plan becomes difficult when both hard and soft tissues are taken under consideration among different divergent patterns and chin morphologies. Mandibular symphysis morphology has an impact on diagnosing and treatment planning in orthodontic patients. It serves as a reference anatomical guide for aesthetics and beauty of the face in general and in particular to the lower third of the face (Nanda R.S., 2000).The development of the chin in modern humans has largely been viewed in the literature as an evolutionary change in mandibular architecture brought about by altered function and biomechanical forces as the mandible diminished in size (DuBrul E. et al.,1954). Recent studies, however, have documented that the formation of the human chin can not be explained entirely as a function of biomechanics (Ichim I. et al.,2006). In contrast to a purely biomechanical explanation, other studies have suggested that modern human chin morphology is the result of a posterior displacement of the mandibular dentition relative to the basal region of the mandible, and the evolution of the human chin is the result of a relative independence of the alveolar and basilar regions of the mandible as shown in the studies of Waterman in 1911 and Robinson in 1913. This would suggest that the degree of development of the chin is largely a function of the alveolar region of the mandible "drifting back" along the basal region of the mandibular corpus.

It is well established that during facial growth the anterior aspect of the mandibular alveolus at the symphysis is resorptive (Enlow,1964) while the lower symphyseal border near Pogonion, is developmentally stable and exhibits little to no remodeling (Bjork 1954). As such, formation of the human chin is not the result of bony deposition along its anterior surface (Fig.2.13). Among the Bjork's five criteria for establishing the mandibular rotation pattern, the relationship between the height and width of the mandibular symphysis remains critical with an emphasis on the symphysis with its long axis and greater lingual inclination (Bjork,1969).

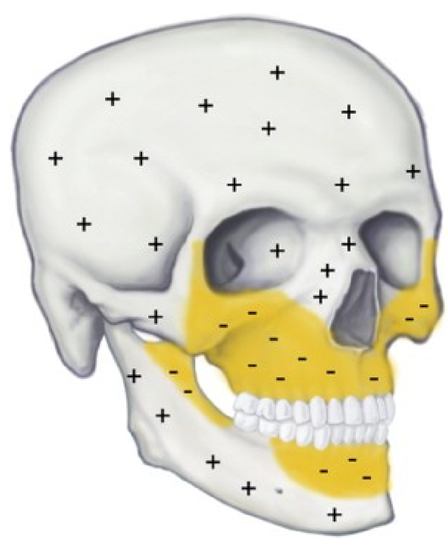


Fig. 2.13: Resorption at the anterior border of the symphysis thus the creation of the bony chin (Bjork 1954)

In contrast, the sagittal growth also plays an important role in influencing the morphology of the mandibular symphysis. The height and projection of basal symphysis has an important role in influencing the position of the adjacent soft tissue, thereby determining the esthetic and facial harmony (Arat Z.M. at al.,2005). The mandibular symphysis is divided into two regions, the dento-alveolar and basal symphysis (Arruda et al.,2014). The dento-alveolar symphysis includes the alveolar process and lower incisors. The long axis of the lower incisors cephalometrically matches the long axis of the alveolar process and its inclination is influenced by facial type. Cephalometrically, the long axis of the basal symphysis is different from that of the alveolar symphysis with the shape and position being independent of the tooth movement of the lower incisors. the prominence of the chin results from the posterior placement of the mandibular incisors relative to the chin rather than from an increase in the relative size of the chin at Pogonion (Chen et al.,2000). Relationship between mandibular incisors and anterior chin projection has been the subject studied in the literature for several years, little are the studies that focused on the relationship between posterior dentoalveolar heights and the bony chin projection. In our study, we will be evaluating the existence of this relationship and its effect in treatment of Class II division 1 malocclusion.

2.10. Research significance

A retruded chin constitutes a major chief complaint in Class II division 1 malocclusion. Anterior chin projection particularly during growth might be affected by the height of the posterior teeth. The significance of this research project is in studying this association in pre-pubertal, post-pubertal and adult individuals to reach meaningful conclusions, in providing personalized treatment, and exploring predictors for a favorable improvement of the chin projection post-treatment. The relevant components should help in improving diagnosis and projecting more reasonable treatment plans.

2.11. Hypotheses

1. The horizontal projection of the chin is a function of the variation of posterior dentoalveolar heights during the treatment of Class II malocclusion.

2. The change of the rotation of the functional occlusal plane is directly associated with the anterior chin projection

2.12. Specific aims

1. To assess the development of the chin as a function of the vertical level of posterior teeth throughout the treatment.
2. To evaluate the impact of the functional occlusal plane on the anterior chin projection and this association between growing and adult patients with Class II division 1 malocclusion.
3. Determine the facial components that contribute to favorable or unfavorable treatment outcome with respect to enhancement of anterior chin projection in Class II treatment.
   2. Develop predictive models of treatment outcome (favorable vs unfavorable) based on objective cephalometric classification

CHAPTER 3

MATERIALS AND METHODS

3.1. Materials

3.1.1. General characteristics

The sample consisted of pre- and post-treatment lateral cephalometric radiographs of patients screened and treated at the division of Orthodontics and Dentofacial Orthopedics of the American University of Beirut Medical Center (AUBMC), as well as patients from a a study of early treatment of Class II division 1 malocclusion in which treatment timing and treatment with either a headgear or a function regulator were explored (Ghafari et al, 1998; Efstratiadis et al 2005). constituted ≈10% of the total sample recruited in our study. The patients from this sample (nearly ---% of the growing sample) had been randomly assigned to the treatment modality and were subdivided in low and high severity groups based on the ANB angle. They were treated for 2 years and many of them received a later phase of comprehensive orthodontic treatment.

The radiographic images were part of the diagnostic records collected for orthodontic treatment. All patients were diagnosed with Class II, division 1 malocclusion and treated to a Class I occlusion with a non-surgical approach that consisted of either an orthodontic treatment with fixed appliances alone or a combined orthopedic-orthodontic treatment for the growing patients. None of the patients were contacted nor were photos or radiographs taken for the objective of the present research. The institutional review board

(IRB) approval was granted before initiation of the study to evaluate the existing radiographs under specified conditions.

A total of 285 subjects were recruited and divided into two age groups (Growing/Adults) based on growth potential evaluated through superimposition of pre- and post-treatment lateral cephalograms. More specifically, when an increase of more than 1 mm in anterior cranial base length (SN), maxillary length (ANS-PNS) and mandibular length (Co-Gn) was present between pre- and post-treatment lateral cephalograms, the patient was considered as growing.

The growing group consisted of a total of 195 subjects as per the distribution adopted by Pancherz and Hägg's (1988), the growing sample was further divided into two age groups; pre-pubertal (n=96) and post-pubertal (n=99) whereby the cutoff age for female patients was 12 years and for male patients 14 years. The skeletal age was evaluated on handwrist radiographs; the deviation from this classification was minimal therefore the Pancherz and Hagg's classification on chronologic age was applied. The distribution of the patients between pre-pubertal and post-pubertal is summarized in Table 3.2. The adult group consisted of 90 subjects (Table 3.1).

Table 3.1: Distribution of subjects (N) in growing and adult groups and subgroups

	Growing		**Adult**
Total Sample	Pre-pubertal	Post-pubertal	
	96	99	90
Low Severity	147		55
High Severity	48		35

Table 3.2: Distribution of growing patients between pre-pubertal and post-pubertal

	Started before or during growth spurt(pre-pubertal)					Started after growth spurt (post-pubertal)			
	-4yrs	-3yrs	-2yrs	-1yr	Cut off age	+1r	+2yrs	+3yrs	+4yrs
Girls	7.9	8.9	9.9	10.9	12	12.9	13.9	14.9	15.9
Boys	9.9	10.9	11.9	12.9	14	14.9	15.9	16.9	17.9

To study the effect of malocclusion severity on treatment outcomes, the growing and adult groups were stratified into low severity and high severity subgroups based on the pre-treatment (T1) ANB angle being 4.5<ANB≤6.5 and ANB≥6.5, respectively. The growing (195 subjects) and adult (90 subjects) groups consisted of 147 and 55 subjects in the low severity subgroup, and 48 and 35 subjects in the high severity subgroups (Table 3.1)

3.1.2. Inclusion criteria

The requirements for inclusion in this study were:

-ANB angle equal to or greater than 4.5 degrees (over one standard deviation from the normal ANB = $2^o + 1.5^o$), reflecting definite maxillo-mandibular discrepancy.

- Overjet (OJ) greater than 3 mm. Although this minimal value is close to normal, it accounts for malocclusions with severe dentoalveolar compensation (particularly proclination of mandibular incisors) camouflaging a severe Class II, division 1 malocclusion.

- Non surgical treatment of Class II division 1 malocclusion

3.1.3. Exclusion criteria

Excluded from the study were subjects:

- who underwent orthognathic surgery to correct the Class II/1 malocclusion

-who had previous orthodontic treatment

-with craniofacial anomalies (e.g. Pierre Robin syndrome, hemifacial microsomia,)

-whose cephalograms were not available at T2 or were of non-diagnostic quality.

3.2. Methods

Pre and post-treatment lateral cephalograms were taken at the AUBMC Division of Orthodontics and Dentofacial Orthopedics using the same digital machine (GE, Instrumentarium, Tuusula, Finland).

All lateral cephalometric radiographs were taken in natural head position (Moorrees and Kean, 1958) with posterior teeth in maximum intercuspation. The patient's body was covered with lead apron. The 2D digital radiographs were automatically saved and stored in a dedicated computer within the available software (Cliniview 9.3). Regarding the NIH study sample, T1 and T4 lateral cephalograms were scanned and imported into the same software. In this software, the identity of the patient is not a visible part of the image. Accordingly, the radiographs were located and exported from the software to a digital folder. The radiographs were assigned a serial number by the administrator (Dr. Elie Haddad) starting from Patient 1, Patient 2, Patient 3, etc. The exported image could not be linked back to the subject. Accordingly, the "coding" of all radiographs was assured.

Upon this process, the administrator provided the investigator (SJK) with the following coded records for data collection:

- The digital folders containing the radiographs.

- A list that contains the serial number, gender, and chronological age of the subjects when the records were taken. This list did not contain the patients' names.

The radiographs were digitized by one investigator (SJK) using the imaging program (Dolphin Imaging and Management Solutions, version 11.5, La Jolla, California). The screen view during digitization in the Dolphin Imaging software is illustrated in Fig.3.1.

3.2.1. Cephalometric landmarks

The definition of soft and hard tissue landmarks was adopted from the glossary of the American Association of Orthodontists (Table 3.3 and 3.4) and their corresponding locations are identified in Fig. 3.2.

3.2.2. Cephalometric measurements

Linear and angular measurements were performed to gauge the characteristics of the cranial base and each jaw, as well as the relationships of the jaws to the cranial base and to each other. Each component that would potentially contribute to treatment outcome was quantified by its corresponding cephalometric measurement. All landmarks and angles used to describe the relationship among cranial base, jaws, and teeth are presented in Figures 3.2 and 3.3. The definitions of cephalometric measurements are listed in Table 3.5.

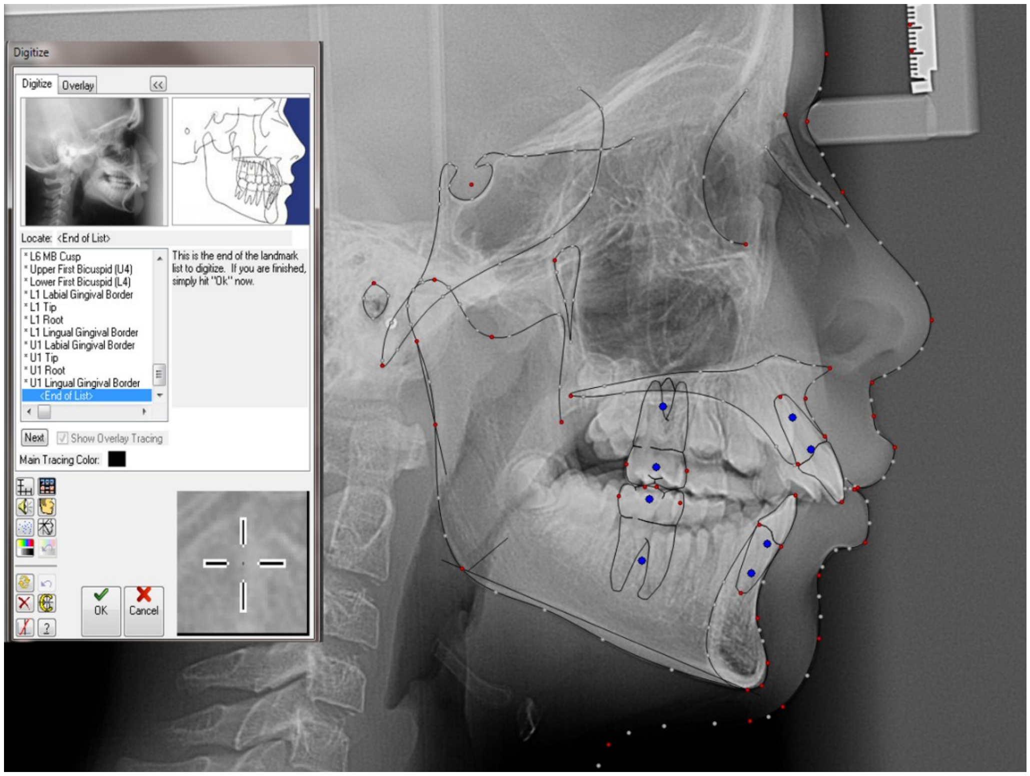


Fig. 3.1: Illustration of the computer view while digitizing a lateral cephalometric radiograph using Dolphin Imaging software.

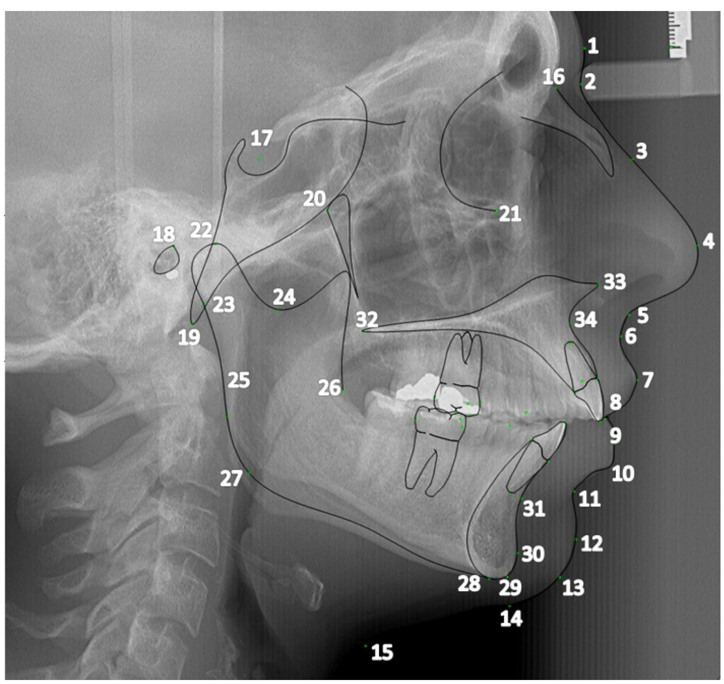


Fig. 3.2: Soft and hard tissue landmarks digitized on a lateral cephalometric radiograph.

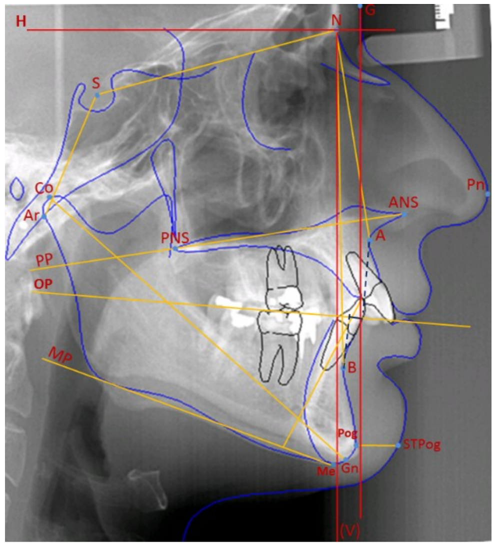


Fig. 3.3: A lateral cephalometric tracing showing some landmarks and measurements used to describe the relationship between jaws, cranial base, and horizontal

Table 3.3: Soft tissue landmarks definition

#	Landmark	Definition
1	Glabella (G)	Most prominent or anterior point in the mid-sagittal plane of the forehead at the level of the superior orbital ridges
2	Soft tissue Nasion	Point of intersection of the soft-tissue profile with a line drawn from the center of Sella turcica through Nasion
3	Bridge of nose	Mid-way between the soft tissue N and tip of nose
4	Tip of nose/Pronasale Pn	Most prominent or anterior point of the nose
5	Subnasale (Sn)	Midpoint of the columella base at the apex of the angle where the lower border of the nasal septum and the surface of the upper lip meet
6	Soft tissue A point	Deepest point on the upper lip determined by an imaginary line joining subnasale with laberale superius
7	Superior lip	Midpoint of the upper vermilion line
8	Stomion superior	Most inferior point located on the upper lip
9	Stomion inferior	Most superior point located on the lower lip
10	Lower lip	Midpoint of the lower vermilion line
11	Soft tissue B point	Point at the deepest concavity between laberale inferius and soft-tissue pogonion
12	Soft tissue pogonion	Most prominent or anterior point on the soft-tissue chin in the mid-sagittal plane
13	Soft tissue gnathion	Midpoint between soft-tissue pogonion and soft-tissue menton
14	Soft tissue menton	Most inferior point on the soft-tissue chin
15	Throat point	Intersection of lines tangent to the neck and throat

Table 3.4: Hard tissue landmarks definition

#	Landmark	Definition
16	Nasion (N)	The junction of the frontal and nasal bones
17	Sella (S)	The pituitary fossa. The center is used as a cephalometric landmark
18	Porion (Po)	Highest point on the roof of the external auditory meatus
19	Basion (Ba)	Most inferior point of the anterior margin of the foramen magnum in the midsagittal plane
20	Pterygoid point	Most posterior point on the outline of the pterygopalatine fossa
21	Orbitale (Or)	Lowest point on the lower margin of the orbit
22	Condylion (Co)	The highest point on the superior outline of the mandibular condyle
23	Articulare (Ar)	A constructed point representing the intersection of three radiographic images: the inferior surface of the cranial base and the posterior outlines of the ascending rami or dorsal contour of the mandibular condyles bilaterally
24	Sigmoid notch	Deepest point on the sigmoid notch of the mandible
25	Ramus point	Most posterior point up the border of the ramus
26	Mid ramus	Most concave point of the inferior of the ramus
27	Gonion	The most posterior inferior point on the outline of the angle of the mandible. It is identified by bisecting the angle formed by the tangents to the mandibular corpus (mandibular plane) and posterior border of the mandible (dorsal ramal plane)
28	Menton (Me)	The most inferior point on the chin in the lateral view
29	Gnathion	The lowest point of the mandibular symphysis
30	Pogonion (Pog)	The most anterior point on the contour of the bony chin in the midsagittal plane
31	B point	The deepest (most posterior) midline point on the bony curvature of the anterior mandible, between infradentale and pogonion. Also called supramentale. (Downs)
32	Posterior nasal spine (PNS)	The most posterior point on the bony hard palate in the midsagittal plane; the meeting point between the inferior and the superior surfaces of the bony hard palate (nasal floor) at its posterior aspect
33	Anterior nasal spine (ANS)	The tip of the bony anterior nasal spine at the inferior margin of the piriform aperture, in the midsagittal plane
34	A point	Subspinale, the deepest (most posterior) midline point on the curvature between the ANS and prosthion (dental alveolus) (Downs)

Table 3.5: Definition of cephalometric measurements

Cranial base measurements	
SN	Anterior cranial base length: reference line connecting the center of sella turcica with nasion
SN/H	Inclination of anterior cranial base in reference to the NHP
S-Ar	Posterior cranial base length
SN/Ar	Saddle angle: Evaluates cant of the anterior cranial base
Relationship between jaws, cranial base and horizontal	
SNA (maxilla)	Angle between anterior cranial base cant (SN) and point A (most posterior point on anterior contour of the maxilla)
SNB (mandible)	Angle between anterior cranial base cant (SN) and point B (most posterior point on anterior contour of the mandible)
ANB	Sagittal skeletal relationship: Angle between points A and B
Witts (Ao-Bo)	Sagittal skeletal relationship: Distance between the projections from points A and B to the occlusal plane.
NA/Apog	Angle of convexity: Formed by the intersection of lines NA and Apog
N-ANS	Upper facial height
ANS-Me (AFH)	Anterior facial height
Ar-Go (PFH)	Posterior facial height
LFH/TFH (%)	Lower to total facial height: depicts the relationship between anterior facial height (ANS-Me) and total facial height (N-Me)
PP/MP	Palatal plane to mandibular plane: represents the vertical divergence
MP/SN	Represents vertical inclination of the mandible relative to SN
PP/H	Represents vertical inclination of PP to the true Horizontal in (NHP)
Y axis (S-Gn /FH)	Represents growth axis angle
MP/H	Vertical inclination of the mandible relative to the true Horizontal
Pog-N	Pogonion projection to the perpendicular passing through Nasion
Jaw specific measurements	
Co-Gn	Length of the mandible
Co-Go, Go-Gn	Length of mandibular components (ramus and body)
Co/Go/Me	Mandibular angle between ramus and body
ANS-PNS	Length of the maxilla
Relationship between teeth and jaws	
U1-NA, U1/NA	Distance and inclination of maxillary incisors to NA
U1/SN	Inclination of maxillary incisors to anterior cranial base SN
U1/PP	Inclination of maxillary incisors to PP
L1-NB, L1/NB	Distance and inclination of mandibular incisors to NB
L1/MP	Inclination of mandibular incisors to MP
OP/PP	Angle formed between functional occlusal plane and palatal plane
U6-PP	Dentoalveolar height between maxillary first permanent molar and palatal plane
L6-MP	Dentoalveolar height between mandibular first permanent molar and mandibular plane
Relationship between teeth	
U1/L1	Inter-incisal angle
Overbite (OB)	Percentage of overlap of mandibular incisors by maxillary incisors
Overjet (OJ)	Horizontal projection of maxillary incisors tip to mandibular incisors
Soft tissue measurements	
UL- E line	Distance between point superior lip and Esthetic line (Nose tip - Me)
LL- E line	Distance between point lower lip and Esthetic line (Nose tip - Me)
Naso labial angle	Angle formed by the points upper lip, subnasale and columella (c’)
Mento labial angle	Angle formed by the points Lower lip, St B-point and St Pogonion
U lip length	Distance between subnasale and stomion superius
U lip thickness @ A	Distance between St A-point and A point

U lip inclination	Angle formed by the intersection of subnasale-Upper lip/ N perp(FH)
L lip length	Distance between ST B-point and stomion inferius
L lip thickness @ B	Distance between ST B-point and B point
St Chin thickness	Distance between ST Pogonion and Pogonion
Pn-D	Pronasale distance to vertical through glabella G

3.2.3. Symphyseal components

These components consisted of measurements within the symphysis (height, depth and slope inclinations), involving the use of point D (symphyseal center) as a reference point (Steiner, 1959) (Fig. 3.4, Table 3.4). Chin anatomy was further delineated through the methods adapted from Ghafari and Macari (2014) (Fig. 3.5) along with cephalometric measurements in Table 3.5. The anterior and posterior slopes of the symphysis helped determine the inclination of the symphysis.

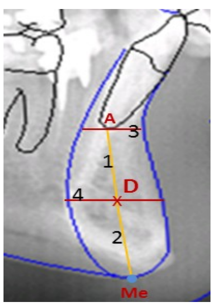


Fig. 3.4: Cephalometric tracing indicating the measurements used to evaluate some components of the symphysis (centered at point D).

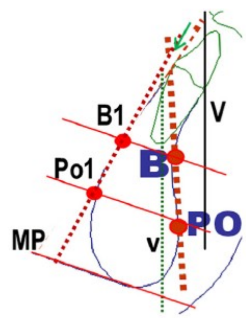


Fig. 3.5: Chin drawing from cephalometric radiograph indicating the component analysis of the symphysis (Table 3.6) (Adapted from Ghafari and Macari, 2014).

Table 3.6: Definition of symphyseal cephalometric measurements

	Measurement	Landmarks
1	Distance between point D and incisor apex **(D-Apex)**	Point D to Apex
2	Distance between point D and menton **(D-Me)**	Point D to Menton
3	Chin width at the level of the incisor apex **(CW-Apex)**	Line through A parallel to the horizontal, intersecting anterior and posterior contours of symphysis
4	Chin width at the level of point D **(CW-D)**	Line through D parallel to the horizontal, intersecting anterior and posterior contours of symphysis
5	Anterior Symphyseal Angle **(ASA)**	Angle between Pog-B line and the vertical
6	Posterior Symphyseal angle **(PSA)**	Angle between Po1-B1 and the vertical.

3.2.4. Definition of favorable and unfavorable treatment response

The responses to treatment measured between pre (T1) and post (T2) treatment cephalograms were defined as “favorable” (FR) and “unfavorable” (UFR) based on objective criteria determined by treatment changes in specific cephalometric measurement in the growing and adult groups. Individual responsiveness to Class II treatment was defined on the basis of the chin anterior projection gauged at the level of Pogonion, the most anterior point on the mandible. Specifically, the measurement was projection of Pogonion to the perpendicular passing through Nasion (N) between T1 and T2. A “favorable response” (FR) corresponded to a (T2-T1) Pog-N that was equal or higher than the mean Pog-N change in the corresponding group; an “unfavorable response” (UFR) was assigned when (T2-T1) Pog-N was less than the mean Pog-N change of the corresponding group.

Treatment outcome was evaluated relative to eight cephalometric measurements that reflected significant assessments of jaw size and vertical pattern: anterior facial height (ANS-Me), posterior facial height (Ar-Go), posterior ramal height (Co-Go), SNB angle, growth axis or Y axis for the growing group (SN,Gn/FH),MP/SN for the adult group, OP/PP angle ,and posterior dentoalveolar heights represented by the distances U6-PP and L6-MP.

3.2.5. Repeated measurements

To determine intra-examiner reliability, 60 lateral cephalometric radiographs (30 pre- and 30 post-treatment lateral cephalograms) of 30 randomly selected patients (≈10% of the sample) were re-digitized by the same investigator (SJK) 4 months after initial digitization. The two-way mixed effects intra-class Correlation Coefficient (ICC) was computed to test intra-examiner reliability of cephalometric measurements for absolute agreement on single measures.

3.2.6. Statistical Analyses

Descriptive statistics were computed for all the variables for each of the three age groups (pre-pubertal, post-pubertal and adults) at both T1 and T2 time points for both genders. Frequency distribution was performed for the categorical variables (age groups and gender). The quantitative variables, means, standard deviations, minimums and maximums are presented in appendices 2, 3, and 4.

The Kolmogorov-Smirnov test was applied to test if the data is normally distributed.

To compare the variables between T1 and T2 taking into consideration the gender, a two-way mixed ANOVA was applied with gender as a "between-group" factor, and time as "within-group" factor in each age group.

For comparisons between the three age groups, a two-way ANOVA was applied with age group and gender as "between-group" factors and the change in the variables (T2-T1) as the dependent variables.

Independent t test was applied to compare the change in Pog-N between the severity subgroups of the growing and adult samples.

After having established a statistically significant interaction existed between time and gender for each age group, the Pearson product-moment correlation coefficient was applied to determine the associations among the change of the 8 cephalometric measurements previously mentioned.

Logistic regressions were applied using clinically significant variables at T2-T1 as the independent variable and treatment outcome (favorable or unfavorable change in Pog-N measurement) as the dependent variable to predict the improvement of the anterior chin projection in Class II division 1 malocclusion after treatment.

A Multivariate discriminant analysis was applied on the treatment outcome which was related to the change in the Pogonion projection represented by Pog-N to extract predictors that might affect favorably the treatment result.

SPSS *27.0* and STATA statistical packages were used to perform all tests at a level of significance of 0.05.

CHAPTER 4

RESULTS

4.1. Intra-examiner reliability

The intra-class correlation coefficients (ICC) gauging intra-examiner reliability of repeated measurement ranged from 0.90 to 0.99 for the various cephalometric measurements.

4.2. Sample characteristics

The recruited 285 subjects were stratified nearly equally into pre-pubertal (n=96), post-pubertal (n=99) and adult (n= 90) age groups (Table 4.1).

Table 4.1: Age distribution among the 3 age groups

	Pre-pubertal (1)		**Post-pubertal (2)**		**Adults (3)**	
N (%)	96 (33.68)		99 (34.73)		90 (31.57)	
Age	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range
	10.8 (1.26)	7.91-13.5	13.3 (1.07)	11.75-16.83	24.53 (7.65)	15-52.33
Tx duration	4.38(1.44)	1.75-8.1	3.27(1.15)	1.25-7.42	3.39(1.14)	1.1-6.75

The sample consisted of almost 58.94% females and 41.06% males. The number of female participants was greater in the post-pubertal (n=69) than the adult (n=55) and pre-pubertal (n=44) groups. The male participants were better represented in the pre-pubertal group (n=52), than the post-pubertal (n=30) and the adult (n=35) periods (Table 4.2).

Table 4.2: Total sample and gender characteristics

	Pre-pubertal (1)				Post-pubertal (2)				Adults (3)			
Gender	Female		Male		Female		Male		Female		Male	
N (%)	44(45.83)		52(54.16)		69(69.7)		30(30.3)		55(61.1)		35(38.9)	
Age	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range
	9.74(0.89)	7.91-11.79	11.44(1.26)	9-13.83	12.89(0.73)	12-15	14.66(0.68)	14-16.83	25.70(8.73)	15.95-52.33	23.68(5.32)	17..93-38
Tx duration	4.38(1.44)	2.1-8.1	4.17(1.46)	1.75-7.83	3.46(1.15)	1.25-7.42	2.84(1.01)	1.25-4.91	3.39(1.14)	1.1-6.75	2.90(0.94)	1.42-5

4.3. Differences among age groups, genders and time points

4.3.1. Comparison of variables between T1 and T2 in each age group

4.3.1.1. Cranial base measurements

-Statistically significant differences in SN, SN/H, and S-Ar between T1 and T2 within each age group (Tables 4.3, 4,4 ,4.5)

-Results of two-way ANOVA indicated statistically significant group x time interactions were observed in the change of the variables SN and S-Ar between the three age groups while the change in the angle SN/H was not statistically significant between age groups (Table 4.6)

4.3.1.2. Relationship between jaws, cranial base and horizontal

4.3.1.2.1 Antero-posterior jaw relationship

-Statistically significant differences, among the variables reflecting the antero-posterior jaw relationship, more specifically the SNA angle and the anterior chin projection Pog-N between T1 and T2 in the pre-pubertal group, whereas the SNB angle and angle of convexity NA/APog were not statistically significant differences with p=0.255 and 0.437 respectively (Table 4.3).

*Regarding the ANB angle which showed an interaction between gender and time, it showed statistically significant differences between T1 and T2 within the male patients and female patients (Table 4.3).

-Statistically significant differences in the angles SNA, ANB and the anterior chin projection Pog-N between T1 and T2 in the post-pubertal group, while the angle SNB and NA/APog were not statistically significant (Table 4.4).

-In the adult group, all the variables reflecting the antero-posterior relationship between the jaws showed statistically significant differences between T1 and T2) (Table 4.5)

-Comparisons between the change of the variables between the three age groups, indicated statistically significant differences for SNA and Pog-N.

More specifically, the change of these variables was statistically significant between groups 1 and 3 and groups 2 and 3, but not significant between groups 1 and 2 (Table 4.6).

*SNB showed an interaction between time and gender in the two-way mixed ANOVA test, when divided into two sub measurements, male patients showed a statistically significant difference between all age groups, moreover results of multiple comparisons showed significant difference between the pre and post-pubertal groups, while comparisons between the pre-pubertal and adult groups, and between the post-pubertal and adult groups did not. On the opposite hand, female patients did not show any statistically significant difference between the three age groups (Table 4.6)

*Similarly, ANB showed an interaction between time and gender, comparison of the change in this angle between male patients of all age groups was not statistically significant ,whereas comparison between female patients was statistically significant, more specifically significant difference was seen between the pre-pubertal and adult groups and between post-pubertal and adult groups (Table 4.6)

<u>4.3.1.2.2. Facial heights</u>

-Statistically significant differences in the variables reflecting facial heights such as the upper (N-ANS), anterior lower (ANS-Me). and posterior facial (Ar-Go) heights, as well as the ratio between lower and total facial heights (LFH/TFH) in the pre-pubertal group (Table 4.3)

-In the post-pubertal group, N-ANS and the ratio LFH/TFH only showed statistically significant differences between T1and T2 while the remaining variables did not (Table 4.4)

*PFH within the post-pubertal group showed an interaction between time and gender, when subdivided this variable showed statistically significant difference between T1 and T2 in both male and female patients (Table 4.4)

-Statistically significant differences in N-ANS, PFH and LFH/TFH between T1 and T2 in the adult group (Table 4.5)

-Comparisons between the three age groups revealed statistically significant differences for the change in N-ANS and AFH more specifically results of the multiple comparisons were also significant for all age groups combinations, i.e between groups 1 and 2, groups 2 and 3, and finally groups 1 and 3 (Table 4.6)

*PFH showed an interaction between time and gender when comparing between all age groups, both male and female patients showed statistically significant differences of the change in this variable between all age groups. As well as that, between the pre and post-pubertal groups and between the pre and adult groups in both genders (Table 4.6)

4.3.1.2.3. Vertical relationship between the jaws

-Variables reflecting the vertical dimensions between jaws Y axis, and the angles MP/SN and PP/MP, all showed statistically significant differences in the pre-pubertal group between T1 and T2 (Table 4.3)

- MP/SN and PP/MP revealed statistically significant differences between T1 and T2 in the post-pubertal group while Y axis did not (Table 4.4)

-In the adult group, where only the angles MP/SN and PP/MP were measured , MP/SN revealed statistically significant difference between T1 and T2 while PP/MP did not (Table 4.5)

-Comparisons between all age groups were only applied for the change of MP/SN and PP/MP (Y axis not measured in adult sample as previously mentioned). Results of the two-way ANOVA showed statistically significant results for PP/MP as well as the results of the multiple comparisons between the three age groups which also showed statistically significant results.On the other hand, the change of MP/SN was not statistically significant (Table 4.6)

4.3.1.3. Jaw specific measurements

- Statistically significant differences in the mandibular length Co-Gn, the posterior ramal height Co-Go and the gonial angle Co/Go/Me between T1 and T2 (Table 4.3)

-The angle Co/Go/Me only showed statistically significant difference between T1 and T2 in the post-pubertal group (Table 4.4)

*Co-Gn showed interaction between time and gender, showed statistically significant difference between T1 and T2 within the male and female patients of this age group ($p<0.001$) (Table 4.4)

-The mandibular length (Co-Gn) was statistically significant between T1 and T2 in the adult group (Table 4.5)

*Co/Go/Me showed interaction between time and gender, showed statistically significant difference between T1 and T2 among the male patients while female patients did not (Table 4.5)

-Comparisons between the three age groups showed statistically significant differences for Co-Gn and Co-Go. Results of multiple comparisons for the change of these previously mentioned variables showed statistically significant differences between all age groups, except for the change of Co-Go between groups 1 and 3 (Table 4.6)

*When comparing the change of Co/Go/Me between all age groups, an interaction between time and gender was found. Moreover, comparison in male patients between all age groups did not reveal any statistically significant difference, while comparisons in female patients were significant. In addition, statistically significant differences were seen between the post-pubertal and adult groups (p=0.01) and between the pre-pubertal and adult groups (p=0.001) (Table 4.6)

4.3.1.4. Relationships between teeth and jaws

4.3.1.4.1. Inclination and position of maxillary incisors

-Variables reflecting the inclination and position of the maxillary incisors U1/NA, U1-NA, U1/PP, and U1/SN did not show statistically significant differences between T1 and T2 in the pre-pubertal group (Table 4.3)

-The variables U1-NA and U1/PP only showed statistically significant differences between T1 and T2 in the post-pubertal group(Table 4.4)

-Finally, in the adult group all the previously mentioned variables showed statistically significant differences between T1 and T2 for all the variables (Table 4.5)

-Comparison between all age groups for the change of the variables showed statistically significant differences between all age groups.

Multiple comparisons showed statistically significant differences between groups 2 and 3 and between groups 1 and 3, whereas comparisons between groups 1 and 2 did not show any statistically significant difference for all the measurements (Table 4.6)

4.3.1.4.2 Inclination and position of mandibular incisors

-Variables reflecting the inclination and position of the mandibular incisors L1/NB, L1-NB and L1/MP did not show any statistically significant differences between T1 and T2 in all age groups (Tables 4.3, 4.4, 4.5)

-Similarly, two-way ANOVA comparing the change of these variables between the age groups did not show any statistically significant differences (Table 4.6)

4.3.1.4.3 Occlusal plane inclination and dentoalveolar heights

-In the pre-pubertal and post-pubertal groups, comparison of the OP/PP, U6-PP and L6-MP showed statistically significant differences between T1 (Tables 4.3, 4.4)

-In the adult group, the measurement OP/PP only showed statistically significant difference between T1 and T2, whereas U6-PP and L6-MP did not (Table 4.5)

-Results of two-way ANOVA showed statistically significant differences in the changes of OP/PP, U6-PP, and L6-MP. Results of multiple comparisons showed statistically significant differences between groups 2 and 3 and between groups 1 and 3, however comparisons between groups 1 and 2 were not significant (Table 4.6)

4.3.1.5. Relationships between teeth

-The interincisal angle U1/L1 did not show any statistically significant differences between T1 and T2 in both the pre and post-pubertal groups (Tables 4.3, 4.4)

-On the opposite side, U1/L1 showed statistically significant differences between T1 and T2 within the adult group (Table 4.5)

-Comparisons between all age groups of the change of U1/L1 did not show any statistically significant differences between the three age groups (Table 4.6)

4.3.1.6. Soft tissue measurements

-Variables reflecting soft tissue measurements UL-E-Line, LL-E-Line, upper and lower lip lengths, nasolabial and mentolabial angles all showed statistically significant differences between T1 and T2 within each age group (Tables 4.3, 4.4 ,4.5)

* The mentolabial angle showed interaction between gender and time in the post-pubertal group; when subdivided this variable showed statistically significant difference between T1 and T2 among the female patients while no significant difference was seen among the male patients (Table 4.4)

-Results of two-way ANOVA showed statistically significant differences in the change of UL-E-Line, LL-E-Line, nasolabial angle and lower lip length. Furthermore, multiple comparisons showed statistically significant differences between all groups for UL-E-Line and between groups 2 and 3 and groups 1 and 3 for nasolabial angle and lower lip length (Table 4.6)

4.3.1.7. Symphyseal components

-Statistically significant differences between T1 and T2 in all variables reflecting the symphyseal components D-Apex,D-Me,CW-Apex,CW-D,ASA, in the pre-pubertal group. (Table 4.3)

-Comparisons between T1 and T2 in the post-pubertal group revealed statistically significant differences in D-Apex,CW-Apex, and ASA .(Table 4.4)

*D-Me showed interaction between time and gender, when subdivided, it indicated statistically significant difference between T1 and T2 among male and female patients of this age group (Table 4.4)

-No statistically significant differences in the latter variables between T1 and T2 in the adult group (Table 4.5)

-Results of two-way ANOVA revealed statistically significant differences for all the measurements reflecting symphyseal components, as well as that multiple comparisons showed statistically significant differences between all age groups, except for D-Apex and CW-Apex between groups 1 and 2 respectively and PSA between groups 1 and 3 (Table 4.6)

4.3.2. Comparison of variables between genders in each age group

4.3.2.1. Cranial base measurements

-Among the variables reflecting cranial base measurements only S-Ar showed statistically significant difference between male and female in the pre-pubertal group. (Table 4.7)

- SN and SN/H showed statistically significant differences between male and female in the post-pubertal group, while S-Ar was not significant (Table 4.8)

-Similarly in the adult group, SN and SN/H were statistically significant different between male and female, whereas S-Ar was not. (Table 4.9)

-Absence of statistically significant differences between genders and the three age groups for all the variables related to the cranial base measurements (Table 4.10)

4.3.2.2. Relationship between jaws, cranial base and horizontal

4.3.2.2.1 Antero-posterior jaw relationship

-None of the variables reflecting the sagittal relationship between the jaws showed statistically significant differences between genders in the pre-pubertal group (Table 4.7)

*ANB showed an interaction between time and gender, when subdivided into two measurements, comparisons in ANB angle between male and female of the pre-pubertal group did not show statistically significant difference nor at T1 nor at T2 (Table 4.7)

-The SNA and SNB angles showed significant differences between male and female in the post-pubertal group. On the opposite hand, the angles ANB and NA/APog as well as the linear measurement Pog-N were not significantly different (Table 4.8)

-In the adult group, SNB was the only variable that showed statistically significant difference between male and female compared to the other remaining variables that did not show statistically significant differences (Table 4.9)

-Two-way ANOVA results indicated no statistically significant differences between the change of these variables and gender (Table 4.10)

*Both SNB and ANB angles showed interaction between time and gender, More specifically comparisons between all age groups of the changes in these two variables showed statistically significant difference in SNB within the post-pubertal group, and within the pre-pubertal group for ANB (Table 4.10)

4.3.2.2.2. Vertical heights

-Variables related to the vertical heights showed statistically significant differences between genders in the pre-pubertal group except for the ratio LFH/TFH (Table 4.7)

- AFH only showed statistically significant difference between male and female in the post-pubertal group while the remaining variables did not (Table 4.8)

*Interaction between time and gender was found at the level of PFH in the post-pubertal group. Comparisons at the level of PFH between male and female patients of this age group were found to be not significant at T1 and at T2 (Table 4.8)

-Amidst the variables reflecting the vertical heights only PFH showed statistically significant difference between genders in the adult group, while the remaining variables did not (Table 4.9)

-Results of the two-way ANOVA indicated no significant differences between genders of the three age groups (Table 4.10)

4.3.2.2.3. Vertical relationship between the jaws

-Variables related to the vertical relationship between the jaws did not show any statistically significant differences between gender in all age groups except for the angular measurements MP/SN within the adult group (Tables 4.7 ,4.8, 4.9)

-When comparing the change of the variables between gender, results of two-way ANOVA indicate no significant differences for MP/SN and PP/MP respectively (Table 4.10)

4.3.2.3. Jaw specific measurements

- Co-Gn and Co-Go showed statistically significant differences between male and female in the pre-pubertal group (Table 4.7)

-Co-Go showed statistically significant difference between gender in the post-pubertal group (Table 4.8)

*Co-Gn within the post-pubertal group showed interaction in the findings of the two-way mixed ANOVA between time and gender. Moreover, when this measurement is subdivided into T1 and T2, there was no significant difference between gender within these two time points. (Table 4.8)

-Similarly, in the adult group, Co-Go showed statistically significant difference between gender while the remaining variables did not (Table 4.9)

*Co/Go/Me showed interaction between gender and time, comparisons in this variable between male and female patients of the adult group did not show any statistically significant differences at T1 and at T2 (Table 4.9)

-Concerning the comparison between male and female between the three age groups, Co-Gn did not show any statistically significant difference while Co-Go did (Table 4.10)

*Co/Go/Me showed interaction between time and gender, comparisons between all age groups of the change of Co/Go/Me did not show statistically significant differences within the pre-pubertal group and post-pubertal group ,whereas significant difference between gender was seen within the adult group (Table 4.10)

4.3.2.4. Relationships between teeth and jaws

4.3.2.4.1 Inclination and position of maxillary incisors

-Variables reflecting the position of the maxillary incisors relative to their underlying jaw U1/NA,U1-NA,U1/PP,U1/SN did not show any statistically significant differences between male and female in all age groups (Tables 4.7, 4.8, 4.9)

-Furthermore, comparison between all age groups also showed no significant differences between male and female in these variables (Table 4.10)

4.3.2.4.2. Inclination and position of mandibular incisors

-Variables reflecting the position of the mandibular incisors L1/NB,L1-NB,L1/MP relative to their underlying jaw did not show any statistically significant differences between male and female in all age groups (Tables 4.7, 4.8, 4.9)

-In addition, results of two-way ANOVA showed no statistically significant differences between genders in these variables (Table 4.10)

4.3.2.4.3 Occlusal plane inclination and dentoalveolar heights

-The angular measurement OP/PP and posterior dentoalveolar heights were not statistically significantly different between male and female in the pre-pubertal group (Table 4.7)

-The maxillary dentoalveolar height U6-PP showed statistically significant difference between genders in the post-pubertal group (Table 4.8)

-The mandibular dentoalveolar height L6-MP showed statistically significant difference between genders in the adult group (Table 4.9)

-Concerning the comparisons between males and females of all age groups none of these variables showed statistically significant differences (Table 4.10)

4.3.2.4. Relationships between teeth

-The interincisal angle U1/L1 was not statistically significant different between male and female within each age group (Tables 4.7, 4.8, 4.9)

-In addition, comparison between the three age groups did not reveal any statistically significant difference (Table 4.10)

4.3.2.5. Soft tissue measurements

- Comparisons of soft tissue related variables such as UL-E-Line, LL-E-Line, upper and lower lip lengths, nasolabial and mentolabial angles did not reveal any statistically significant differences between genders in the pre-pubertal and adult groups (Table 4.7, 4.9)

-Significant differences were seen in nasolabial angle, as well as the lengths of both upper and lower lips respectively (Table 4.8)

*The mentolabial angle revealed interaction between time and gender, comparisons of this variable between male and female patients revealed statistically significant differences at T1 and at T2 (Table 4.8)

-Comparisons between all age groups did not reveal any statistically significant differences between gender in all variables (Table 4.10)

4.3.2.6. Symphyseal components

-Variables related to the symphyseal components did not show any statistically significant differences between male and female in the pre-pubertal group (Table 4.7)

-The measurement D-Apex showed a statistically significant difference between male and female in the post-pubertal group while the remaining variables did not (Table 4.8)

*D-Me showed interaction between gender and time in the two-way mixed ANOVA. When comparing this variable between gender it showed statistically significant differences at T1 and at T2 (Table 4.8)

-The measurements D-Me and CW-Apex showed statistically significant differences between male and female in the adult group,however the remaining variables did not (Table 4.9)

-Results of two-way ANOVA showed no statistically significant differences between all age groups taking into consideration the gender (Table 4.10)

4.4. Predictors of Class II, division 1 treatment outcome

This section includes the result of the discriminant analysis that was applied for the growing (combined pre- and post- pubertal) and adult groups. The classification was based on the treatment changes between T1 and T2 in cephalometric outcome measures: of the projection of Pogonion to the perpendicular passing through Nasion (Pog-N). Treatment outcome was either favorable (FR) when there was increase or no change in the mean difference between T1 and T2, and unfavorable (UFR) when the measurement decreased at the end of the treatment.

4.4.1. Classification based on treatment change in Pog-N

In this scheme, significant predictors of treatment outcome were found in both growing and adult groups.

4.4.1.1. Classification based on treatment change in Pog-N for growing patients

Based on this classification of favorable (FR, n=65) and unfavorable (UFR, n=130) responses, significant predictors of treatment outcome were found. Descriptive statistics for the 8 cephalometric variables at T2-T1 are listed in Table 4.11.

The stepwise analysis identified 1 discriminant function that were statistically significant ($p<0.001$). The predictors are Co-Go, AFH, SNB, OP/PP and U6-PP.

A canonical correlation of 0.839 suggests the model explains 68.89% of the variation in the grouping variable, i.e. whether a respondent is a FR or UFR. The cross-validation rate was 93.3% (Table 4.12).

The following equation was generated using the unstandardized discriminant function coefficients of AFH, SNB, OP/PP, U6-PP, Co-Go, and a constant:

DS = 0.238(AFH) - 0.296(SNB) -0.247(Co-Go)+ 0.416(OP/PP) + 0.314(U6-PP) – 0.236

This equation provides individual scores for assigning a new patient to either FR or UFR groups; the discriminant scores for group means (group centroids) were -2.167 for the FR group and 1.084 for the UFR group. The critical score was -0.541. A new growing Class II/1 patient who scores less than the critical score of -0.541 is more likely to have a favorable response to treatment, with a more forward position of the chin. Conversely, a new patient with the same malocclusion who has a score greater than the critical score is more likely to have an unfavorable response to treatment.

The computed cross-validated accuracy rate was 93.3%, a rate greater than the proportional by chance accuracy rate of 62.5%. Accordingly, the criterion for classification accuracy is satisfied in this classification.

4.4.1.2. Classification based on treatment change in Pog- N for pre-pubertal patients

In the pre-pubertal group, there were FR (n=26) and UFR (n=70). Accordingly, significant predictors for treatment outcome were found. Descriptive statistics for the 8 cephalometric variables at T2-T1 are listed in Table 4.13.

The stepwise analysis identified 1 discriminant function that were statistically significant ($p<0.001$). The predictors are AFH, SNB, OP/PP, and U6-PP. A canonical correlation of 0.822 suggests the model explains 62.88% of the variation in the grouping variable, i.e. whether a respondent is a FR or UFR. The cross-validation rate was 93.8% (Table 4.14).

The following equation was generated using the unstandardized discriminant function coefficients of AFH, SNB, OP/PP, U6-PP, and a constant:

$$DS = 0.250(AFH) - 0.368\ (SNB) + 1.053(OP/PP) + 0.869\ (U6\text{-}PP) - 1.057$$

This equation provides individual scores for assigning a new patient to either FR or UFR groups; the discriminant scores for group means (group centroids) were -2.344 for the FR group and 0.871 for the UFR group. The critical score was -0.736. A new growing Class II/1 patient who scores less than the critical score of -0.736 is more likely to have an unfavorable response to treatment, with a more backward position of the chin. Conversely, a new patient with the same malocclusion who has a score greater than the critical score is more likely to have a favorable response to treatment with a more forward position of the chin.

The computed cross-validated accuracy rate was 93.8%, a rate greater than the proportional by chance accuracy criteria of 43.7%. Accordingly, the criterion for classification accuracy is satisfied in this classification

4.4.1.3. Classification based on treatment change in Pog-N for post-pubertal patients

In the post-pubertal group, there were (FR=39) and (UFR=60). Accordingly, predictors for treatment outcome were found. Descriptive statistics for the 8 cephalometric variables at T2-T1 are listed in Table 4.15.

The stepwise analysis identified 1 discriminant function that were statistically significant ($p<0.001$). The predictors are Co-Go, SNB, OP/PP, and U6.-PP.
A canonical correlation of 0.858 suggests the model explains 76.03% of the variation in the grouping variable, i.e. whether a respondent is a FR or UFR. The cross validation rate was 92.9%. (Table 4.16)

The following equation was generated using the unstandardized discriminant function coefficients of Co-Go, SNB, OP/PP, U6-PP, and a constant:

$$\mathbf{DS = -0.221(Co\text{-}Go) - 0.459(SNB) + 1.978\,(OP/PP) + 0.596(U6\text{-}PP) - 0.504}$$

This equation provides individual scores for assigning a new patient to either FR or UFR groups; the discriminant scores for group means (group centroids) were -2.047 for the FR group and 1.331 for the UFR group. The critical score was -0.368. A new growing Class II/1 patient who scores less than the critical score of -0.368 is more likely to have a favorable response to treatment, with a more forward position of the chin. In contrast, a new patient with the same malocclusion who has a score greater than the critical score is more likely to have an unfavorable response to treatment with a more retrusive position of the chin.

The computed cross-validated accuracy rate was 92.9%, a rate greater than the proportional by chance accuracy criteria of 62.5%. Accordingly, the criterion for classification accuracy is satisfied in this classification

4.4.1.4 Classification based on treatment change in Pog-N for adult patients

Repartition in the adult group showed (FR=59) and UFR (31). Accordingly, predictors for treatment outcome were found. Descriptive statistics for the 8 cephalometric variables at T2-T1 are listed in (Table 4.17).

The stepwise analysis identified 1 discriminant function that were statistically significant ($p<0.001$). The predictors are Co-Go, AFH, MP/SN, and L6-MP.

A canonical correlation of 0.923 suggests the model explains 85.2% of the variation in the grouping variable, i.e. whether a respondent is a FR or UFR. The cross-validation rate was 97.8%. (Table 4.18).

The following equation was generated using the unstandardized discriminant function coefficients AFH, MP/SN, L6-MP, Co-Go, and a constant:

$$\mathbf{DS = 0.337(AFH) + 1.526(MP/SN) + 0.401(L6\text{-}MP) - 0.395\ (Co\text{-}Go) + 0.678}$$

This equation provides individual scores for assigning a new patient to either FR or UFR groups; the discriminant scores for group means (group centroids) were -1.718 for the FR group and 3.270 for the UFR group. The critical score was 1.552. A new growing Class II/1 patient who scores less than the critical score of 1.552 is more likely to have a favorable response to treatment, with a more forward position of the chin. In reverse, a new patient with the same malocclusion who has a score greater than the critical score is more likely to have an unfavorable response to treatment with a more retrusive position of the chin.

The computed cross-validated accuracy rate was 97.8%, a rate greater than the proportional by chance accuracy criteria of 62.5% .Accordingly, the criterion for classification accuracy is satisfied in this classification.

4.5. Pearson Correlation Coefficient between the change of the variables at the end of the treatment

4.5.1. Growing sample

Results of the Pearson correlation indicate that there is a significant positive association between the ramal height (Co-Go) and the anterior chin projection (Pog-N), ($r = 0.821$, $p<0.001$), which means that the posterior growth of the ramus might have a positive effect on the anterior chin projection.

In contrast, significant negative association between AFH (ANS-Me) and the projection of the chin with a coefficient equal to $r = -0.759$ and $p<0.001$, a decrease in the anterior facial height results with a more forward projection of the chin, which is mainly due to a counterclockwise rotation of the mandible. Similarly, a negative association between the angle of convexity (NA/APog) and Pog-N, $r = -0.711$, $p < 0.001$, the angle of convexity increases when the anterior chin projection is more backward.

Moreover, a significant positive association between SNB and Pog-N with $r = 0.579$, $p < 0.001$, a more forward positioning of the mandible results in a more projected chin relative to N perpendicular. More importantly, there was a negative correlation between OP/PP and Pog-N, $r = -0.824$, $p <0.001$, in other terms when the bite opens the angle between OP/PP increases leading to clockwise rotation of the mandible and a more retrusive position of the chin. As for the dentoalveolar heights, both U6-PP and L6-MP have a negative correlation with Pog-N, r = -0.717, p < 0.001, r = -0.696, p< 0.001 respectively, which explains that when the teeth extrude posteriorly the mandible rotates in a clockwise direction resulting in a more backward position of the chin. When the molars are maintained at their place or even intruded, a counterclockwise rotation of the mandible is produced resulting in a more anterior chin position. Pearson coefficient correlation results are presented in Table 4.19.

4.5.2. Pre-pubertal group

Similar to the growing group, significant correlations were found between Pog-N and other variables (Table 4.20). To begin with Co-Go, there was a significant positive correlation with Pog-N r = 0.824, p<0.001. On the opposite hand, there was a significant negative correlation between AFH and Pog-N r= -0.771, p<0.001. Similarly, NA/APog showed a significant negative correlation r = -0.801, p<0.001. Between SNB angle and Pog-N there was a positive significant correlation r = 0.661, p<0.001. More importantly, significant negative correlations were found between OP/PP and Pog-N r = -0.828, p<0.001, and between posterior dentoalveolar heights and Pog-N with the following coefficients r = -0.773, p<0.001 between U6-PP and Pog-N and r = -0.728, p<0.001 between L6-MP and Pog-N. All results are present in Table 4.20.

4.5.3. Post-pubertal group

Results of the Pearson correlation coefficient in the post-pubertal group are similar to the previous two groups. A positive correlation of r = 0.800, p<0.001 between Co-Go and Pog-N, while a negative correlation between AFH and Pog-N was seen r= -0.738, p<0.001. As well as that, between NA/APog and Pog-N there was a statistically significant negative correlation r = -0.661, p<0.001. On the contrary, a positive correlation between SNB and

Pog-N was found r = 0.534, p<0.001. A significant negative correlation was also found between OP/PP and Pog-N r = -0.815, p<0.001. Finally, posterior dentoalveolar heights showed as well significant negative correlations , for instance the Pearson coefficient between U6-PP and Pog-N was r = -0.663, p<0.001 and between L6-MP and Pog-N r = -0.670, p<0.001. All results are summarized in Table 4.21.

4.5.4. Adult sample

Pearson correlation coefficient indicates a strong negative correlation between AFH (ANS-Me) and Pog-N, r = -0.735, p<0.001, which means that a decrease in AFH will be translated by a more forward projection of the chin after the treatment.

In addition, a strong positive correlation between posterior ramal height or Co-Go and Pog-N with a coefficient of r = 0.704, p< 0.001 is present, which can be explained that the more posterior growth at the level of the ramus the more growth at the level of the chin projection.

In contrast, a positive correlation of r = 0.688, p<0.001 between SNB angle and Pog-N is present, which also means that when the mandible comes more forward the anterior chin projection follows and there is improvement of the chin projection. This is also explained by a negative correlation between ANB and Pog-N of r = -0.488, p <0.001.

On the other hand, a strong negative correlation, the strongest in the adult group, is seen between MP/SN and Pog-N with a coefficient r = -0.791, p < 0.001 from which we can conclude that the more the patient has a hyperdivergency facial pattern the more the chin is projected backward, thus the importance of the vertical control not to cause more steepening of the angle MP/SN and a backward position of the chin. Finally, strong negative correlations between each of these variables OP/PP, U6-PP,L6-MP and Pog-N with a coefficient of $r = -0.736$, $p < 0.001$, $r = -0.623$, $p < 0.001$, $r = -0.719$, $p < 0.001$ respectively, indicate that the more the posterior teeth extrude, the more the occlusal plane rotates in a clockwise direction and the chin is in a retruded position. Pearson coefficient correlation results are presented in Table 4.22.

4.6. Logistic regression to predict improvement of Pog-N

For the purpose of predicting response of anterior chin projection after treatment of Class II division 1 malocclusion, logistic regression was performed between the response of Pog-N and the change of the 8 previously mentioned cephalometric variables at T2-T1. Odds ratio were calculated to measure the association between the response groups (FR/UFR) and the change of the 8 cephalometric measurements.

4.6.1. Growing sample

The first model was applied on all the variables, variables that were not statistically significant were excluded from the prediction model. The remaining variables that were statistically significant were used again for the final model so that predictors can be deduced out of it. Four variables out of the final models were found as being predictors of favorable response of Pog-N post-treatment (Table 4.23). The following predicting equation is:

$$(T2 - T1) = (-0.589 * SNB) + (0.417 * OP/PP) + (0.843 * U6\text{-}PP) + (1.642 * AFH) - 0.354$$

4.6.2. Pre-pubertal group

In the pre-pubertal group, two variables were found to be predictors of favorable response in Pog-N which are SNB and OP/PP (Table 4.24). The following predicting equation is:

(T2 – T1) = (2.212* SNB)+(0.417* OP/PP) -0.969

4.6.3. Post-pubertal group

In the post-pubertal group, three variables were found to be predictors of favorable response in Pog-N which are SNB, OP/PP, and U6-PP (Table 4.25) The following predicting equation is:

(T2 – T1) = (2.429* SNB) +(-4.490* OP/PP)+(-1.872*U6-PP) -1.115

4.6.4. Adult sample

The first model that was applied on all the variables showed no statistically significant results; therefore logistic regression in the adult group did not allow us to deduce any predictors for favorable response of Pog-N after treatment (Table 4.26).

4.7. Comparisons between severity subgroups

For the purpose of comparing between severity subgroups independent t test was applied between the change of Pog-N at T2-T1 and severity of malocclusion. In the adult group statistically significant difference between low severity and high severity subgroups (p=0.043) with a change of 0.78 mm in Pog-N post-treatment for the lower severity subgroup and a change of 0.305 mm in Pog-N for the high severity subgroup. Comparisons between severity subgroups of the growing sample did not show statistically significant differences (p=0.138) (Table 4.27).

CHAPTER 5

DISCUSSION

Searching for accurate and reliable predictors in science requires the application of appropriate statistical methods on precise data that reveal the contribution of relevant variables to the final outcome.

We investigated in the different factors that might affect positively or negatively the anterior chin projection based on the analysis of cephalometric components that reflected skeletal and dentoalveolar changes influenced by growth and orthopedic/orthodontic treatment in growing patients and by orthodontic mechanics in adult patients.

The findings indicated a direct relationship between the vertical posterior dentoalveolar dimensions and sagittal projection of the chin, supporting our hypothesis. The details are discussed in separate sections within this discussion.

5.1. Changes in cephalometric measurements in age groups post-treatment

Most of the variables, descriptive statistical tests revealed significant differences between T1 and T2. However, comparisons between genders within each age group disclosed significant differences between male and female patients for some variables. These findings indicate different effects of the different groups on each variable over time, depending on whether the patient started treatment in his pre-pubertal, post-pubertal or adult stage.

Cranial base: The anterior and posterior cranial base lengths (SN and S-Ar) were greatest in adults compared with growing groups. In all age groups, the differences between pretreatment and post-treatment values were statistically significant with the highest difference in the pre-pubertal group, followed by the post-pubertal group and last the adult group. However, the amount of SN and S-Ar change within the adult group is not considered clinically significant (0.25 mm and 0.52 mm respectively) (Table 4.3, 4.4, 4.5) These results were concordant with those of Bjork (1955) and Ford (1958) that indicated growth cessation of most of the cranial base early in life, yet the remaining backward remodeling of sella and the increase in size of the frontal sinus would keep increasing the length of the anterior cranial base. Comparisons between genders within each age group showed statistically significant differences between the different dimensions of the cranial base. These results were also concomitant with the findings of Monirifard (2020) whereby the dimensions of the cranial base were significantly greater in men than that in women.

Sagittal jaw relations: In the pre-pubertal group, a favorable statistically significant change over time was observed in the antero-posterior jaw relations (SNA, ANB, NA/APog and Pog-N). This finding indicated a decrease in profile convexity and improvement of the skeletal discrepancy with more forward extension of the chin owing to a combination of orthopedic treatment and growth. The fact that differences between males and females of this age group were not statistically significant different may be attributed to the onset of puberty later in males, possibly in the retention stage. In the post-pubertal group, SNB remained stable over treatment time and all other angular measurements have shown a slight favorable change over time. A change in Pogonion projection to N perpendicular (1.107 mm) was statistically significant (Table 4.4).Comparisons between genders among the post-pubertal group showed statistically significant differences in SNA and SNB reflecting the further delineation by growth between boys and girls and possibly partially the difference of recruited male and female patients within this age group. Expectedly, the clinically significant change in the sagittal measurements in the adult group was not statistically significant, even though some measurements were statistically significant post-treatment. In addition, there were no statistically significant differences between males and females except for the SNB angle.

Vertical relations: The increase in facial heights over time within age groups was statistically significant in all age groups but may not be considered clinically significant in the adult group given the small amount of change. Comparisons between genders revealed mostly significant in the slightly larger anterior and posterior facial heights in males, a finding supported by Taner et al. (2019).

A significant decrease in vertical divergence reflected by the angles PP/MP and Y axis in the growing group and PP/MP and MP/SN in the adult group resulted in a counter clockwise rotation of the mandibular plane, which might be caused by orthopedic treatment in the growing patients and in contrast with the vertical dentoalveolar heights control in the adult group. Comparisons between genders within each age group did not show statistically significant differences between males and females probably because of the proportionality of these measurements within the individual patient.

Jaw specific measurements: In the growing groups, all mandibular linear measurements showed statistically significant increase over time within each age group, reflecting growth. Mean changes were not clinically significant in the adult group, indicating growth cessation. The mandibular angle Co/Go/Me was stable across age groups and over time except in the pre-pubertal group in which it significantly decreased by 1.75°, suggesting slight flattening over time that has also been related to earlier treatment (Muretić and Rak, 1991). Comparisons between genders did not reveal statistically significant differences except for the mandibular length in the pre-pubertal group, where female patients had smaller mandibles than male patients by around 5mm also reflecting current evidence regarding gender differences (Taner et al., 2019)

Dentoalveolar measurements: Inclinations of the maxillary incisors prior to treatment were close to normal mean values, indicating the absence of natural compensatory inclination of these teeth, on average. After treatment, the maxillary incisors were significantly retroclined in the adult group, followed by lesser retroclination in the post-pubertal group, but nearly none in the pre-pubertal group in which less compensatory inclination of the maxillary incisors was sought, likely due to a successful orthopedic correction of skeletal jaw discrepancy.

On the other hand, the mandibular incisors were already proclined prior to treatment, reflecting the natural compensation of the skeletal discrepancy. The mandibular incisors remained relatively stable over time (average increase of 1°), suggesting an underlying awareness of orthodontists to avoid tooth proclination. Such control would be required for periodontal and facial esthetic reasons (Ghafari and Macari, 2014).

The findings that no statistically significant differences were observed between genders of all age groups that may be associated with the fact that the inclination and position of the maxillary and mandibular incisors are compensatory to the severity of the malocclusion, skeletal discrepancy and amount of crowding.

Soft tissue measurements: Variability between age groups prior to treatment included mainly the nasolabial angle, which was more obtuse in the pre-pubertal group, but none of the other soft tissue variables were different across age groups after treatment. Among changes over time within each age group, a significant improvement was observed in both lips relative to the esthetic line after treatment. In addition, a significant decrease was noted in the nasolabial angle in the pre and post-pubertal groups compared to an increase of this angle in the adult group. These differences may be explained by a possible decrease in upper lip strain in pre-pubertal patients after treatment, and by the greater maxillary incisors compensation in adult patients to camouflage the skeletal discrepancy and correct the overjet. The mentolabial angle increased over treatment time in all age groups.

Clinically and statistically significant differences were observed among different soft tissue measurements between female and male patients. The most significant difference seen in the three age groups was in the nasolabial angle, which was more obtuse in female patients compared to male patients, likely related to a more turned up nose in females, constituent with existing reports (Bathia and Leighton 1993)

Symphysis: Almost all symphyseal components were clinically different between age groups with the largest change of the variables between T1 and T2 in the pre-pubertal group. Moreover, these measurements significantly changed over time in all age groups, but the slight changes in the adult group are not considered clinically significant. These findings reflect the continuous growth of the alveolar bone bringing the lower incisors away from the center of the symphysis (determined by the point D) which is not affected by dental movement and normal growth of the underlying bony base (Steiner, 1959). The distances D-Me and CW-D were statistically but not clinically different over time within pre and post-pubertal groups, indicating their relative stability over time and further supporting the stability of point D. The anterior and posterior slopes changed favorably over time in the pre-pubertal group, suggesting more remodeling of the chin button during the pre-pubertal stage compared to the adult group. Comparisons between genders did not reveal any statistically significant differences.

5.2. Correlations among variables

The original hypothesis stipulated the presence of a correlation between the control of the posterior dentoalveolar heights and anterior chin projection in the treatment of Class II division 1 malocclusion. This hypothesis was supported by the high and statistically significant correlations between the functional occlusal plane and both the dentoalveolar heights and the anterior chin projection. The angle OP/PP showed a negative correlation with Pog-N in the growing and adult groups. The results indicate that the bite is opened (>OP/PP) the more clockwise rotation of the occlusal plane and the more retruded position of the chin. Similarly, dentoalveolar heights showed significant negative correlations with anterior chin projection; the more the posterior teeth extruded the more clockwise rotation of the occlusal plane. Mechanically controlling the vertical heights of the posterior teeth allows the mandible and the occlusal plane to rotate in a counterclockwise rotation of the mandible and a more forward position of the chin, thus improved chin projection.

These results are concomitant with those reported by Buschang et al (2011) demonstrating that the intrusion of mandibular molars using mini-implants induced a counterclockwise rotation of the mandible in patients with a hyperdivergent facial type and

Class II malocclusion. Therefore, a symbiotic relation exists between the anterior chin projection and the rotation of mandible and occlusal plane, not withstanding the concomitant growth or remodeling at the level of the bony chin in growing patients.

The posterior ramal height (Co-Go) was positively correlated with the anterior chin projection in the growing and adult groups, indicating that an increase at the level of the posterior ramal height would be associated with a more anterior chin projection. In contrast, the anterior facial height (ANS-Me) showed high statistically significant negative correlations with Pog-N, coefficients, almost similar in the growing and adult groups. These findings suggest that the more control of the lower anterior facial height with orthodontic mechanics (i.e. avoiding bite opening), the better the post-treatment chin projection.

Negative correlations were observed between the angle of convexity (NA/APog) and Pog-N; the angle of convexity decreases when the anterior chin projection increases. In the growing group, convexity was slightly more correlated with Pog-N than in the adult group.

Positive correlations between the SNB angle and Pog-N connected a more forward mandible with better chin projection. This finding underlines the importance of starting an orthopedic treatment during the late mixed dentition phase (Gianelly 1994, Ghafari and Macari 2014) in order to benefit as much as possible from the ongoing growth to enhance differential growth of the mandible, thus a more anteriorly projected chin. Results are quite similar with the ANB angle, the negative correlations indicating that an increase of this angle reflects a tendency to skeletal Class II malocclusion with a more retruded chin and vice versa.

To better evaluate the correlation between vertical angular measurements and anterior chin projection, the correlation between the angle MP/SN and Pog-N was gauged in the adult group. A high negative correlation demonstrated a tendency toward hyperdivergency with more chin retrusion. These results would support the findings by Macari and Hanna (2013), of reduced soft tissue thickness at the levels of gnathion and menton, thus the potential indication of genioplasty to improve chin projections.

In the growing group, the correlation between the growth or Y axis (SN-Gn/FH), calculated to evaluate the anterior chin projection relative to the vertical dimension. Correlated negatively with Pog-N, also indicating that the more the growth potential in the vertical dimension, the more the chin retrusion. Therefore, if growing patients have a tendency to hyperdivergent growth pattern, controlling the vertical dimension by using high pull headgear and mechanics to prevent the extrusion of posterior teeth indicated in the treatment of Class II/1 malocclusion.

In adult patients Pog-N correlated with the mandibular molar height L6-MP, whereas in growing patients Pog-N correlated with the maxillary molar height U6-PP. These differences are likely associated with the different treatment mechanics in the age groups, whereby the maxillary molars in growing patients were controlled mechanically (e.g. with headgear).

5.3. Prediction of treatment outcome

We investigated several methods of predicting responses to treatment as favorable or unfavorable based on the treatment changes in anterior chin projection (Pog-N). Favorable treatment response corresponded to no change or increase in Pog-N measurement, while an unfavorable result corresponded to a decrease in the latter measurement. The treatment outcome was evaluated relative to the change of other variables which were: AFH, PFH, Co-Go, Y axis (for growing patients), MP/SN (for adult patients), NA/APog, OP/PP, U6-PP, and L6-MP.

The predictive model was developed separately for growing (pre- and post-pubertal) and adult patients at the end of comprehensive orthodontic treatment upon removal of the fixed appliances.

Treatment predictors: In the adult group, predictors computed in the discriminant analysis (Table 5.1) were all vertical measures, and by descending order of importance: MP/SN, AFH, Co-Go, and L6-MP with a cross validation accuracy of 97.8% (Table 1). This finding indicated that the vertical dimension has an impact on growth at the level of the chin. The more the patient has a tendency to hyperdivergent facial pattern the less chance to develop a better chin button. In contrast, a patient with normodivergent or hypodivergent facial pattern might have higher chances for more anterior extension of the chin. In addition, anterior facial height constituted a good predictor: a decreased lower AFH predicting a favorable response, and an increased AFH forecasting a more retruded chin position. A higher posterior ramal height Co-Go would predict an increased anterior chin projection.

Finally, the L6-MP measurement indicated that the less extruded the mandibular molars are or held in place (and ideally intruded), the more likelihood for improved chin position. These findings might be explained by the counterclockwise rotation of the mandible being the impetus for the favorable response and by extension that the practitioners considered in their treatment the control of the vertical dimension.

In the growing group, the predictors that emerged from the discriminant analysis were also posterior measures (in descending order of importance: Co-Go, OP/PP, AFH, SNB, and U6-PP). The more growth of posterior ramal height , the more reduced AFH, the greater increase of the SNB angle, the more anterior the chin projection. On the other hand, the greater the occlusal plane angle (OP/PP) or the extrusion of the maxillary molars (U6-PP), the more clockwise the mandibular rotation and less chin projection. Results of discriminant analysis are summarized in Table 5.1.

Table 5.1: Summary of all the predictors that emerged based on Pog-N

Classification	Adults			Growing		
	Predictor	**p-value**	**cross validation**	**Predictor**	**p-value**	**cross validation**
Pog-N	**Co-Go**	<0.001	97.8%*	**Co-Go**	<0.001	93.3%*
	AFH			**AFH**		
	MP/SN			**SNB**		
	L6-MP			**OP/PP**		
				U6-PP		

**Classification accuracy was satisfied*

In addition to the multivariate discriminant analysis, a logistic regression was applied for both growing and adult groups. In the growing group the final significant model yielded 4 cephalometric predictors SNB, OP/PP, AFH and U6-PP. The results were coincident with those from the discriminant analysis. When applied to the subgroups, the logistic regression resulted in similar predictors for both subgroups: SNB and OP/PP and an additional predictor (U6-PP) in the post-pubertal group. The logistic regression applied for the adult group did not show any significant prediction model.

5.4. Severity subgroups

The results of the independent t test revealed a marginally statistically significant difference in posttreatment Pog-N between severity subgroups in the adult sample. Low severity groups had better anterior chin advancement post-treatment compared to high severity groups, suggesting that the pre-treatment ANB angle in adult patients might be a determining factor in the improvement of anterior chin projection post-treatment. Comparisons between severity subgroups of the growing sample did not reveal statistically significant differences in the change of Pog-N, indicating that the pre-treatment ANB angle value does not influence, on average, the posttreatment anterior chin projection.

5.5. Research considerations

Our findings contribute to the knowledge on the interaction between vertical and sagittal dimensions of the dentoalveolar complex during orthodontic treatment While this interaction has been acknowledged, the specific focus on posterior vertical control and chin extension had not been explored to the best of our knowledge. The delineation was practical for the population studied, but ideally a panel of judges would be needed to correlate cephalometric changes with facial favorability. Several analyses converged in finding predictors for Pog-N favorable and unfavorable response, and in finding the relationship between posterior dentoalveolar heights and inclination of the functional occlusal plane with the anterior chin projection.

Unlike other studies, the cutoff used for outcome measure to separate between favorable and unfavorable responses were simplified and individualized to the sample population by calculating the mean (T2-T1) change for each outcome measure within each age group and then assigning each patient to his response group based on the individual change. We used the multivariate discriminant analysis to differentiate between the two categories of responses. More specifically, the stepwise method selects the best and most correlated variables to use in the model. The pre-treatment variables were limited to 8 cephalometric measurements. Nevertheless, other cephalometric variables that were not included in the analyses might possibly have influenced the prediction models.

The reliability of the pretreatment predictors within each classification was cross-validated and compared with the proportional by chance accuracy rate to evaluate the usefulness of each model. All of the cross-validation rates were higher than the proportional by chance accuracy rate, thus the classification accuracy was satisfied in those prediction models.

Methodological limitations of our study encompass the retrospective nature of our sample of patients who were treated by different practitioners. While this variation in the choice of treatment mechanics, orthopedic appliances and treatment timing inherently includes the bias for specific approaches to treatment, it reflects the reality across orthodontic practices. Nevertheless, it seems that control of the vertical dimension was respected reflecting a common basis of knowledge of research and mechanics. On the other hand, prospective clinical trials represent the ultimate research preference. Future research could be planned under stricter conditions of recruitment, treatment protocols, compliance, and a larger sample of Class II patients for more generalizable conclusions. Our results indicated that there was an improvement of the anterior chin projection cephalometrically, but might not be clinically significant in the individual patient, particularly considering the thickness of all draping soft tissue. This aspect should be investigated through esthetic judgements of independent panels of dentists, orthodontists and lay people.

Prediction models may be specific to the studied population; however the conversion of different methods in this research suggests that the significant variables could be tested in other studies and subject to more validation. Moreover, a control sample of Class II division1 untreated patients should be included to compare the changes in Pog-N between treated and untreated patients. This comparison will shed better light on the impact of the orthodontic vertical control on the anterior chin projection.

5.6. Clinical implications

The findings suggest that careful examination of the studied craniofacial components prior to treatment may facilitate a thorough diagnosis and promote better control of the evaluated vertical variables.

This research also indicated that in both growing and adult groups, controlling the vertical heights of posterior teeth with treatment mechanics such as using a high-pull headgear, mini-implants, or bite blocks, a consequent counterclockwise rotation of the occlusal plane would enhance the anterior projection of the chin. Such control is more consequential in adult patients with hyperdivergent facial pattern to avoid the extrusion of posterior teeth and the clockwise rotation of the mandible, because growth is absent as a potential compensatory factor. Treatment would be more challenging when a hyperdivergent pattern is accompanied with a deep overbite, whereby attention might be focused on the intrusion of the maxillary and mandibular incisors as indicated by judicious diagnosis.

CHAPTER 6

CONCLUSIONS

1. The control of the posterior dentoalveolar heights through treatment mechanics is associated with more anterior chin projection.
2. The occlusal plane dictated by the posterior dentoalveolar heights of the molars is strongly correlated with the anterior chin projection.
3. The improvement in the anterior chin projection was the highest in the pre-pubertal group followed by the post-pubertal and the adult group, a finding that underscores the importance of early treatment to take advantage of ongoing growth. This finding also indicates that growth at the level of the chin is not completely related to the dentition although more directly associated with the rotation of the mandible consequent to treatment mechanics.
4. The predictive equations employed in this study pointed to the posterior dentoalveolar heights and the inclination of the occlusal plane as predictors of favorable anterior chin projection
5. The results indicate the awareness by the treating orthodontists of the included patients to avoid the extrusion of posterior teeth and further proclination of mandibular incisors in Class II/1 treatment for both periodontal and esthetic reasons, as most of the overjet correction resulted from the retraction of the maxillary incisors.
6. Novel approaches in this study include the use of categorization on specific cephalometric components of the malocclusion to develop predictive models for

favorable and unfavorable treatment response. The categorization on N-Pog proved practical in differentiating favorable and unfavorable responses. However it should be complemented in future research with the assessment of the corresponding soft tissue measurements.

7. Future research should expand the boundaries of the methodology used in this study, by including larger samples, in addition to including panels to judge facial characteristics in relation to the underlying structures before and after treatment more specifically on the anterior chin projection after treatment.
8. A control of untreated Class II patients should be included in a future study to compare the changes in the different dentofacial components more specifically in the anterior chin projection to evaluate the impact of orthodontic treatment on anterior chin projection.

APPENDIX 1

TABLES

Table 4.3: Comparison between measurements at T1 and T2 in the pre-pubertal group (n=96)

	T1		T2		Difference (T2-T1)		Two-way ANOVA	
	Mean	SE	Mean	SE	Mean	SE	F	P
Cranial base measurements								
SN*	64.597	0.324	67.553	0.353	2.955	0.158	3.500	<0.001
SN/H*	12.872	0.313	12.992	0.317	0.120	0.050	5.720	0.019
S-Ar*	32.213	0.310	34.626	0.310	2.413	0.170	2.010	<0.001
Relationship between jaws, cranial base and horizontal								
SNA*	81.747	0.286	80.674	0.324	-1.073	0.151	0.650	<0.001
SNB	75.719	0.285	76.076	0.303	0.357	0.137	0.785	0.255
ANB								
Males	5.771	0.224	5.183	0.235	-0.588	0.204	8.293	0.006
Females	6.139	0.264	4.875	0.259	-1.264	0.274	21.215	<0.001
N-ANS*	48.552	0.321	52.731	0.275	4.178	0.217	5.158	<0.001
NA/Apog	11.524	0.438	11.304	0.471	-0.220	0.282	0.956	0.437
ANS-Me*	61.075	0.473	62.091	0.487	1.015	0.205	0.241	<0.001
PFH*	40.259	0.465	43.027	0.477	2.768	0.135	1.113	<0.001
LFH %*	55.459	0.184	56.033	0.183	0.574	0.084	4.619	<0.001
Y Axis*	68.878	0.297	69.355	0.301	0.477	0.118	1.784	<0.001
PP/MP*	27.397	0.465	25.336	0.475	-2.061	0.245	0.126	<0.001
MP/SN*	36.743	0.455	35.939	0.480	-0.804	0.234	0.136	<0.001
Pog-N*	-3.721	0.300	-2.296	0.311	1.424	0.114	1.102	<0.001
Jaw specific measurements								
Co-Gn*	103.178	0.526	108.239	0.741	5.061	1.120	4.125	<0.001
Co-Go*	48.526	0.500	55.042	0.569	6.516	0.331	3.882	<0.001
Co/Go/Me*	122.879	0.542	121.134	0.576	-1.745	0.318	3.018	<0.001
Relationship between teeth and jaws								
U1/NA	21.500	0.665	21.366	0.620	-0.134	0.809	0.341	0.868
U1-NA	3.420	0.226	3.013	0.233	-0.407	0.235	0.506	0.087
U1/SN	103.222	0.747	102.137	0.668	-1.086	0.832	0.878	0.195
U1/PP	112.705	0.659	112.683	0.598	-0.023	0.816	1.223	0.978
L1/NB	31.224	0.505	31.721	0.526	0.497	0.570	0.760	0.386
L1-NB	6.219	0.185	6.767	0.204	0.547	0.161	0.115	0.256
L1/MP	99.114	0.616	99.674	0.589	0.559	0.573	1.115	0.331
OP/PP*	7.173	0.220	7.386	0.220	0.213	0.050	0.859	<0.001
U6-PP*	15.933	0.239	16.637	0.248	0.704	0.099	0.130	<0.001
L6-MP*	26.668	0.281	27.919	0.275	1.251	0.238	2.752	<0.001
Relationship between teeth								
U1/L1	121.485	0.869	122.619	0.850	1.134	1.040	0.846	0.279
Soft tissue measurements								
UL-E-Line*	-0.246	0.196	-3.207	0.223	-2.962	0.172	2.961	<0.001
LL-E-Line*	1.708	0.215	0.033	0.252	-1.675	0.173	0.293	<0.001
Nasolabial Angle*	114.258	1.004	111.610	1.159	-2.648	0.717	1.274	<0.001
Mentolabial Angle*	120.758	1.554	125.296	1.261	4.539	1.261	0.461	<0.001
U lip length*	21.589	0.250	22.477	0.257	0.888	0.114	0.364	<0.001
L lip length*	18.403	0.297	19.331	0.299	0.928	0.124	0.305	<0.001
Symphyseal components								
D-Apex*	6.243	0.219	8.713	0.224	2.470	0.174	0.905	<0.001
D-Me*	11.027	0.095	11.797	0.127	0.770	0.100	5.910	<0.001
CW-Apex*	10.188	0.185	9.044	0.189	-1.144	0.114	0.356	<0.001

(CW-D)*	12.257	0.148	12.894	0.328	0.637	0.314	0.515	<0.001
ASA*	4.313	0.665	7.413	0.729	3.100	0.321	2.956	<0.001
PSA*	-23.913	0.603	-21.605	0.670	2.326	0.429	2.874	<0.001

*Statistically significant at $p \leq 0.05$

Table 4.4: Comparison between measurements at T1 and T2 in the post-pubertal group (n=99)

	T1		T2		Difference (T2-T1)		Two-way ANOVA	
	Mean	SE	Mean	SE	Mean	SE	F	P
Cranial base measurements								
SN*	66.180	0.358	67.861	0.375	1.680	0.134	1.560	<0.001
SN/H*	11.873	0.325	11.949	0.322	0.076	0.022	11.615	0.001
S-Ar*	33.289	0.365	34.857	0.393	1.568	0.167	2.003	<0.001
Relationship between jaws, cranial base and horizontal								
SNA*	82.394	0.368	81.598	0.395	-0.796	0.115	0.541	<0.001
SNB	76.653	0.344	76.941	0.365	0.288	0.102	5.471	0.391
ANB*	5.682	0.148	4.799	0.154	-0.883	0.136	0.547	<0.001
N-ANS*	50.147	0.348	52.652	0.389	2.505	0.228	0.102	<0.001
NA/Apog	10.786	0.448	10.351	0.399	-0.435	0.335	0.551	0.197
ANS-Me	63.155	0.573	63.152	0.596	0.357	0.222	0.051	0.112
PFH								
Males	43.23	0.993	44.653	1.017	1.423	0.309	21.191	<0.001
Females	41.238	0.517	43.714	0.509	2.477	0.159	241.345	<0.001
LFH %*	55.361	0.214	55.931	0.225	0.570	0.074	0.329	<0.001
Y Axis	68.308	0.288	68.437	0.290	0.128	0.119	1.002	0.282
PP/MP*	26.515	0.484	25.249	0.463	-1.266	0.257	0.056	<0.001
MP/SN*	35.656	0.490	35.107	0.458	-0.548	0.238	0.301	0.028
Pog-N*	-2.441	0.487	-1.334	0.485	1.107	0.118	0.501	<0.001
Jaw specific measurements								
Co-Gn								
Males	108.41	1.839	113.933	1.939	5.523	0.724	58.262	<0.001
Females	105.864	0.673	113.358	0.71	7.494	0.52	208.1	<0.001
Co-Go	51.899	0.573	51.781	0.553	-0.118	0.233	1.124	0.614
Co/Go/Me*	121.570	0.573	120.729	0.530	-0.841	0.330	0.904	0.012
Relationship between teeth and jaws								
U1/NA	21.734	0.715	20.396	0.638	-0.978	0.912	1.150	0.286
U1-NA*	3.521	0.245	2.806	0.253	-0.715	0.298	5.739	0.019
U1/SN	103.752	0.739	102.088	0.634	-1.663	0.918	3.285	0.073
U1/PP*	112.366	1.332	112.130	0.747	-0.235	1.388	0.029	0.036
L1/NB	29.904	0.605	31.259	0.658	1.355	0.608	4.963	0.304
L1-NB	6.087	0.221	6.605	0.222	0.518	0.202	6.576	0.125
L1/MP	99.083	0.697	99.330	0.763	1.247	0.704	3.139	0.080
OP/PP*	6.989	0.220	7.096	0.227	0.107	0.054	0.506	0.050
U6-PP*	17.696	0.305	18.157	0.291	0.461	0.106	8.784	<0.001
L6-MP*	28.247	0.301	28.730	0.306	0.483	0.135	12.730	<0.001
Relationship between teeth								
U1/L1	123.729	0.998	124.612	1.069	0.883	1.251	0.498	0.482
Soft tissue measurements								
UL-E-Line*	-0.819	0.222	-3.182	0.268	-2.363	0.206	1.317	<0.001
LL-E-Line*	1.073	0.322	-0.031	0.334	-1.104	0.234	2.217	<0.001
Nasolabial Angle	113.440	1.049	112.094	1.029	-1.346	0.716	3.537	0.063
Mentolabial Angle								
Males	115.53	1.563	114.607	1.659	-0.923	0.824	1.255	0.272
Females	111.351	1.205	109.581	1.149	-1.77	0.872	4.118	0.046
U lip length*	21.571	0.250	22.614	0.271	1.043	0.111	8.837	<0.001
L lip length*	17.260	0.254	19.227	0.242	1.967	0.156	1.592	<0.001
Symphyseal components								
D-Apex*	7.684	0.294	9.588	0.256	1.904	0.200	9.057	<0.001
D-Me								
Males	12.027	0.239	12.983	0.327	0.957	0.187	26.06	<0.001
Females	11.239	0.105	11.762	0.144	0.523	0.096	29.88	<0.001
CW-Apex*	9.997	0.224	9.148	0.234	-0.849	0.125	4.634	<0.001
(CW-D)	10.758	0.325	11.218	0.374	0.460	0.602	2.213	0.681
ASA*	6.004	0.668	7.757	0.732	1.753	0.321	2.974	<0.001
PSA	-23.059	0.745	-22.375	0.812	0.684	0.381	3.224	0.076

*Statistically significant at $p \leq 0.05$

Table 4.5: Comparison between measurements at T1 and T2 in the adult group (n=90)

Variables T2-T1	Pre-pubertal(1) n=96		Post-pubertal(2) n=99		Adult(3) n=90		F	p-value	p-value†		
	Mean	SE	Mean	SE	Mean	SE			1-2	1-3	2-3
Cranial base measurements											
SN	2.955	0.121	1.680	0.130	0.250	0.129	11.64	<0.001	<0.001	<0.001	<0.001
SN/H	0.120	0.033	0.076	0.035	0.048	0.035	1.148	0.319	-	-	-
S-Ar	2.413	0.152	1.568	0.163	0.528	0.161	3.605	<0.001	<0.001	<0.001	<0.001
Relationship between jaws, cranial base and horizontal											
SNA	-1.073	0.116	-0.796	0.124	-0.170	0.123	14.795	<0.001	0.311	<0.001	<0.001
SNB†											
M	0.343	0.197	-0.294	0.15	0.166	0.183	3.845	0.024	0.011	0.054	0.511
F	-0.02	0.141	-0.168	0.113	0.111	0.127	1.361	0.259	-	-	-
ANB†											
M	-0.588	0.175	-0.99	0.23	-0.411	0.213	1.772	0.175	-	-	-
F	-1.264	0.198	-0.777	0.158	-0.211	0.179	7.862	0.001	0.137	<0.001	0.05
N-ANS	4.178	0.181	2.505	0.194	0.431	0.192	10.54	<0.001	<0.001	<0.001	<0.001
NA/APog	-0.480	0.254	-0.435	0.271	-0.461	0.269	2.218	0.111	-	-	-
ANS-Me (AFH)	1.015	0.191	0.357	0.204	-0.297	0.202	11.168	<0.001	0.057	<0.001	0.007
Ar-Go (PFH)†											
M	2.9	0.21	1.423	0.277	1.234	0.256	15.785	<0.001	<0.001	0.871	<0.001
F	2.636	0.197	2.477	0.157	1.241	0.178	18.216	<0.001	<0.001	0.802	<0.001
LFH/TFH (%)	-0.610	0.135	-0.524	0.112	0.086	0.175	0.240	0.918	-	-	-
PP/MP*	-1.200	0.145	-0.626	0.155	0.125	0.154	1.966	<0.001	0.022	<0.001	0.002
MP/SN	-0.382	0.133	-0.260	0.142	0.275	0.141	0.238	0.789	-	-	-
Pog-N	-0.424	0.112	-0.107	0.119	0.479	0.118	1.5651	<0.001	0.161	<0.001	0.002
Jaw specific measurements											
Co-Gn	7.393	0.680	6.509	0.726	2.383	0.721	2.417	<0.001	<0.001	<0.001	<0.001
Co-Go	0.516	0.242	0.118	0.258	0.254	0.256	2.27	<0.001	<0.001	<0.001	0.922
Co/Go/Me†											
M	-1.563	0.417	-0.367	0.548	-1.049	0.508	1.518	0.223	-	-	-
F	-1.927	0.402	-1.314	0.321	0.122	0.363	7.937	0.001	0.459	0.01	0.001
Relationship between teeth and jaws											
U1/NA	-0.134	0.779	-1.978	0.831	-5.377	0.825	11.990	<0.001	0.999	<0.001	<0.001
U1-NA	-0.407	0.256	-0.715	0.273	-3.204	0.271	3.290	<0.001	0.999	<0.001	<0.001
U1/SN	-1.086	0.855	-1.663	0.913	-7.652	0.906	16.481	<0.001	0.879	<0.001	<0.001
U1/PP	-0.023	1.029	-0.235	1.098	-7.353	1.090	14.939	<0.001	0.999	<0.001	<0.001
L1/NB	0.547	0.188	0.518	0.201	-0.605	0.200	11.050	<0.001	0.875	<0.001	<0.001
L1-NB	0.234	0.175	0.073	0.145	-0.161	0.227	0.502	0.295	-	-	-
L1/MP	0.559	0.638	1.247	0.681	-0.581	0.676	1.858	0.158	-	-	-
OP/PP	0.213	0.048	0.107	0.051	-0.183	0.050	17.216	<0.001	0.390	<0.001	<0.001
U6-PP	0.605	0.084	0.399	0.089	0.031	0.089	11.199	<0.001	0.282	<0.001	0.012
L6-MP	0.660	0.094	0.373	0.101	-0.111	0.100	15.976	<0.001	0.115	<0.001	0.002
Relationship between teeth											
U1/L1	3.214	1.088	3.393	0.902	0.178	1.413	0.016	0.679	-	-	-
Soft tissue measurements											
UL- E line	-2.962	0.168	-2.363	0.179	-0.989	0.178	3.379	<0.001	0.046	<0.001	<0.001
LL- E line	-1.675	0.189	-1.104	0.202	-1.071	0.200	3.085	0.047	0.120	0.088	0.999
Nasolabial angle	-2.648	0.682	-1.346	0.728	2.354	0.723	13.386	<0.001	0.580	<0.001	<0.001
Mentolabial angle	4.539	1.132	2.310	1.208	4.581	1.199	1.183	0.301	-	-	-
U lip length	1.133	0.110	1.043	0.117	0.862	0.116	1.460	0.232	-	-	-
L lip length	2.297	0.134	1.967	0.143	0.837	0.142	3.021	<0.001	0.278	<0.001	<0.001
Symphyseal components											
D-Apex	2.375	0.168	1.904	0.180	0.525	0.178	3.027	<0.001	0.170	<0.001	<0.001
D-Me	0.770	0.089	0.740	0.095	-0.023	0.095	2.30	<0.001	<0.001	<0.001	<0.001
CW-Apex	-1.144	0.119	-0.372	0.126	-0.849	0.127	10.102	<0.001	0.268	<0.001	0.024
CW-D	0.341	0.083	0.348	0.089	0.085	0.088	2.934	0.055	-	-	-
ASA	3.100	0.292	1.753	0.311	0.697	0.309	16.160	<0.001	0.050	<0.001	0.005
PSA	2.326	0.401	0.684	0.428	0.025	0.425	8.331	<0.001	0.016	<0.001	0.827

*Significant at p<0.05; **Significant at p<0.01.
†Simple main effects reported when a significant interaction between gender and age group was found.

Table 4.6: Comparison of the change (T2-T1) in cephalometric variables between different age groups in both genders (n=285)

Variables T2-T1	Pre-pubertal(1) n=96		Post-pubertal(2) n=99		Adult(3) n=90		F	p-value	p-value†		
	Mean	SE	Mean	SE	Mean	SE			1-2	1-3	2-3
Cranial base measurements											
SN	2.955	0.121	1.680	0.130	0.250	0.129	11.64	<0.001	<0.001	<0.001	<0.001
SN/H	0.120	0.033	0.076	0.035	0.048	0.035	1.148	0.319	-	-	-
S-Ar	2.413	0.152	1.568	0.163	0.528	0.161	3.605	<0.001	<0.001	<0.001	<0.001
Relationship between jaws, cranial base and horizontal											
SNA	-1.073	0.116	-0.796	0.124	-0.170	0.123	14.795	<0.001	0.311	<0.001	<0.001
SNB †											
M	0.343	0.197	-0.294	0.15	0.166	0.183	3.845	0.024	0.011	0.054	0.511
F	-0.02	0.141	-0.168	0.113	0.111	0.127	1.361	0.259	-	-	-
ANB †											
M	-0.588	0.175	-0.99	0.23	-0.411	0.213	1.772	0.175	-	-	-
F	-1.264	0.198	-0.777	0.158	-0.211	0.179	7.862	0.001	0.137	<0.001	0.05
N-ANS	4.178	0.181	2.505	0.194	0.431	0.192	10.54	<0.001	<0.001	<0.001	<0.001
NA/APog	-0.480	0.254	-0.435	0.271	-0.461	0.269	2.218	0.111	-	-	-
ANS-Me (AFH)	1.015	0.191	0.357	0.204	-0.297	0.202	11.168	<0.001	0.057	<0.001	0.007
Ar-Go (PFH) †											
M	2.9	0.21	1.423	0.277	1.234	0.256	15.785	<0.001	<0.001	0.871	<0.001
F	2.636	0.197	2.477	0.157	1.241	0.178	18.216	<0.001	<0.001	0.802	<0.001
LFH/TFH (%)	-0.610	0.135	-0.524	0.112	0.086	0.175	0.240	0.918	-	-	-
PP/MP*	-1.200	0.145	-0.626	0.155	0.125	0.154	1.966	<0.001	0.022	<0.001	0.002
MP/SN	-0.382	0.133	-0.260	0.142	0.275	0.141	0.238	0.789	-	-	-
Pog-N	-0.424	0.112	-0.107	0.119	0.479	0.118	1.5651	<0.001	0.161	<0.001	0.002
Jaw specific measurements											
Co-Gn	7.393	0.680	6.509	0.726	2.383	0.721	2.417	<0.001	<0.001	<0.001	<0.001
Co-Go	0.516	0.242	0.118	0.258	0.254	0.256	2.27	<0.001	<0.001	<0.001	0.922
Co/Go/Me †											
M	-1.563	0.417	-0.367	0.548	-1.049	0.508	1.518	0.223	-	-	-
F	-1.927	0.402	-1.314	0.321	0.122	0.363	7.937	0.001	0.459	0.01	0.001
Relationship between teeth and jaws											
U1/NA	-0.134	0.779	-1.978	0.831	-5.377	0.825	11.990	<0.001	0.999	<0.001	<0.001
U1-NA	-0.407	0.256	-0.715	0.273	-3.204	0.271	3.290	<0.001	0.999	<0.001	<0.001
U1/SN	-1.086	0.855	-1.663	0.913	-7.652	0.906	16.481	<0.001	0.879	<0.001	<0.001
U1/PP	-0.023	1.029	-0.235	1.098	-7.353	1.090	14.939	<0.001	0.999	<0.001	<0.001
L1/NB	0.547	0.188	0.518	0.201	-0.605	0.200	11.050	<0.001	0.875	<0.001	<0.001
L1-NB	0.234	0.175	0.073	0.145	-0.161	0.227	0.502	0.295	-	-	-
L1/MP	0.559	0.638	1.247	0.681	-0.581	0.676	1.858	0.158	-	-	-
OP/PP	0.213	0.048	0.107	0.051	-0.183	0.050	17.216	<0.001	0.390	<0.001	<0.001
U6-PP	0.605	0.084	0.399	0.089	0.031	0.089	11.199	<0.001	0.282	<0.001	0.012
L6-MP	0.660	0.094	0.373	0.101	-0.111	0.100	15.976	<0.001	0.115	<0.001	0.002
Relationship between teeth											
U1/L1	3.214	1.088	3.393	0.902	0.178	1.413	0.016	0.679	-	-	-
Soft tissue measurements											
UL- E line	-2.962	0.168	-2.363	0.179	-0.989	0.178	3.379	<0.001	0.046	<0.001	<0.001
LL- E line	-1.675	0.189	-1.104	0.202	-1.071	0.200	3.085	0.047	0.120	0.088	0.999
Nasolabial angle	-2.648	0.682	-1.346	0.728	2.354	0.723	13.386	<0.001	0.580	<0.001	<0.001
Mentolabial angle	4.539	1.132	2.310	1.208	4.581	1.199	1.183	0.301	-	-	-
U lip length	1.133	0.110	1.043	0.117	0.862	0.116	1.460	0.232	-	-	-
L lip length	2.297	0.134	1.967	0.143	0.837	0.142	3.021	<0.001	0.278	<0.001	<0.001
Symphyseal components											
D-Apex	2.375	0.168	1.904	0.180	0.525	0.178	3.027	<0.001	0.170	<0.001	<0.001
D-Me	0.770	0.089	0.740	0.095	-0.023	0.095	2.30	<0.001	<0.001	<0.001	<0.001
CW-Apex	-1.144	0.119	-0.372	0.126	-0.849	0.127	10.102	<0.001	0.268	<0.001	0.024
CW-D	0.341	0.083	0.348	0.089	0.085	0.088	2.934	0.055	-	-	-
ASA	3.100	0.292	1.753	0.311	0.697	0.309	16.160	<0.001	0.050	<0.001	0.005
PSA	2.326	0.401	0.684	0.428	0.025	0.425	8.331	<0.001	0.016	<0.001	0.827

*Significant at p<0.05; **Significant at p<0.01.
†Simple main effects reported when a significant interaction between gender and age group was found.

Table 4.7: Comparison between males and females in the pre-pubertal group (n=96)

	Male (n=52)		Female (n=44)		Difference (Female-Male)		Two-way ANOVA	
	Mean	SE	Mean	SE	Mean	SE	F	P
Cranial base measurements								
SN	66.657	0.446	65.493	0.485	-1.164	0.659	0.910	0.081
SN/H	12.699	0.425	13.166	0.462	-0.467	0.627	0.554	0.459
S-Ar*	34.269	0.404	32.570	0.439	-1.699	0.597	8.100	0.005
Relationship between jaws, cranial base and horizontal								
SNA	80.977	0.401	81.444	0.436	-0.467	0.593	1.144	0.432
SNB	75.624	0.387	75.972	0.421	-0.348	0.571	0.993	0.544
ANB								
T1	5.771	0.232	6.139	0.253	0.367	0.343	1.146	0.287
T2	5.183	0.236	4.875	0.257	-0.308	0.349	0.776	0.380
N-ANS*	51.486	0.377	49.798	0.410	-1.688	0.557	9.175	0.030
NA/Apog	10.938	0.585	11.891	0.636	-0.953	0.864	0.947	0.273
ANS-Me*	63.156	0.635	60.010	0.690	3.146	0.938	0.407	<0.001
PFH*	42.906	0.631	40.380	0.686	2.526	0.932	0.950	0.008
LFH %	55.768	0.242	55.724	0.263	0.044	0.357	0.139	0.901
Y Axis	69.052	0.397	69.181	0.432	-0.129	0.587	1.963	0.827
PP/MP	26.069	0.615	26.664	0.668	-0.594	0.908	0.131	0.514
MP/SN	36.083	0.613	36.600	0.666	-0.517	0.905	0.000	0.569
Pog-N*	-3.045	0.406	-3.972	0.442	0.926	0.600	0.906	0.126
Jaw specific measurements								
Co-Gn*	108.894	0.742	105.230	0.807	-3.664	1.096	5.910	0.017
Co-Go*	53.336	0.690	50.233	0.751	3.103	1.020	3.052	0.030
Co/Go/Me	121.734	0.726	122.280	0.789	0.546	1.072	0.259	0.612
Relationship between teeth and jaws								
U1/NA	21.145	0.677	21.720	0.736	0.575	1.002	0.331	0.566
U1-NA	3.085	0.267	3.349	0.290	0.264	0.394	0.450	0.504
U1/SN	102.119	0.776	103.240	0.844	1.121	1.147	0.955	0.331
U1/PP	112.190	0.648	113.198	0.705	1.007	0.958	1.106	0.296
L1/NB	31.168	0.582	31.777	0.633	0.609	0.859	0.502	0.480
L1-NB	6.561	0.241	6.425	0.261	-0.136	0.355	0.146	0.704
L1/MP	99.552	0.718	99.236	0.781	-0.316	1.061	0.089	0.767
OP/PP	7.492	0.296	7.066	0.322	0.426	0.437	0.814	0.332
U6-PP	16.630	0.323	15.940	0.351	0.690	0.477	0.128	0.151
L6-MP	27.753	0.340	26.834	0.370	0.919	0.502	2.514	0.071
Relationship between teeth								
U1/L1	122.634	0.926	121.470	1.007	-1.163	1.368	0.723	0.397
Soft tissue measurements								
UL-E-Line	-1.470	0.259	-1.983	0.282	-0.513	0.383	1.792	0.184
LL-E-Line	0.902	0.295	0.840	0.320	-0.620	0.435	0.020	0.887
Nasolabial Angle*	111.688	1.386	114.181	1.507	2.493	2.047	1.483	0.006
Mentolabial Angle	122.259	1.730	123.795	1.880	1.537	2.555	0.362	0.549
U lip length	14.840	0.324	15.164	0.114	0.324	0.357	0.241	0.237
L lip length	17.121	0.547	18.458	0.621	1.337	0.415	0.226	0.435
Symphyseal components								
D-Apex	7.663	0.276	7.293	0.300	-0.370	0.407	0.827	0.407
D-Me	11.578	0.136	11.066	0.147	-0.692	0.200	11.930	0.236
CW-Apex	9.729	0.241	9.503	0.262	-0.225	0.356	0.401	0.528
(CW-D)	12.257	0.148	12.894	0.328	0.637	0.314	0.515	0.615
ASA	7.067	0.920	4.659	1.000	-2.408	1.358	3.143	0.079
PSA	-23.840	0.813	-21.695	0.883	2.145	1.200	3.194	0.077

*Statistically significant at p≤0.05

Table 4.8: Comparison between males and females in the post-pubertal group (n=99)

	Male (n=30)		Female (n=69)		Difference (Female-Male)		Two-way ANOVA	
	Mean	SE	Mean	SE	Mean	SE	F	P
Cranial base measurements								
SN	67.833	0.601	66.207	0.396	1.626	0.720	0.717	0.026
SN/H*	10.922	0.540	12.901	0.356	1.979	0.647	9.364	0.030
S-Ar	34.610	0.618	33.537	0.407	-1.073	0.740	2.102	0.150
Relationship between jaws, cranial base and horizontal								
SNA*	82.748	0.630	81.243	0.415	1.505	0.754	0.743	0.049
SNB*	77.472	0.585	75.922	0.386	1.550	0.701	6.322	0.029
ANB	5.108	0.225	5.372	0.148	-0.264	0.270	0.610	0.330
N-ANS	51.468	0.586	51.331	0.386	-0.137	0.702	0.038	0.846
NA/Apog	10.425	0.651	10.712	0.429	-0.287	0.779	0.450	0.713
ANS-Me*	64.543	0.958	62.123	0.632	2.420	1.148	0.038	0.038
PFH								
T1	43.23	0.852	41.238	0.562	-1.992	1.021	3.810	0.054
T2	44.653	0.852	43.714	0.562	-0.939	1.021	0.846	0.36
LFH %	55.828	0.361	55.464	0.238	0.364	0.432	0.293	0.402
Y Axis	67.833	0.472	68.912	0.311	-1.078	0.566	0.941	0.060
PP/MP	26.022	0.761	25.742	0.502	0.280	0.912	0.047	0.760
MP/SN	34.505	0.767	36.258	0.505	-1.753	0.918	0.118	0.059
Pog-N*	-2.693	0.805	-3.082	0.531	-0.389	0.965	0.066	0.153
Jaw specific measurements								
Co-Gn								
T1	108.41	1.32	105.864	0.87	-2.546	1.581	2.594	0.111
T2	113.933	1.391	113.358	0.917	-0.575	1.667	0.119	0.731
Co-Go*	53.255	0.920	50.425	0.606	2.830	1.102	1.320	0.012
Co/Go/Me	121.643	0.880	120.656	0.580	-0.988	1.054	0.878	0.351
Relationship between teeth and jaws								
U1/NA*	21.520	0.837	20.249	0.552	-1.271	1.003	1.605	0.208
U1-NA	3.357	0.333	2.970	0.219	-0.387	0.398	0.944	0.334
U1/SN	104.202	0.858	101.638	0.566	-2.563	1.027	6.225	0.145
U1/PP	113.063	1.382	111.433	0.911	-1.631	1.655	0.970	0.327
L1/NB	30.568	0.925	30.595	0.610	0.270	1.108	0.128	0.981
L1-NB	6.332	0.330	6.360	0.218	0.028	0.395	0.050	0.943
L1/MP	98.950	1.070	98.464	0.706	-0.486	1.282	0.144	0.705
OP/PP	6.950	0.370	7.135	0.244	-0.185	0.443	0.455	0.678
U6-PP*	18.835	0.490	17.019	0.323	1.816	0.587	0.296	0.030
L6-MP	28.905	0.493	28.072	0.325	0.833	0.591	3.870	0.162
Relationship between teeth								
U1/L1	123.657	1.375	124.684	0.907	1.027	1.647	0.389	0.534
Soft tissue measurements								
UL-E-Line	-2.142	0.373	-1.860	0.246	0.282	0.447	0.397	0.530
LL-E-Line	0.113	0.511	0.928	0.337	0.815	0.613	1.770	0.187
Nasolabial Angle*	110.068	1.629	115.466	1.074	5.398	1.951	5.564	0.020
Mentolabial Angle								
T1	115.53	1.752	111.351	1.155	-4.179	2.099	3.965	0.049
T2	114.607	1.718	109.581	1.133	-5.026	2.058	5.964	0.016
U lip length*	15.267	0.228	15.368	0.125	0.101	0.451	1.120	<0.001
L lip length*	18.621	0.519	19.184	0.345	0.563	0.187	0.551	0.009
Symphyseal components								
D-Apex*	9.237	0.428	8.035	0.283	-1.202	0.513	5.485	0.021
D-Me								
T1	12.027	0.187	11.239	0.123	-0.788	0.224	12.41	0.001
T2	12.983	0.256	11.762	0.169	-1.221	0.306	15.877	<0.001
CW-Apex	9.480	0.368	9.665	0.243	0.185	0.441	0.176	0.675
(CW-D)	10.870	0.249	11.174	0.368	0.304	0.516	0.217	0.387
ASA	6.330	1.139	7.431	0.751	1.101	1.364	0.652	0.421
PSA	-23.320	1.261	-22.114	0.831	1.206	1.510	0.638	0.426

*Statistically significant at p≤0.05

Table 4.9: Comparison between males and females in the adult group (n=90)

	Male (n=35)		Female (n=55)		Difference (Female-Male)		Two-way ANOVA	
	Mean	SE	Mean	SE	Mean	SE	F	P
Cranial base measurements								
SN*	68.723	0.622	66.667	0.501	2.056	0.799	0.767	0.012
SN/H*	11.044	0.577	13.344	0.465	2.300	0.741	0.946	0.030
S-Ar	34.786	0.618	34.169	0.498	-0.616	0.793	0.603	0.439
Relationship between jaws, cranial base and horizontal								
SNA	83.193	0.665	82.366	0.535	0.827	0.854	0.250	0.335
SNB*	77.606	0.626	75.748	0.504	1.858	0.803	0.232	0.023
ANB	6.000	0.271	6.367	0.219	-0.367	0.348	1.213	0.296
N-ANS	51.846	0.605	51.020	0.487	-0.825	0.777	1.270	0.291
NA/Apog	10.724	0.646	11.496	0.520	-0.772	0.829	1.385	0.354
ANS-Me	67.959	0.816	66.643	0.657	1.316	1.047	0.026	0.212
PFH*	46.997	0.847	44.067	0.682	2.930	0.008	0.001	0.008
LFH %	56.469	0.424	56.627	0.342	-0.158	0.545	0.688	0.772
PP/MP	27.019	0.950	27.421	0.764	-0.403	1.219	5.773	0.742
MP/SN*	34.133	1.063	37.411	0.856	-3.278	1.364	0.046	0.018
Pog-N	-2.359	0.712	-2.710	0.573	0.352	0.914	0.026	0.701
Jaw specific measurements								
Co-Gn	114.647	1.388	112.189	1.117	2.458	1.782	2.046	0.171
Co-Go*	57.697	0.789	54.478	0.636	3.219	1.013	0.025	0.020
Co/Go/Me								
T1	122.700	0.905	121.370	0.729	-1.33	1.162	1.309	0.256
T2	121.651	0.956	121.493	0.77	-1.159	1.227	0.017	0.897
Relationship between teeth and jaws								
U1/NA	19.086	1.077	18.528	0.867	-0.558	1.383	0.163	0.688
U1-NA	2.996	0.358	2.919	0.288	-0.770	0.460	0.028	0.867
U1/SN	101.777	1.350	100.637	1.087	-1.140	1.733	0.433	0.512
U1/PP	109.996	1.162	109.669	0.936	-0.327	1.492	0.048	0.827
L1/NB	30.661	0.859	32.833	0.692	2.172	1.103	3.879	0.052
L1-NB	7.099	0.329	7.591	0.265	0.492	0.423	1.356	0.247
L1/MP	98.263	1.110	100.258	0.893	1.995	1.424	1.962	0.165
OP/PP	6.533	0.375	7.425	0.302	-0.892	0.481	0.114	0.067
U6-PP	20.666	0.376	20.280	0.303	0.386	0.483	2.450	0.426
L6-MP*	31.614	0.612	29.959	0.493	1.655	0.786	0.445	0.038
Relationship between teeth								
U1/L1	125.071	1.358	122.960	1.093	-2.111	1.744	1.466	0.229
Soft tissue measurements								
UL-E-Line	-3.179	0.361	-2.461	0.291	0.717	0.463	2.398	0.125
LL-E-Line	-0.431	0.411	0.453	0.331	0.884	0.528	2.809	0.097
Nasolabial Angle*	108.793	1.735	114.204	1.397	5.411	2.228	8.748	0.04
Mentolabial Angle	120.834	2.246	123.869	1.809	3.035	2.884	1.108	0.296
U lip length	15.566	0.221	16.114	0.203	0.548	0.331	0.287	0.578
L lip length	18.625	0.441	18.784	0.365	0.159	0.185	0.269	0.621
Symphyseal components								
D-Apex	10.730	0.326	10.382	0.263	-0.348	0.419	0.688	0.409
D-Me*	11.850	0.195	11.092	0.157	-0.758	0.251	9.163	0.030
CW-Apex*	9.641	0.403	8.069	0.324	-1.573	0.517	9.248	0.030
(CW-D)	12.736	0.205	12.964	0.412	0.228	0.111	0.654	0.587
ASA	3.299	1.275	5.752	1.026	2.453	1.636	2.248	0.137
PSA	-21.256	1.062	-23.355	0.855	-2.099	1.363	2.372	0.127

*Statistically significant at $p \leq 0.05$

Table 4.10: Comparisons of the change (T2-T1) in cephalometric variables between males and females in all age groups (n=285)

Variables T2-T1	Male (n=117)		Female (n=168)		Difference (Female-Male)		Two-way ANOVA	
	Mean	SE	Mean	SE	Mean	SE	F	P
Cranial base measurements								
SN	1.657	0.113	1.601	0.093	-0.056	0.321	0.145	0.703
SN/H	0.082	0.031	0.080	0.025	-0.020	0.040	0.002	0.963
S-Ar	1.615	0.141	1.391	0.117	-0.223	0.183	1.482	0.224
Relationship between jaws, cranial base and horizontal								
SNA	-0.606	0.107	-0.754	0.089	-0.148	0.140	1.128	0.289
SNB								
Pre	-0.294	0.186	-0.02	0.202	0.274	0.275	0.993	0.322
Post	0.343	0.170	-0.168	0.112	-0.511	0.203	6.322	0.014
Adult	0.166	0.088	0.111	0.071	-0.055	0.113	0.232	0.631
ANB								
Pre	-0.588	0.228	-1.264	0.247	-0.675	0.336	4.035	0.047
Post	-0.990	0.228	-0.777	0.15	1.053	0.316	0.213	0.437
Adult	-0.411	0.142	-0.211	0.114	0.2	0.182	1.213	0.274
N-ANS	2.340	0.168	2.403	0.139	0.063	0.218	0.082	0.774
NA/Apog	-0.100	0.235	-0.350	0.195	-0.250	0.305	0.669	0.414
ANS-Me	0.396	0.177	0.321	0.147	-0.75	0.230	0.108	0.743
PFH								
Pre	2.9	0.183	2.636	0.199	-0.264	0.271	0.95	0.332
Post								
Adult	1.234	0.24	1.241	0.193	0.006	0.309	0.000	0.983
PP/MP	-0.610	0.135	-0.524	0.112	0.086	0.175	0.240	0.918
MP/SN	-0.300	0.123	-0.311	0.102	-0.011	0.160	0.005	0.624
Pog-N	0.050	0.104	0.015	0.086	0.065	0.135	0.230	0.943
Jaw specific measurements								
Co-Gn	2.967	0.631	2.699	0.523	-0.268	0.819	0.107	0.744
Co-Go*	2.506	0.224	1.929	0.186	-0.577	0.291	3.940	0.048
Co/Go/Me								
Pre	-1.563	0.43	-1.927	0.468	-0.364	0.635	0.328	0.568
Post	-0.367	0.551	-1.314	0.363	0.948	0.660	2.064	0.154
Adult	-1.049	0.365	0.122	0.294	1.171	0.468	6.254	0.014
Relationship between teeth and jaws								
U1/NA	-2.189	0.722	-2.137	0.598	0.052	0.938	0.003	0.956
U1-NA	-1.414	0.237	-1.470	0.196	-0.056	0.308	0.034	0.885
U1/SN	-3.253	0.793	-3.680	0.657	-0.427	1.030	0.172	0.679
U1/PP	-2.551	0.954	-2.522	0.790	0.029	1.239	0.001	0.981
L1/NB	0.529	0.562	0.523	0.466	-0.005	0.730	0.002	0.994
L1-NB	0.234	0.175	0.073	0.145	-0.161	0.227	0.502	0.479
L1/MP	0.496	0.591	0.321	0.490	-0.175	0.768	0.052	0.820
OP/PP	0.052	0.044	0.039	0.037	-0.013	0.057	0.049	0.825
U6-PP	0.406	0.078	0.284	0.064	-0.122	0.101	1.459	0.228
L6-MP	0.297	0.087	0.317	0.072	0.020	0.113	0.031	0.861
Relationship between teeth								
U1/L1	3.214	1.088	3.393	0.902	0.178	1.413	0.016	0.679
Soft tissue measurements								
UL-E-Line	-2.211	0.155	-1.998	0.129	0.213	0.202	1.115	0.292
LL-E-Line	-1.341	0.175	-1.226	0.145	0.115	0.228	0.255	0.614
Nasolabial Angle	-0.759	0.632	-0.334	0.524	0.425	0.821	0.268	0.605
Mentolabial Angle	3.120	1.049	4.500	0.869	1.379	1.363	1.025	0.312
U lip length*	1.138	0.102	0.887	0.084	-0.250	0.132	3.593	0.059
L lip length	1.757	0.124	1.644	0.103	-0.113	0.161	0.491	0.484
Symphyseal components								
D-Apex	1.714	0.156	1.489	0.129	-0.226	0.203	1.244	0.266
D-Me	0.609	0.083	0.383	0.069	-0.226	0.107	4.416	0.121
CW-Apex	-0.711	0.110	-0.865	0.091	-0.154	0.143	1.159	0.283
(CW-D)	0.295	0.077	0.222	0.064	-0.073	0.100	0.532	0.467
ASA	1.781	0.270	1.919	0.224	0.138	0.351	0.155	0.684
PSA	0.879	0.372	1.144	0.308	0.266	0.483	0.302	0.583

*Statistically significant at $p \le 0.05$

Table 4.11: Descriptive statistics for the eight cephalometric variables at (T2-T1) (growing patients)

Growing Patients	UFR		FR	
	n=130		n=65	
	Mean	**SD**	**Mean**	**SD**
AFH	1.64	1.46	-1.23	1.22
PFH	2.26	1.23	2.36	1.18
SNB	-0.589	0.867	0.867	0.925
OP/PP	0.796	0.836	-0.67	0.876
Y Axis	0.417	0.299	-0.347	0.346
U6-PP	0.841	0.518	-0.238	0.509
L6-MP	0.773	0.453	-0.235	0.578
Co-Go	-1.43	1.54	1.81	1.27

**Statistically significant: p<0.01.*

Table 4.12: Classification results for the stepwise discriminant analysis (growing patients)

Growing patients	Predicted group membership			
	UFR		FR	
Original group	N	%	N	%
UFR (n=130)	121	93.1	9	6.9
FR (n=65)	2	3.1	63	96.9
94.4% of original grouped cases correctly classified				
Cross-validated	N	%	N	%
UFR (n=130)	120	92.3	10	7.7
FR (n=65)	2	4.6	62	95.4
93.3% of cross-validated grouped cases correctly classified				

Table 4.13: Descriptive statistics for the ten cephalometric variables at T2-T1 (pre-pubertal group)

Pre-pubertal patients	UFR		FR	
	N=70		N=26	
	Mean	**SD**	**Mean**	**SD**
AFH	1.89	1.49	-1.30	1.14
PFH	2.47	0.96	2.80	1.07
SNB	-0.69	0.84	1.14	1.26
OP/PP	0.88	0.81	-0.64	1.07
Y Axis	0.42	0.32	-0.33	0.40
U6-PP	0.86	0.49	-0.21	0.38
L6-MP	0.82	0.37	-0.06	0.55
Co-Go	-1.4	1.5	1.96	1.35

**Statistically significant: p<0.01*

Table 4.14: Classification results for the stepwise discriminant analysis (pre-pubertal group)

Pre-pubertal patients	Predicted group membership			
	UFR		FR	
Original group	N	%	N	%
UFR (n=70)	65	92.9	5	7.1
FR (n=26)	1	3.8	25	96.2
93.8% of original grouped cases correctly classified				
Cross-validated	N	%	N	%
UFR (n=70)	65	92.9	5	7.1
FR (n=26)	1	3.8	25	96.2
93.8% of original grouped cases correctly classified				

Table 4.15: Descriptive statistics for the eight cephalometric measurements at T2-T1 (post-pubertal group)

Post-pubertal patients	UFR		FR	
	N=60		N=39	
	Mean	**SD**	**Mean**	**SD**
AFH	1.34	1.38	-1.19	1.28
PFH	2.01	1.46	2.06	1.17
SNB	-0.46	0.88	0.68	0.55
OP/PP	0.69	0.85	-0.68	0.72
Y Axis	0.41	0.27	-0.35	0.31
U6-PP	0.81	0.54	-0.25	0.58
L6-MP	0.71	0.52	-0.35	0.57
Co-Go	-1.46	1.57	1.71	1.22

**Statistically significant: p<0.01.*

Table 4.16: Classification results for the stepwise discriminant analysis (post-pubertal group)

Post-pubertal patients	Predicted group membership			
	UFR		FR	
Original group	N	%	N	%
UFR (n=60)	55	91.7	5	8.3
FR (n=39)	1	2.6	38	97.4
93.9% of original grouped cases correctly classified				
Cross-validated	N	%	N	%
UFR (n=60)	55	91.7	5	8.3
FR (n=39)	2	5.1	37	94.9
92.9% of cross-validated grouped cases correctly classified				

Table 4.17: Descriptive statistics for the eight cephalometric variables at T2-T1 (adult group)

Adult patients	UFR n=31		FR n=59	
	Mean	**SD**	**Mean**	**SD**
AFH	1.25	0.92	-1.14	0.87
PFH	1.35	1.31	1.18	1.46
SNB	-0.38	0.39	0.42	0.36
OP/PP	0.20	0.31	-0.39	0.28
MP/SN	0.77	0.51	-0.84	0.43
U6-PP	0.97	0.93	-0.43	0.82
L6-MP	1.45	1.09	-0.90	1.03
Co-Go	-1.03	0.83	0.94	0.69

**Statistically significant: p<0.01.*

Table 4.18: Classification results for the stepwise discriminant analysis (adult group)

Adult patients	**Predicted group membership**			
	UFR		FR	
Original group	N	%	n	%
UFR (n=31)	30	96.8	1	3.2
FR (n=59)	1	1.7	58	98.3
97.8% of original grouped cases correctly classified				
Cross-validated	N	%	n	%
UFR (n=31)	30	96.8	1	3.2
FR (n=59)	1	1.7	58	98.3
97.8% of original grouped cases correctly classified				

Table 4.19: Correlations between the change of the variables between T2-T1 for growing patients

	SN/H2_1	Co-Go2_1	AFH2_1	PFH2_1	NA-Pog2_1	Pog-N2_1	SNB2_1	ANB2_1	Y axis2_1	OP/PP2_1	U6-PP2_1	L6-MP2_1
SN/H2_1	1											
Co-Go2_1	-.138	1										
AFH2_1	.158	-.672***	1									
PFH2_1	0.017	0.053	-0.025	1								
NAPog2_1	.125	-.712***	.602**	-0.004	1							
Pog-N2_1	-.113	.821**	-.759**	0.047	-.711**	1						
SNB2_1	-0.083	.577**	-.592**	-0.024	-.536**	.579**	1					
ANB2_1	-0.003	-.405**	.425**	0.032	.341**	-.417**	-.536**	1				
Y axis2_1	0.042	-.667**	.613**	-0.015	.636**	-.694**	-.554**	.336**	1			
OP/PP2_1	.129	-.749**	.672**	-0.071	.652**	-.824**	-.523**	.429**	.655**	1		
U6-PP2_1	.137	-.649**	.645**	-0.006	.619**	-.717**	-.484**	.365**	.628**	.681**	1	
L6-MP2_1	.113	-.670**	.641**	-0.067	.597**	-.696**	-.530**	.367**	.544**	.672**	.690**	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 4.20: Correlations between the change of the variables between T2-T1 for growing patients (pre-pubertal)

	SN/H2_1	Co-Go2_1	AFH2_1	PFH2_1	NA-Pog2_1	Pog-N2_1	SNB2_1	ANB2_1	Y axis2_1	OP/PP2_1	U6-PP2_1	L6-MP2_1
SN/H2_1	1											
Co-Go2_1	-.114	1										
AFH2_1	.128	-.723**	1									
PFH2_1	0.032	0.09	-0.074	1								
NAPog2_1	.106	-.781**	.744**	-.117	1							
Pog-N2_1	-0.053	.844**	-.771**	0.06	-.801**	1						
SNB2_1	-0.054	.620**	-.623**	.188	-.643**	.616**	1					
ANB2_1	-0.006	-.427**	.513**	0.017	.453**	-.480**	-.529**	1				
Y axis2_1	-0.011	-.713**	.597**	-0.086	.668**	-.687**	-.547**	.395**	1			
OP/PP2_1	0.055	-.757**	.643**	-0.052	.719**	-.828**	-.556**	.477**	.629**	1		
U6-PP2_1	.100	-.724**	.677**	0.037	.788**	-.773**	-.533**	.433**	.623**	.687**	1	
L6-MP2_1	0.062	-.705**	.677**	-0.138	.696**	-.728**	-.594**	.432**	.541**	.649**	.699**	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 4.21: Correlations between the change of the variables between T2-T1 for growing patients (post-pubertal)

	SN/H2_1	Co-Go2_1	AFH2_1	PFH2_1	NA-Pog2_1	Pog-N2_1	SNB2_1	ANB2_1	Y axis2_1	OP/PP2_1	U6-PP2_1	L6-MP2_1
SN/H2_1	1											
Co-Go2_1	-.207	1										
AFH2_1	.236	-.621**	1									
PFH2_1	-0.023	0.057	-0.062	1								
NAPog2_1	.183	-.692**	.504**	-0.012	1							
Pog-N2_1	-.240	.800**	-.738**	0.091	-.661**	1						
SNB2_1	-.158	.532**	-.547**	-.194	-.492**	0.534**	1					
ANB2_1	0.004	-.390**	.328**	0.056	.298**	-.357**	-.555**	1				
Y axis2_1	.149	-.619**	.609**	-0.02	.621**	-.690**	-.561**	.274**	1			
OP/PP2_1	.296	-.739**	.694**	-0.135	.620**	-.815**	-.480**	.382**	.672**	1		
U6-PP2_1	.227	-.584**	.607**	-0.081	.514**	-.663**	-.439**	.313**	.624**	.670**	1	
L6-MP2_1	.211	-.658**	.604**	-.108	.521**	-.670**	-.499**	.352**	.535**	.694**	.677**	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 4.22: Correlations between the change of the variables between T2-T1 for adult patients

	SN/H2_1	Co-Go2_1	AFH2_1	PFH2_1	NA-Pog2_1	Pog-N2_1	SNB2_1	ANB2_1	MP/SN2_1	OP/PP2_1	U6-PP2_1	L6-MP2_1
SN/H2_1	1											
Co-Go2_1	-0.09	1										
AFH2_1	0.140	-.792**	1									
PFH2_1	0.214	0.029	0.063	1								
NAPog2_1	-0.016	-.550**	.513**	0.091	1							
Pog-N2_1	-0.085	.704**	-.735**	-0.038	-.566**	1						
SNB2_1	-0.042	.715**	-.627**	0.009	-.542**	.688**	1					
ANB2_1	0.052	-.626**	.492**	-0.099	.517**	-.488**	-.578**	1				
MP/SN2_1	-0.039	-.688**	.715**	0.166	.551**	-.791**	-.638**	.518**	1			
OP/PP2_1	0.005	-.622**	.667**	0.121	.348*	-.736**	-.592**	.354**	.660**	1		
U6-PP2_1	-0.098	-.589**	.564**	-0.065	.521**	-.623**	-.495**	.288**	.509**	.467**	1	
L6-MP2_1	-0.085	-.648**	.610**	-0.019	.569**	-.719**	-.598**	.433**	.610**	.530**	.653**	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

TTable 4.23:Logistic Regression for the improvement of Pog-N in Growing group(n=195)

Variables	B	SE	Wald	df	Exp(B)	Significance
SNB2_1	-.589	0.696	1.424	1	0.591	0.02
OPPP2_1	0.417	0.104	1.297	1	0.001	0.04
U6PP2_1	0.843	0.232	0.088	1	0.502	<0.001
AFH2_1	1.642	1.224	1.774	1	0.158	<0.001
Constant	-.354	0.529	.329	1	0.004	0.01

*Statistically significant at p≤0.05

Table 4.24: Logistic Regression for the improvement of Pog-N in Pre-pubertal group(n=96)

Variables	B	SE	Wald	df	Exp(B)	Significance
SNB2_1	2.429	1.230	3.902	1	11.351	0.048
OPPP2_1	0.417	0.104	1.297	1	0.04	0.01
Constant	-0.969	0.658	2.168	1	0.379	0.01

*Statistically significant at p≤0.05

Table 4.25:Logistic Regression for the improvement of Pog-N in Post-pubertal group(n=99)

Variables	B	SE	Wald	df	Exp(B)	Significance
SNB2_1	2.212	0.985	5.040	1	9.130	0.025
OPPP2_1	-4.490	1.832	6.009	1	0.011	0.014
U6PP2_1	-1.872	0.861	4.723	1	0.154	0.030
Constant	-1.115	0.729	2.341	1	0.328	0.126

*Statistically significant at p≤0.05

Table 4.26: Logistic Regression for the improvement of Pog-N in Adult group(n=90)

Variables	B	SE	Wald	df	Exp(B)	Significance
SNH	-77.83	56918.18	.000	1	.000	.999
CoGo	-1.84	15190.89	.000	1	.158	1.000
AFH	3.77	9062.26	.000	1	43.707	1.000
PFH	8.89	6546.33	.000	1	7283.418	.999
NAApog	-17.24	5858.33	.000	1	.000	.998
PogN	11.19	11871.39	.000	1	72667.744	.999
SNB	12.76	18173.85	.000	1	349803.519	.999
ANB	-1.37	9663.41	.000	1	.252	1.000
MPSN	-21.92	17468.53	.000	1	.000	.999
OPPP	-20.22	20385.02	.000	1	.000	.999
U6PP	14.14	7565.71	.000	1	1384012.379	.999
L6MP	-14.31	5529.28	.000	1	.000	.998
Constant	-15.50	11475.52	.000	1	.000	.999

*Statistically significant at p≤0.05

Table 4.27. Independent t test results between severity subgroups

Age group	Severity	Mean change in Pog-N at T2-T1 (mm)	SD	P-value
Adult (n=90)	Low severity n=55	0.780	1.02	0.043*
	High severity n=35	0.305	1.08	
Growing (n=195)	Low severity n=147	0.339	1.07	0.138
	High severity n=48	0.066	1.16	

*Statistically significant at p≤0.05

APPENDIX 2

Intra-class coefficient of all variables for repeated measurements in 10% of the sample

Variables	T1		T2	
	R	p-Value	r	p-Value
SN	0.906	<0.001	0.997	<0.001
SN/H	0.982	<0.001	0.999	<0.001
S-Ar	0.904	<0.001	0.962	<0.001
SN/Ar	0.991	<0.001	0.976	<0.001
SNA	0.973	<0.001	0.993	<0.001
SNB	0.989	<0.001	0.996	<0.001
ANB	0.983	<0.001	0.991	<0.001
NA/Apog	0.994	<0.001	0.994	<0.001
N-ANS	0.987	<0.001	0.975	<0.001
ANS-Me (AFH)	0.997	<0.001	0.992	<0.001
Ar-Go (PFH)	0.897	<0.001	0.93	<0.001
LFH/TFH (%)	0.901	<0.001	0.99	<0.001
PP/MP	0.951	<0.001	0.979	<0.001
MP/SN	0.977	<0.001	0.979	<0.001
PP/H	0.98	<0.001	0.97	<0.001
MP/H	0.964	<0.001	0.979	<0.001
Pog Proj	0.987	<0.001	0.985	<0.001
Co-Gn	0.98	<0.001	0.997	<0.001
Co-Pog	0.982	<0.001	0.997	<0.001
Co-Go	0.922	<0.001	0.893	<0.001
Go-Gn	0.933	<0.001	0.938	<0.001
Co/Go/Me	0.912	<0.001	0.96	<0.001
ANS-PNS	0.98	<0.001	0.997	<0.001
U1/NA	0.919	<0.001	0.99	<0.001
U1-NA	0.97	<0.001	0.984	<0.001
U1/SN	0.946	<0.001	0.985	<0.001
U1/PP	0.93	<0.001	0.985	<0.001
L1/NB	0.987	<0.001	0.981	<0.001
L1-NB	0.988	<0.001	0.987	<0.001
L1/MP	0.937	<0.001	0.985	<0.001
U1/L1	0.969	<0.001	0.982	<0.001
Overbite (OB)	0.995	<0.001	0.956	<0.001
Overjet (OJ)	0.991	<0.001	0.949	<0.001
UL- E line	0.971	<0.001	0.933	<0.001
LL- E line	0.972	<0.001	0.981	<0.001
Naso labial angle	0.986	<0.001	0.988	<0.001
Mento labial angle	0.987	<0.001	0.994	<0.001
U lip length	0.967	<0.001	0.972	<0.001
U lip thickness @ A	0.893	<0.001	0.964	<0.001
U lip inclination	0.974	<0.001	0.986	<0.001
L lip length	0.972	<0.001	0.958	<0.001
L lip thickness @ B	0.883	<0.001	0.882	<0.001
St Chin thickness	0.991	<0.001	0.987	<0.001
Pn-D	0.97	<0.001	0.994	<0.001
D-Apex	0.88	<0.001	0.89	<0.001
D-Me	0.91	<0.001	0.92	<0.001
CW-Apex	0.893	<0.001	0.891	<0.001
(CW-D)	0.936	<0.001	0.984	<0.001
ASA	0.989	<0.001	0.996	<0.001
PSA	0.992	<0.001	0.947	<0.001

APPENDIX 3

Descriptive statistics for all cephalometric variables of pre-pubertal group at T1

Descriptive	T1											
	Pre-pubertal (n=96)				Male (n=52)				Female (n=44)			
Variables	**Mean**	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**
Cranial base measurements												
SN	64.64	3.18	56.40	75.80	65.10	2.74	60.50	71.60	64.09	3.59	56.40	75.80
SN/H	12.85	3.04	5.50	21.20	12.64	3.10	5.50	21.20	13.10	3.00	7.70	18.80
S-Ar	32.28	3.11	24.00	41.30	33.03	2.91	27.60	41.30	31.40	3.16	24.00	39.50
Relationship between jaws, cranial base and horizontal												
SNA	81.72	2.79	74.70	89.40	81.43	2.88	74.70	88.00	82.06	2.70	77.70	89.40
SNB	75.69	2.76	70.00	82.40	75.77	2.56	71.10	82.40	75.98	3.02	70.00	82.40
ANB	6.93	1.67	4.50	10.60	5.77	1.61	4.50	9.10	6.14	1.75	4.70	10.60
NA/APog	12.25	4.61	1.20	22.40	10.69	4.74	1.20	20.90	11.92	4.41	1.60	22.40
N-ANS	48.61	3.2	41.70	56.90	49.30	2.46	45.40	56.90	47.81	3.78	41.70	56.70
ANS-Me (AFH)	61.20	4.83	53.80	76.80	62.58	5.20	53.80	76.80	59.57	3.81	54.00	74.50
Ar-Go (PFH)	40.35	4.67	30.00	53.10	41.46	4.42	32.80	53.10	39.06	4.68	30.00	49.50
LFH	55.45	1.78	49.50	58.80	55.47	1.88	49.50	58.80	55.45	1.69	51.70	58.80
Y axis	68.86	2.88	63.20	78.70	68.73	2.90	63.20	78.70	69.03	2.91	63.30	76.80
PP/MP	27.37	4.52	15.70	41.20	27.14	5.05	15.70	41.20	27.65	3.84	20.30	37.70
MP/SN	36.72	4.42	26.10	51.70	36.48	4.80	26.10	51.70	37.00	3.99	31.00	47.30
Pog-N	-3.25	3.06	-5.90	3.80	-2.78	3.15	-4.0	3.80	-3.81	2.89	-5.9	2.80
Jaw specific measurements												
Co-Go	49.79	4.64	37.00	62.70	47.26	5.16	37.00	63.10	49.79	4.64	42.30	62.70
Co/Go/Me	122.52	5.49	112.5	139.30	123.24	5.05	113.30	133.00	122.52	5.49	112.50	139.30
Relationship between teeth and jaws												
U1/NA	21.47	6.46	8.50	33.50	21.25	6.83	10.60	33.50	21.75	6.06	8.50	21.25
U1-NA	3.41	2.19	-1.10	7.90	3.37	2.30	-.40	7.90	3.47	2.09	-1.10	3.37
U1/SN	103.17	7.27	86.40	116.40	102.62	7.42	86.40	115.30	103.83	7.14	86.90	116.40
U1/PP	112.64	5.82	100.4	126.1	112.14	6.58	101.5	126.1	113.27	6.26	100.4	125.8
L1/NB	31.22	4.9	17.10	44.60	31.25	5.00	17.10	42.10	31.20	4.85	20.90	44.60
L1-NB	6.23	1.86	1.50	9.80	6.37	1.82	1.50	9.10	6.07	1.80	2.70	9.80
L1/MP	99.15	6.00	83.90	116.20	99.60	6.38	84.70	116.20	98.63	5.56	83.90	99.60

Descriptive	T1											
	Pre-pubertal (n=96)				Male(n=52)				Female(n=44)			
Variables	**Mean**	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**
OP/PP	7.18	2.14	2.80	11.30	7.36	2.10	2.80	11.30	6.98	2.20	3.10	10.60
U6-PP	15.95	2.33	11.60	23.90	16.25	2.38	11.60	23.90	15.61	2.27	12.10	22.70
L6-MP	26.9	2.6	21.10	34.60	26.94	3.14	21.10	34.60	26.40	2.17	22.50	34.00
Relationship between teeth												
U1/L1	121.15	8.44	101.7	140.5	121.75	9.17	104.2	140.5	121.22	7.60	101.7	135.7
Soft tissue measurements												
UL- E line	-0.22	1.91	-4.80	4.20	-.03	2.16	-4.80	4.20	-.46	1.56	-4.40	3.40
LL- E line	1.71	2.09	-3.60	6.40	1.80	2.38	-3.60	6.40	1.62	1.70	-2.00	5.00
Nasolabial angle	114.16	9.91	88.00	134.2	113.16	10.36	88.00	134.2	115.35	9.10	94.70	130.4
Mentolabial angle	120.73	15.61	80.50	151.2	120.44	14.33	85.7	145.1	121.08	16.11	80.50	151.2
U lip length	20.53	2.01	16.20	27.60	21.88	2.37	16.20	27.60	21.30	2.53	17.00	27.40
L lip length	16.67	2.36	12.80	27.80	18.74	2.88	12.80	27.80	18.07	2.92	14.00	27.70
Symphyseal Components												
D-Apex	6.25	2.12	1.80	13.20	6.38	2.26	1.80	10.00	6.10	1.98	3.00	13.20
D-Me	11.04	0.95	9.20	13.50	11.29	1.01	9.20	13.50	10.76	0.82	9.50	12.80
CW-Apex	10.19	1.79	4.90	14.80	10.25	1.95	7.00	14.80	10.12	1.61	4.90	13.70
(CW-D)	12	1.35	8.40	16.50	11.56	2.12	8.40	14.2	12.13	1.26	8.9	16.50
ASA	4.43	6.61	-12.6	18.20	5.76	6.35	-8.40	18.20	2.87	6.67	-12.6	14.80
PSA	-24	5.92	-38.4	-10.1	-24.84	5.74	-38.4	-12.3	-23.03	6.05	-36.9	-10.1
Time Factors												
Age	10.8	1.41	7.91	13.83	11.44	1.27	9.00	13.83	9.74	0.93	7.91	11.79

Descriptive statistics for all cephalometric variables of pre-pubertal group at T2

Descriptive	T2											
	Pre-pubertal (n=96)				Male (n=52)				Female (n=44)			
Variables	**Mean**	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**
Cranial base measurements												
SN	67.6	3.49	59.3	78.1	68.62	4.42	60.30	76.30	67.10	2.90	60.80	74.50
SN/H	12.97	3.08	5.5	21.2	10.95	3.37	2.60	17.80	12.94	2.75	7.10	22.30
S-Ar	34.7	3.14	26.1	43.4	35.50	4.16	27.90	43.40	34.21	3.32	28.00	42.40
Relationship between jaws, cranial base and horizontal												
SNA	80.66	2.79	73.2	88.9	82.40	4.41	73.20	91.30	80.80	3.21	73.30	90.80
SNB	75.86	2.94	69	82	77.64	4.52	69.90	84.70	75.84	2.67	69.70	82.70
ANB	5.04	1.70	1	9	4.61	1.34	2.30	7.40	4.98	1.43	1.80	9.40
NA/APog	10.49	4.26	1	23.1	10.32	3.21	2.20	15.30	10.38	3.82	3.00	22.20
N-ANS	52.8	2.83	46.9	59.7	52.56	4.56	35.10	58.60	52.74	3.04	47.00	60.10
ANS-Me (AFH)	62.22	5.00	53.1	78.1	64.70	6.82	50.80	83.00	62.32	4.74	49.80	76.20
Ar-Go (PFH)	43.13	4.81	32.8	55.5	44.65	5.57	36.80	59.60	43.71	4.23	35.60	57.70
LFH	55.45	1.78	50.50	61.20	56.09	2.31	51.80	61.20	55.77	1.94	50.50	59.90
Y axis	69.35	2.92	63	79	67.84	2.85	61.50	74.50	69.03	2.57	63.30	75.00
PP/MP	25.3	4.63	12.2	36.8	25.42	3.74	18.20	36.30	25.08	4.43	16.40	38.10
MP/SN	35.91	4.66	23.3	48.4	34.19	4.28	26.40	43.30	36.02	4.15	26.30	47.30
Pog-N	-1.68	2.93	-12.4	2.5	-1.76	5.03	-14.20	8.60	-2.12	4.18	-12.40	7.90
Jaw specific measurements												
Co-Go	55.19	5.82	35.6	62.5	53.33	5.99	44.20	67.50	50.23	4.61	40.50	60.60
Co/Go/Me	121.11	5.59	108.5	135.5	121.46	5.23	113.60	132.10	120.00	4.67	110.90	134.20
Relationship between teeth and jaws												
U1/NA	21.33	6.02	6.9	35.7	20.99	5.07	9.80	31.20	19.80	6.14	7.00	30.10
U1-NA	2.99	2.27	-1.1	8.3	3.06	2.47	-5.00	8.90	2.55	2.24	-5.00	8.40
U1/SN	102.56	7.21	86.4	117.8	103.38	5.29	94.00	114.50	100.80	6.00	88.30	113.20
U1/PP	112.65	5.82	97.8	125.2	112.43	5.50	100.50	122.30	111.83	7.33	95.00	122.90
L1/NB	31.66	5.14	18.5	41.1	31.58	6.37	17.90	42.80	30.93	5.86	17.00	41.00
L1-NB	6.76	1.98	1.5	11.2	6.72	2.24	2.30	12.00	6.49	1.94	3.50	13.00
L1/MP	99.65	5.72	82.2	112.5	100.10	7.69	81.00	113.10	98.56	6.66	85.50	112.50

Descriptive	T2											
	Pre-pubertal (n=96)				Male(n=52)				Female(n=44)			
Variables	**Mean**	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**
OP/PP	7.40	2.15	3.10	11.80	6.98	1.97	3.50	11.80	7.21	2.12	3.10	10.60
U6-PP	16.66	2.43	12.10	31.40	19.04	3.48	12.70	31.40	17.28	2.23	12.10	22.70
L6-MP	27.9	2.75	22.20	39.10	29.01	3.85	22.20	39.10	28.45	2.20	22.60	37.50
Relationship between teeth												
U1/L1	122.69	8.29	105.50	148.70	124.08	9.18	109.20	148.70	125.14	10.02	105.50	148.70
Soft tissue measurements												
UL- E line	-3.18	2.18	-9.00	2.00	-3.43	2.40	-9.00	0.80	-2.93	2.47	-9.00	2.00
LL- E line	0.32	2.44	-7.10	5.70	-0.47	3.06	-7.10	4.70	0.40	3.05	-6.40	5.70
Naso labial angle	111.49	11.34	80.00	135.10	114.61	9.08	97.50	132.90	109.58	9.55	80.00	135.10
Mento labial angle	126.1	11.11	95.40	145.50	122.83	11.04	100.70	144.60	124.79	10.62	95.40	145.50
U lip length	21.7	2.07	17.20	29.20	22.77	2.53	17.60	29.20	22.17	2.47	17.20	27.80
L lip length	18.96	2.28	14.50	27.70	19.45	2.65	15.30	27.70	19.34	2.90	14.50	27.70
Symphyseal Components												
D-Apex	8.73	2.18	4.20	15.10	10.20	2.76	4.70	15.10	8.97	2.13	4.20	14.30
D-Me	11.83	1.3	9.30	16.90	12.98	1.79	9.60	16.90	11.76	1.20	9.30	14.40
CW-Apex	9.05	1.84	4.00	13.20	9.10	2.52	4.00	13.10	9.20	1.96	4.20	13.20
(CW-D)	13.05	1.76	7.90	19.40	13.28	2.11	7.9	18	12.89	2	9.5	19.4
ASA	7.49	7.14	-10.20	22.50	7.12	6.47	-6.80	19.00	8.40	6.78	-10.20	22.50
PSA	-21.7	6.62	-37.10	-8.00	-22.92	7.63	-35.80	-7.60	-21.83	7.33	-37.10	-8.00
Time Factors												
Age	15.04	1.76	11.75	20.74	15.61	1.90	11.75	20.74	14.36	1.34	12.08	17.85
Tx time	4.38	1.44	1.75	8.10	4.17	1.46	1.75	7.83	4.62	1.38	2.10	8.10

APPENDIX 4

Descriptive statistics for all cephalometric variables of post-pubertal group at T1

Descriptive	T1											
	Post-pubertal (n=99)				Male(n=30)				Female(n=69)			
Variables	**Mean**	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**
Cranial base measurements												
SN	65.83	3.35	59.00	74.00	67.05	4.25	59.00	74.00	65.31	2.75	60.10	72.30
SN/H	12.26	3.09	2.50	22.20	10.89	3.42	2.50	17.80	12.86	2.75	7.10	22.20
S-Ar	33.12	3.34	26.80	40.30	33.72	3.97	26.80	40.30	32.86	3.03	27.30	38.40
Relationship between jaws, cranial base and horizontal												
SNA	82.11	3.4	74.60	91.70	83.10	4.06	74.60	91.70	81.69	3.02	74.60	90.10
SNB	76.39	3.18	70.10	84.80	77.30	3.97	70.10	84.80	76.01	2.72	70.10	84.50
ANB	5.71	1.35	4.50	9.80	5.60	1.13	4.50	9.00	5.76	1.44	4.50	9.80
NA/APog	11.88	4.08	1.30	21.20	10.53	3.58	1.30	15.30	11.04	4.30	1.50	21.20
N-ANS	50.05	3.17	34.00	56.10	50.38	4.25	34.00	56.10	49.92	2.59	44.00	56.20
LFH	55.45	1.78	50.00	61.20	55.56	2.20	51.00	61.20	55.16	1.84	50.00	59.20
ANS-Me (AFH)	62.66	5.33	50.50	83.90	64.39	6.40	51.50	83.90	61.92	4.66	50.50	75.60
Ar-Go (PFH)	41.84	4.73	32.40	59.60	43.23	5.44	35.60	59.60	41.24	4.30	32.40	54.90
Y axis	68.67	2.69	61.50	75.00	67.84	2.85	61.50	74.50	69.03	2.57	63.30	75.00
PP/MP	27	4.88	16.40	38.10	25.42	3.74	18.20	36.30	25.08	4.43	16.40	38.10
MP/SN	36.67	4.74	26.30	47.30	34.19	4.28	26.40	43.30	36.02	4.15	26.30	47.30
Pog-N	-2.90	5.28	-14.2	8.60	-3.12	5.03	-14.2	8.60	-3.76	4.18	-12.4	7.90
Jaw specific measurements												
Co-Gn	106.63	7.28	87.00	128.40	113.93	10.62	87.00	128.40	113.36	5.90	100.00	128.40
Co-Go	51.39	5.34	40.50	67.50	53.33	5.99	44.20	67.50	50.23	4.61	40.50	60.60
Co/Go/Me	121.46	5.22	110.9	134.20	121.46	5.23	113.60	132.10	120.00	4.67	110.90	134.20
Relationship between teeth and jaws												
U1/NA	21.1	6.53	7.00	31.20	20.99	5.07	9.80	31.20	19.80	6.14	7.00	30.10
U1-NA	3.46	2.23	-5.00	8.90	3.06	2.47	-5.00	8.90	2.55	2.24	-5.00	8.40
U1/SN	101.58	5.89	88.30	114.5	103.38	5.29	94.00	114.50	100.80	6.00	88.30	113.20
U1/PP	111.84	12.18	95.00	122.9	112.43	5.50	100.50	122.30	111.83	7.33	95.00	122.90
L1/NB	30.04	5.51	17.00	42.80	31.58	6.37	17.90	42.80	30.93	5.86	17.00	41.00
L1-NB	6.14	2.01	2.30	13.00	6.72	2.24	2.30	12.00	6.49	1.94	3.50	13.00
L1/MP	98.19	6.34	81.00	113.10	100.10	7.69	81.00	113.10	98.56	6.66	85.50	112.50

Descriptive	T1											
	Post-pubertal (n=99)				Male(n=30)				Female(n=69)			
Variables	**Mean**	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**
OP/PP	7.01	1.99	3.10	11.80	6.98	1.97	3.50	11.80	7.21	2.12	3.10	10.60
U6-PP	17.32	2.90	12.10	31.40	19.04	3.48	12.70	31.40	17.28	2.23	12.10	22.70
L6-MP	28.03	2.78	22.20	39.10	29.01	3.85	22.20	39.10	28.45	2.20	22.60	37.50
Relationship between teeth												
U1/L1	123.92	9.08	105.5	148.7	124.08	9.18	109.2	148.7	125.14	10.02	105.5	148.7
Soft tissue measurements												
UL- E line	-0.8	2.15	-9.00	2.00	-3.43	2.40	-9.00	0.80	-2.93	2.47	-9.00	2.00
LL- E line	1.22	2.86	-7.10	5.70	-0.47	3.06	-7.10	4.70	0.40	3.05	-6.40	5.70
Nasolabial angle	112.6	9.72	80.00	135.1	114.6	9.08	97.5	132.9	109.5	9.55	80.00	135.1
Mentolabial angle	120.85	11.8	95.40	145.5	122.83	11.04	100.7	144.6	124.79	10.62	95.40	145.5
U lip length	21.18	2.44	16.40	28.80	22.54	2.78	17.50	28.80	20.60	2.03	16.40	24.7
L lip length	17.02	2.37	12.70	23.00	17.84	2.26	12.70	21.30	16.67	2.34	14	23.00
Symphyseal components												
D-Apex	7.65	2.55	4.20	15.10	10.20	2.76	4.70	15.10	8.97	2.13	4.20	14.30
D-Me	11.5	1.67	9.30	16.90	12.98	1.79	9.60	16.90	11.76	1.20	9.30	14.40
CW-Apex	9.95	2.02	4.00	13.20	9.10	2.52	4.00	13.10	9.20	1.96	4.20	13.20
(CW-D)	12.88	2.02	8.10	17.6	12.75	2.36	8.10	15.4	12.85	2.45	9.6	17.6
ASA	6.27	6.64	-10.2	22.50	7.12	6.47	-6.80	19.00	8.40	6.78	-10.20	22.50
PSA	-22.16	7.05	-37.1	-8.00	-22.92	7.63	-35.8	-7.60	-21.83	7.33	-37.10	-8.00
Time factors												
Age	13.43	1.08	12.0	16.83	14.66	0.68	14.00	16.83	12.89	0.73	12	15

Descriptive statistics for all cephalometric variables of post-pubertal group at T2

Descriptive	T2											
	Post-pubertal (n=90)				Male(n=30)				Female(n=69)			
Variables	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max
Cranial base measurements												
SN	67.56	3.47	60.80	76.30	68.62	4.42	60.30	76.30	67.10	2.90	60.80	74.50
SN/H	12.34	3.07	2.60	22.30	10.95	3.37	2.60	17.80	12.94	2.75	7.10	22.30
S-Ar	34.6	3.62	27.90	43.40	35.50	4.16	27.90	43.40	34.21	3.32	28.00	42.40
Relationship between jaws, cranial base and horizontal												
SNA	81.28	3.66	73.20	91.30	82.40	4.41	73.20	91.30	80.80	3.21	73.30	90.80
SNB	76.38	3.41	69.70	84.70	77.64	4.52	69.90	84.70	75.84	2.67	69.70	82.70
ANB	4.87	1.40	2.00	9.00	4.61	1.34	2.30	7.40	4.98	1.43	2.00	9.00
NA/Apog	10.36	3.62	2.20	18.50	10.32	3.21	2.20	15.30	10.38	3.82	3.0	18.50
N-ANS	53.37	2.98	35.10	60.10	52.56	4.56	35.10	58.60	52.74	3.04	47.00	60.10
ANS-Me (AFH)	63.04	5.53	49.80	83.00	64.70	6.82	50.80	83.00	62.32	4.74	49.80	76.20
Ar-Go (PFH)	43.99	4.66	35.60	59.60	44.65	5.57	36.80	59.60	43.71	4.23	35.60	57.70
Y axis	69.26	2.73	61.50	75.00	67.84	2.85	61.50	74.50	69.03	2.57	63.30	75.00
PP/MP	25.18	4.21	16.40	38.10	25.42	3.74	18.20	36.30	25.08	4.43	16.40	38.10
MP/SN	35.46	4.52	26.30	47.30	34.19	4.28	26.40	43.30	36.02	4.15	26.30	47.30
Pog-N	-1.85	5.08	-14.2	8.60	-1.76	5.03	-14.2	8.60	-2.04	4.18	-12.4	7.90
Jaw specific measurements												
Co-Gn	113.53	7.58	100.4	129.8	113.93	10.62	87.00	128.40	113.36	5.90	100.4	129.80
Co-Go	51.17	5.17	40.50	67.50	53.33	5.99	44.20	67.50	50.23	4.61	40.50	60.60
Co/Go/Me	120.44	4.86	110.9	134.2	121.46	5.23	113.60	132.10	120.00	4.67	110.90	134.20
Relationship between teeth and jaws												
U1/NA	18.23	5.83	7.00	31.20	20.99	5.07	9.80	31.20	19.80	6.14	7.00	30.10
U1-NA	2.70	2.31	-5.00	8.90	3.06	2.47	-5.00	8.90	2.55	2.24	-5	8.40
U1/SN	98.86	5.89	88.30	114.50	103.38	5.29	94.00	114.50	100.80	6.00	88.30	113.20
U1/PP	107.57	6.83	95.00	122.90	112.43	5.50	100.50	122.30	111.83	7.33	95.00	122.90
L1/NB	31.13	5.99	17.00	42.80	31.58	6.37	17.90	42.80	30.93	5.86	17.00	41.00
L1-NB	6.55	2.02	2.30	12.00	6.72	2.24	2.30	12.00	6.49	1.94	3.50	13.00
L1/MP	99.02	6.98	81.00	113.10	100.10	7.69	81.00	113.10	98.56	6.66	85.50	112.50

Descriptive Variables	T2											
	Post-pubertal(n=99)				Male(n=30)				Female(n=69)			
	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max
OP/PP	7.14	2.08	3.10	11.80	6.98	1.97	3.50	11.80	7.21	2.12	3.10	10.60
U6-PP	17.64	5.54	12.10	31.40	19.04	3.48	12.70	31.40	17.28	2.23	12.10	22.70
L6-MP	28.80	2.59	22.20	39.10	29.01	3.85	22.20	39.10	28.45	2.20	22.60	37.50
Relationship between teeth												
U1/L1	125.58	9.28	105.50	148.70	124.08	9.18	109.20	148.70	125.14	10.02	105.50	148.70
Soft tissue measurements												
UL- E line	-3.08	2.45	-9.00	2.00	-3.43	2.40	-9.00	0.80	-2.93	2.47	-9.00	2.00
LL- E line	-0.21	3.01	-7.10	5.70	-0.47	3.06	-7.10	4.70	0.40	3.05	-6.40	5.70
Naso labial angle	110.10	9.64	80.00	135.10	114.61	9.08	97.50	132.90	109.58	9.55	80.00	135.10
Mento labial angle	124	10.73	95.40	145.50	122.83	11.04	100.70	144.60	124.79	10.62	95.40	145.50
U lip length	22.19	2.22	17.20	30.50	23.67	3.18	18.00	30.50	21.55	2.10	17.20	27.80
L lip length	18.56	2.31	13.50	25.20	19.88	2.63	13.50	25.20	18.56	2.00	13.50	23.70
Symphyseal components												
D-Apex	9.63	2.39	4.20	15.10	10.20	2.76	4.70	15.10	8.97	2.13	4.20	14.30
D-Me	12.26	1.44	9.30	16.90	12.98	1.79	9.60	16.90	11.76	1.20	9.30	14.40
CW-Apex	9.02	2.12	4.20	13.20	9.10	2.52	4.00	13.10	9.20	1.96	4.20	13.20
(CW-D)	13.28	2.11	7.90	18.00	12.87	2.01	7.90	16.52	13.21	2.31	8.50	18.00
ASA	7.99	6.64	-10.20	20.50	7.12	6.47	-6.80	19.00	8.40	6.78	-10.20	20.50
PSA	-21.75	7.41	-37.10	-7.60	-22.92	7.63	-35.80	-7.60	-21.83	7.33	-37.10	-7.00
Time factor												
Age	16.71	1.41	14.25	20.92	17.54	1.18	15.75	20.83	16.35	1.36	14.25	20.92
Tx time	3.27	1.15	1.25	7.42	2.84	1.03	1.25	4.91	3.46	1.16	1.83	7.42

APPENDIX 5

Descriptive statistics for all cephalometric variables of adult group at T1

Descriptive Variables	T1											
	Adult(n=90)				Male(n=35)				Female(n=55)			
	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max
Cranial base measurements												
SN	67.35	3.78	59.00	77.00	68.57	3.76	60.40	77.00	66.56	3.62	59.00	73.60
SN/H	12.37	3.54	4.00	21.30	11.01	3.07	4.10	18.20	13.33	3.62	4.00	21.30
S-Ar	34.15	3.82	24.80	44.70	34.50	3.81	27.90	42.20	33.93	3.85	24.80	44.70
Relationship between jaws, cranial base and horizontal												
SNA	82.77	3.92	74.00	93.40	83.30	4.42	76.20	92.60	82.43	3.58	74.00	93.40
SNB	76.47	3.73	68.90	85.60	77.52	3.47	71.40	85.60	75.69	3.88	68.90	85.30
ANB	6.34	1.52	4.50	10.3	6.21	1.61	4.50	10.20	6.47	1.68	4.50	10.70
NA/APog	11.49	3.93	1.30	21.00	11.02	3.90	1.30	19.30	11.66	3.88	3.00	21.00
N-ANS	51.13	3.59	43.50	58.40	51.61	3.84	43.50	57.90	50.82	3.43	44.00	58.40
LFH	56.38	2.42	51.20	61.80	56.25	2.61	51.30	61.80	56.46	2.32	51.20	61.00
ANS-Me (AFH)	67.23	4.76	54.30	76.90	68.09	4.79	58.30	76.90	66.80	4.65	54.30	75.60
Ar-Go (PFH)	44.49	5.24	33.40	55.70	46.38	5.00	34.00	55.70	43.45	5.04	33.40	51.50
PP/MP	27.37	5.46	18.40	41.50	26.91	4.99	18.80	36.00	27.31	5.79	18.40	41.50
MP/SN	36.31	6.52	25.80	52.70	34.26	5.83	26.60	52.40	37.56	6.64	25.80	52.70
Pog-N	-2.87	4.60	-13.7	8.20	-2.59	3.91	-12.5	8.20	-2.96	4.58	-13.7	7.70
Jaw specific measurements												
Co-Gn	113.25	6.40	95.90	126.00	112.62	18.84	111.20	126.00	111.83	5.88	95.90	123.50
Co-Go	55.49	5.06	43.90	68.20	57.56	5.31	43.90	68.20	54.36	4.32	44.50	62.40
Co/Go/Me	121.89	5.36	109.1	134.7	122.70	5.16	113.70	133.50	121.37	5.48	109.10	134.70
Relationship between teeth and jaws												
U1/NA	22.19	7.42	1.60	43.00	22.03	8.32	1.60	42.80	22.30	6.86	4.60	43.00
U1-NA	4.56	2.63	-1.20	10.10	4.54	2.82	-1.20	9.90	4.58	2.54	-.60	10.10
U1/SN	105.8	8.91	79.60	133.10	105.33	9.99	79.60	133.10	104.92	8.25	86.90	128.80
U1/PP	113.56	7.53	90.80	131.90	113.24	8.21	90.80	130.00	113.77	7.14	98.80	131.90
L1/NB	32.11	6.21	17.00	47.50	30.81	6.11	17.80	46.20	32.96	6.18	17.00	47.50
L1-NB	7.71	2.31	2.60	13.00	7.33	2.33	2.60	11.80	7.96	2.29	3.00	13.00
L1/MP	99.75	6.89	87.00	114.00	98.62	6.67	88.00	113.90	100.49	7.00	87.00	114.00

Descriptive Variables	T1											
	Adult(n=90)				Male(n=35)				Female(n=55)			
	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max
OP/PP	7.23	2.02	2.70	11.80	6.62	2.17	2.70	11.10	7.52	2.24	3.30	11.80
U6-PP	20.47	2.32	13.60	25.50	20.53	2.27	16.80	25.30	20.33	2.23	13.60	25.50
L6-MP	30.61	3.73	22.30	43.20	31.57	4.31	23.50	43.20	30.03	3.19	22.30	35.20
Relationship between teeth												
U1/L1	119.75	10.23	97.30	147.4	121.56	10.41	97.30	137.8	118.58	10.05	97.30	147.4
Soft tissue measurements												
UL- E line	-2.26	2.20	-7.30	3.60	-2.59	2.30	-7.30	3.60	-2.06	2.15	-6.80	2.90
LL- E line	0.64	2.65	-5.00	8.40	.11	2.28	-5.00	4.90	.99	2.85	-4.70	8.40
Nasolabial angle	109.53	11.68	73.60	138.3	113.99	11.36	88.30	138.3	106.65	11.06	73.60	134.5
Mentolabial angle	120.54	14.91	83.40	157.4	117.82	12.49	99.00	144.2	122.31	16.16	83.40	157.4
U lip length	21.76	2.45	16.20	27.60	21.56	2.36	16.20	26.70	21.64	2.47	16.70	27.60
L lip length	18.62	2.89	14.00	27.8	18.55	2.65	14.00	25.6	18.43	2.79	15.12	27.8
Symphyseal components												
D-Apex	10.23	1.88	5.80	14.80	10.26	1.90	6.40	14.80	10.22	1.89	5.80	14.50
D-Me	11.39	1.32	9.00	14.80	11.88	1.40	9.20	14.80	11.08	1.18	9.00	13.80
CW-Apex	8.87	2.33	4.80	16.30	9.80	2.48	6.20	16.30	8.28	2.05	4.80	14.70
(CW-D)	12.81	2.03	9.60	20.00	12.76	2.12	10.87	19.12	12.56	2.10	9.60	20.00
ASA	4.48	8.26	-14.3	17.60	2.73	9.21	-14.3	16.80	5.63	7.46	-11.20	17.60
PSA	-22.56	6.71	-35.8	-5.10	-21.17	6.72	-35.8	-9.20	-23.46	6.61	-35.60	-5.10
Time factor												
Age	24.53	7.65	15.95	52.33	23.68	5.32	17.93	38	25.70	8.73	15.95	52.33

Descriptive statistics for all cephalometric variables of adult group at T2

Descriptive Variables	T2											
	Adult(n=90)				Male(n=35)				Female(n=55)			
	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max
Cranial base measurements												
SN	67.59	3.82	59.10	77.60	68.87	3.72	60.40	77.30	66.77	3.69	59.10	73.60
SN/H	12.48	3.51	4.10	21.40	11.08	3.06	4.10	18.20	13.36	3.62	4.10	21.40
S-Ar	34.67	3.57	27.20	43.70	35.07	3.64	29.10	41.70	34.41	3.54	27.20	43.70
Relationship between jaws, cranial base and horizontal												
SNA	82.61	3.96	73.20	92.50	83.09	4.52	73.80	92.20	82.30	3.58	73.20	92.50
SNB	76.03	3.92	69.00	85.60	77.69	3.57	70.40	85.30	75.80	3.78	69.00	85.60
ANB	6.2	1.72	3.10	9.50	5.79	1.55	3.10	9.00	6.26	1.73	3.10	9.50
NA/Apog	10.84	3.89	1.00	20.40	10.43	3.93	1.00	17.90	11.33	3.74	2.90	20.40
N-ANS	1.55	3.59	43.60	58.40	52.08	3.86	43.60	58.10	51.22	3.41	44.10	58.40
LFH	56.75	2.60	51.30	62.20	56.68	2.86	51.30	62.20	56.79	2.44	51.30	61.20
ANS-Me (AFH)	66.91	5.41	53.70	76.50	67.82	5.23	57.50	76.50	66.48	4.93	53.70	76.50
Ar-Go (PFH)	45.81	5.13	33.40	57.40	47.61	5.16	34.50	57.40	44.69	5.06	33.40	53.40
PP/MP	27.15	5.82	16.50	44.40	27.13	5.41	17.30	35.50	27.53	6.13	16.50	44.40
MP/SN	35.84	6.34	26.20	51.50	34.01	5.85	26.30	51.50	37.26	6.53	26.20	51.40
Pog-N	-2.06	4.52	-13.9	7.40	-2.13	4.00	-11.90	7.40	-2.46	4.26	-13.90	7.70
Jaw specific measurements												
Co-Gn	114.16	6.06	97.10	125.30	116.67	5.77	102.00	125.30	112.54	5.74	97.10	123.50
Co-Go	55.76	5.04	45.20	68.50	57.83	5.41	45.20	68.50	54.59	4.15	46.00	62.50
Co/Go/Me	121.55	5.62	105.20	132.70	121.65	5.10	112.00	131.50	121.49	5.99	105.20	132.70
Relationship between teeth and jaws												
U1/NA	15.30	7.58	-0.9	36.10	16.15	7.12	1.60	36.10	14.75	7.89	-.90	35.90
U1-NA	1.33	2.20	-3.40	8.00	1.45	1.98	-2.70	5.00	1.26	2.35	-3.40	8.00
U1/SN	97.08	9.27	77.40	119.30	98.22	9.70	77.40	118.50	96.36	9.00	78.30	119.30
U1/PP	106.02	8.58	88.50	128.00	106.75	8.48	90.80	127.60	105.56	8.70	88.50	128.00
L1/NB	31.84	6.04	15.70	47.50	30.52	6.19	15.70	40.30	32.70	5.84	21.10	47.50
L1-NB	7.07	2.10	3.20	12.30	6.87	2.38	3.20	12.30	7.22	1.91	3.50	11.30
L1/MP	99.19	7.83	80.6	115.3	97.91	7.00	80.60	110.20	100.03	8.28	82.90	115.30

Descriptive Variables	T2											
	Adult(n=90)				Male(n=35)				Female(n=55)			
	Mean	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**
OP/PP	7.48	3.34	2.20	11.60	6.45	2.29	2.20	11.60	7.33	2.20	3.00	11.00
U6-PP	20.45	2.49	13.70	25.60	20.80	2.59	14.70	25.60	20.23	2.16	13.70	25.10
L6-MP	30.53	3.85	23.40	42.60	31.65	4.29	24.60	42.60	29.89	3.31	23.40	35.80
Relationship between teeth												
U1/L1	127.83	10.27	102.80	154.00	128.58	9.82	108.60	154.00	127.34	10.63	102.80	150.80
Soft tissue measurements												
UL- E line	-3.21	2.27	-8.00	1.90	-3.77	2.30	-8.00	1.30	-2.86	2.20	-6.90	1.90
LL- E line	-0.43	2.51	-5.90	4.60	-.97	2.44	-5.90	4.40	-0.08	2.53	-5.40	4.60
Naso labial angle	112.05	10.64	82.30	139.40	115.59	11.11	94.60	139.40	109.76	9.76	82.30	134.30
Mento labial angle	124.8	13.18	89.10	152.10	123.85	9.78	101.60	147.30	125.43	15.04	89.10	152.10
U lip length	22.64	2.52	17.20	29.20	22.59	2.35	17.20	28.3	22.47	2.49	17.47	29.20
L lip length	19.42	2.96	14.50	27.7	19.12	2.76	14.50	23.6	19.38	2.85	14.76	27.7
Symphyseal components												
D-Apex	10.8	2.27	6.00	17.10	11.20	2.58	6.20	17.10	10.54	2.03	6.00	15.90
D-Me	11.38	1.19	8.60	14.70	11.82	1.16	10.30	14.70	11.10	1.14	8.60	13.80
CW-Apex	8.49	2.77	4.20	18.40	9.48	3.40	5.70	18.40	7.86	2.08	4.20	12.90
(CW-D)	12.89	2.00	9.50	19.40	13.12	2.10	9.50	18.36	12.96	2.12	9.67	19.40
ASA	5.08	7.06	-11.60	17.20	3.87	7.76	-11.60	17.20	5.88	6.53	-8.80	17.00
PSA	-22.49	6.57	-38.90	-6.20	-21.34	5.90	-30.80	-9.80	-23.25	6.93	-38.90	-6.20
Time factor												
Age	27.90	7.77	19.15	58.00	26.42	5.55	19.41	42.17	28.86	8.84	19.15	58.00
Tx time	3.15	1.00	1.1	6.75	2.90	0.94	1.42	5	3.39	1.14	1.1	6.75

REFERENCES

Ackerman, J. L., & Proffit, W. R. (1969). The characteristics of malocclusion: A modern approach to classification and diagnosis. *American journal of orthodontics*, *56*(5), 443-454.

Adams, G. L., Gansky, S. A., Miller, A. J., Harrell, W. E., & Hatcher, D. C. (2004). Comparison between traditional 2-dimensional cephalometry and a 3-dimensional approach on human dry skulls. *American journal of orthodontics and dentofacial orthopedics*, *126*(4), 397-409.

Anderson, D. L., & POPOVICH, F. (1983). Lower cranial height vs craniofacial dimensions in Angle Class II malocclusion. *The Angle orthodontist*, *53*(3), 253-260.

Andrews, L. F. (1972). The six keys to normal occlusion. *American journal of orthodontics*, *62*(3), 296-309.

Angle, E. H. (1907). *Treatment of malocclusion of the teeth: Angle's system*. White Dental Manufacturing Company.Hunter J. A practical treatise on the diseases of the teeth. New-York: [s.n.]. 1839: 30

Arat, Z.M. and Rübendüz, M., 2005. Changes in dentoalveolar and facial heights during early and late growth periods: a longitudinal study. *The Angle Orthodontist*, *75*(1), pp.69-74.

Arruda K, Valladares Neto J, Almeida G. Assessment of the mandibular symphysis of Caucasian Brazilian adults with well-balanced faces and normal occlusion: the influence of gender and facial type. Dental Press J Orthod. 2012;17(3):40–50.

Baccetti, T., Franchi, L., McNamara, J. A., & Tollaro, I. (1997). Early dentofacial features of Class II malocclusion: A longitudinal study from the deciduous through the mixed dentition. *American Journal of Orthodontics and Dentofacial Orthopedics*, *111*(5), 502-509.

Barton, S., Cook, P. A., & Institute, F. L. D. (1997). Predicting functional appliance treatment outcome in Class II malocclusions–a review. *American journal of orthodontics and dentofacial orthopedics*, *112*(3), 282-286.

Bathia SN, Leighton BC, A manual of facial growth. Oxford University Press,1993.

Baumrind, S. (1991). Prediction in the planning and conduct of orthodontic treatment. *Current controversies in orthodontics. Chicago: Quintessence*, 25-43.

Baumrind, S., Korn, E. L., Isaacson, R. J., West, E. E., & Molthen, R. (1983). Quantitative analysis of the orthodontic and orthopedic effects of maxillary traction. *American journal of orthodontics*, *84*(5), 384-398.

Beckmann S, Kuitert R, Prahl-Andersen B, Segner DR, Tuinzing D. Alveolar and skeletal dimensions associated with lower face height. American Journal of Orthodontics and Dentofacial Orthopedics. 1998;113(5):498–506

Berkey, C. S., Dockery, D. W., Wang, X., Wypij, D., & Ferris, B. (1993). Longitudinal height velocity standards for US adolescents. *Statistics in medicine*, *12*(3-4), 403-414.

Birnie, D. (2012). Integrated Clinical Orthodontics (2012).

Bishara, S. E. (1998). Mandibular changes in persons with untreated and treated Class II division 1 malocclusion. *American Journal of Orthodontics and Dentofacial Orthopedics*, *113*(6), 661-673.

Bishara, S. E., Jakobsen, J. R., Vorhies, B., & Bayati, P. (1997). Changes in dentofacial structures in untreated Class II division 1 and normal subjects: A longitudinal study. *The Angle orthodontist*, *67*(1), 55-66.

Björk, A. (1955). Cranial base development: a follow-up x-ray study of the individual variation in growth occurring between the ages of 12 and 20 years and its relation to brain case and face development. *American Journal of Orthodontics*, *41*(3), 198-225.

Bjork A.(1963) Variations in the growth pattern of the human mandible:longitudinal radiographic study by the implant method. J Dent Res1963;42:400-11.

Björk, A. (1969). Prediction of mandibular growth rotation. *American journal of orthodontics*, *55*(6), 585-599.

Broadbent, B. H. (1981). A new X-ray technique and its application to orthodontia: the introduction of cephalometric radiography. *The Angle Orthodontist*, *51*(2), 93-114.

Bondevik, O. (1991). How effective is the combined activator-headgear treatment?. *The European Journal of Orthodontics*, *13*(6), 482-485.

Burden, D. J., McGuinness, N., Stevenson, M., & McNamara, T. (1999). Predictors of outcome among patients with Class II Division 1 malocclusion treated with fixed appliances in the permanent dentition. *American journal of orthodontics and dentofacial orthopedics*, *116*(4), 452-459.

Buschang, P.H., Carrillo, R. and Rossouw, P.E., 2011. Orthopedic correction of growing hyperdivergent, retrognathic patients with miniscrew implants. *Journal of oral and maxillofacial surgery*, *69*(3), pp.754-762.

Buschang P, Gandini L. Mandibular skeletal growth and modeling between 10 and 15 years of age. Eur J Orthod 2002;24:69-79.

Caldwell, S., & Cook, P. (1999). Predicting the outcome of twin block functional appliance treatment: a prospective study. *European journal of orthodontics*, *21*(5), 533-539.

Chen SYY, Lestrel PE, Kerr WJS, McColl JH. Describing shape changes in the human mandible using elliptical Fourier functions.Eur J Orthod 2000;22:205-16

Chhibber, A., Upadhyay, M., Uribe, F., & Nanda, R. (2012). Mechanism of Class II correction in prepubertal and postpubertal patients with Twin Force Bite Corrector. *The Angle Orthodontist*, *83*(4), 718-727.

Cochrane, A. L. (1972). *Effectiveness and efficiency: random reflections on health services* (Vol. 900574178). London: Nuffield Provincial Hospitals Trust.

Corruccini, R. S., & Potter, R. H. Y. (1980). Genetic analysis of occlusal variation in twins. *American journal of orthodontics*, *78*(2), 140-154.

Daegling D. Functional morphology of the human chin. EvolAnthropol 1993;1:170-7.

Daegling D. Geometry and biomechanics of hominoid mandibles[dissertation]. Stony Brook: State University of New York; 1990.

Dobson S, Trinkaus E. Cross-sectional geometry and morphology of the mandibular symphysis in middle and late Pleistocene Homo. J Hum Evol 2002;43:67-87.

Dhopatkar, A., Bhatia, S., & Rock, P. (2002). An Investigation Into the Relationship Between the Cranial Base Angle and Malocclusion. *The Angle Orthodontist*, *72*(5), 456-463.

DuBrul E, Sicher H. The adaptive chin. Springfield: Charles C Thomas; 1954.

Efstratiadis, S., Baumrind, S., Shofer, F., Jacobsson-Hunt, U., Laster, L., & Ghafari, J. (2005). Evaluation of Class II treatment by cephalometric regional superpositions versus conventional measurements. *American journal of orthodontics and dentofacial orthopedics*, *128*(5), 607-618.

Enlow D, Harris D. A study of the postnatal growth of the human mandible. Am J Orthod 1964;50:25-50.

Enlow D. A comparative study of facial growth in Homo and Macaca. Am J Phys Anthropol 1966;24:293-308.from implant and anatomic best-fit superimpositions. AmJ Orthod Dentofacial Orthop 1992;102:227-38.

Ferreira, J. T. L., Lima, M. D. R. F., & Pizzolato, L. Z. (2012). Relation between Angle Class II malocclusion and deleterious oral habits. *Dental Press Journal of Orthodontics*, *17*(6), 111-117.

Fisk, G. V., Culbert, M. R., Grainger, R. M., Hemrend, B., & Moyers, R. (1953). The morphology and physiology of distoclusion: A summary of our present knowledge. *American Journal of Orthodontics*, *39*(1), 3-12.

Ford, E. H. R. (1958). Growth of the human cranial base. *American Journal of Orthodontics*, *44*(7), 498-506.

Franchi, L., & Baccetti, T. (2006). Prediction of individual mandibular changes induced by functional jaw orthopedics followed by fixed appliances in Class II patients. *The Angle Orthodontist*, *76*(6), 950-954.

Francisconi, M. F., Henriques, J. F. C., Janson, G., FREITAS, K. M. S. D., & SANTOS, P. B. D. D. (2013). Stability of Class II treatment with the Bionator followed by fixed appliances. *Journal of Applied Oral Science*, *21*(6), 547-553.

Genecov, J. S., Sinclair, P. M., & Dechow, P. C. (1990). Development of the nose and soft tissue profile. *The Angle Orthodontist*, *60*(3), 191-198.

Ghafari J, Efstratiadis S. (2009). Contribution of Component Analysis to Outcome of Class II Treatment. *International Association of Dental Research.* [Abstract]

Ghafari, J. G. (1997). GUEST EDITORIAL Emerging paradigms in orthodontics—An essay. *American journal of orthodontics and dentofacial orthopedics*, *111*(5), 573-580.

Ghafari, J. G., Haddad, R. V., & Saadeh, M. E. (2011). Class III Malocclusion—The Evidence on Diagnosis and Treatment. *Evidence-Based Orthodontics*, 247-280.

Ghafari, J., King, G. J., & Tulloch, J. F. (1998). Early treatment of Class II, division 1 malocclusion--comparison of alternative treatment modalities. *Clinical orthodontics and research*, *1*(2), 107-117.

Ghafari, J. G., & Macari, A. T. (2014, December). Component analysis of Class II, Division 1 discloses limitations for transfer to Class I phenotype. In *Seminars in Orthodontics* (Vol. 20, No. 4, pp. 253-271). WB Saunders.

Ghafari, J. G., & Macari, A. T. (2013, December). Component analysis of predominantly vertical occlusal problems. In *Seminars in Orthodontics* (Vol. 19, No. 4, pp. 227-238). WB Saunders.

Ghafari, J., Shofer, F. S., Jacobsson-Hunt, U., Markowitz, D. L., & Laster, L. L. (1998). Headgear versus function regulator in the early treatment of Class II, division 1 malocclusion: a randomized clinical trial. *American Journal of Orthodontics and Dentofacial Orthopedics*, *113*(1), 51-61.

Ghafari, J. G., Shofer, F. S., Laster, L. L., Markowitz, D. L., Silverton, S., & Katz, S. H. (1995, September). Monitoring growth during orthodontic treatment. In *Seminars in orthodontics* (Vol. 1, No. 3, pp. 165-175). WB Saunders.

Ghafari, J., Shofer, F. S., Markowitz, D. L., Jacobsson Hunt, U., Leoni, A., & Laster, L. L. (1997, January). Patient compliance and outcome measures in the early treatment of distoclusion. In *JOURNAL OF DENTAL RESEARCH* (Vol. 76, pp. 34-34). 1619 DUKE ST, ALEXANDRIA, VA 22314: AMER ASSOC DENTAL RESEARCH.

Ghafari, J. (1998). Timing the early treatment of Class II, division 1 malocclusion--clinical and research considerations. *Clinical orthodontics and research*, *1*(2), 118-129.

Gianelly, A. A. (1994). Crowding: timing of treatment. *The Angle Orthodontist*, *64*(6), 415-418.

Graber, L. W., Vanarsdall, R. L., Vig, K. W., & Huang, G. J. (2011). *Orthodontics-E-Book: Current Principles and Techniques*. Elsevier Health Sciences.

Gu, Y. and McNamara Jr, J.A., 2007. Mandibular growth changes and cervical vertebral maturation: a cephalometric implant study. *The Angle Orthodontist*, *77*(6), pp.947-953.

Guyer, E. C., Ellis III, E. E., McNamara Jr, J. A., & Behrents, R. G. (1986). Components of Class III malocclusion in juveniles and adolescents. *The Angle orthodontist*, *56*(1), 7-30.

Haddad, R. V., & Ghafari, J. G. (2017). Chin-throat anatomy: Normal relations and changes following orthognathic surgery and growth modification. *The Angle Orthodontist*.

Hägg, U., & Taranger, J. (1982). Maturation indicators and the pubertal growth spurt. *American journal of orthodontics*, *82*(4), 299-309.

Harvold, E. P., Tomer, B. S., Vargervik, K., & Chierici, G. (1981). Primate experiments on oral respiration. *American journal of orthodontics*, *79*(4), 359-372.

Heinig, N., & Göz, G. (2001). Clinical Application and Effects of the Forsus™ Spring A Study of a New Herbst Hybrid. *Journal of Orofacial Orthopedics/Fortschritte der Kieferorthopädie*, *62*(6), 436-450.

Herzberg, B. L. (1952). Facial esthetics in relation to orthodontic treatment. *The Angle Orthodontist*, *22*(1), 3-22.

Hoffelder L, de Lima E, Martinelli F, Bolognese A. Soft-tissue changes during facial growth in skeletal Class II individuals. American Journal of Orthodontics and Dentofacial Orthopedics. 2007;131(4):490–95

Hopkin, G. B., Houston, W. J. B., & James, G. A. (1968). The cranial base as an aetiological factor in malocclusion. *The Angle orthodontist*, *38*(3), 250-255.

Hrdlička, A. and Pearson, K., 1911. *Human dentition and teeth from the evolutionary and racial standpoint*. Ontario Dental Association.

Ichim, I., Swain, M. and Kieser, J.A., 2006. Mandibular biomechanics and development of the human chin. *Journal of Dental Research*, *85*(7), pp.638-642.

Ishikawa H, Nakamura S, Iwasaki H, Kitazawa S. Dentoalveolar compensation related to variations in sagittal jaw relationships. Angle Orthod 1999; 69:534-8.

Islam, Z.U., Shaikh, A.J. and Fida, M., 2016. Dentoalveolar heights in vertical and sagittal facial patterns. *J Coll Physicians Surg Pak*, *26*(09), pp.753-757.

Janson, G., Barros, S. E. C., Simão, T. M., & Freitas, M. R. D. (2009). Relevant variables of Class II malocclusion treatment. *Revista Dental Press de Ortodontia e Ortopedia Facial*, *14*(4), 149-157.

Janson, G., da Costa Brambilla, A., Henriques, J. F. C., de Freitas, M. R., & Neves, L. S. (2004). Class II treatment success rate in 2-and 4-premolar extraction protocols. *American journal of orthodontics and dentofacial orthopedics*, *125*(4), 472-479.

Johnson, J. S., & Eid, A. A. (1979). Recent developments in diagnosis and treatment planning of antero-posterior jaw discrepancies from the lateral skull cephalostat radiograph. *British Journal of Oral Surgery*, *17*(3), 256-264.

Johnston, L. E. (1975). A simplified approach to prediction. *American journal of orthodontics*, *67*(3), 253-257.

Kucera, J., Marek, I., Tycova, H. and Baccetti, T., 2011. Molar height and dentoalveolar compensation in adult subjects with skeletal open bite. *The Angle Orthodontist*, *81*(4), pp.564-569.

Keeling, S. D., Wheeler, T. T., King, G. J., Garvan, C. W., Cohen, D. A., Cabassa, S., ... & Taylor, M. G. (1998). Anteroposterior skeletal and dental changes after early Class II treatment with bionators and headgear. *American Journal of Orthodontics and Dentofacial Orthopedics*, *113*(1), 40-50.

Kerns, L. L., Silveira, A. M., Kerns, D. G., & Regennitter, F. J. (1997). Esthetic preference of the frontal and profile views of the same smile. *Journal of esthetic dentistry*, *9*, 76-85.

Kerr, W. J. S., & Hirst, D. (1987). Craniofacial characteristics of subjects with normal and postnormal occlusions—a longitudinal study. *American Journal of Orthodontics and Dentofacial Orthopedics*, *92*(3), 207-212.

Klecka, W. R. (1980). Discriminant analysis. Sage Publications, London.

Kuitert, R., Beckmann, S., van Loenen, M., Tuinzing, B., & Zentner, A. (2006). Dentoalveolar compensation in subjects with vertical skeletal dysplasia. *American journal of orthodontics and dentofacial orthopedics*,*129*(5), 649-657.

KURIHARA, S., ENLOW, D.H. and RANGEL, R.D., 1980. Remodeling reversals in anterior parts of the human mandible and maxilla. *The Angle Orthodontist*, *50*(2), pp.98-106.

LaHaye, M.B., Buschang, P.H. and Boley, J.C., 2006. Orthodontic treatment changes of chin position in Class II Division 1 patients. *American journal of orthodontics and dentofacial orthopedics*, *130*(6), pp.732-741.

Livieratos, F. A., & Johnston, L. E. (1995). A comparison of one-stage and two-stage nonextraction alternatives in matched Class II samples. *American Journal of Orthodontics and Dentofacial Orthopedics*, *108*(2), 118-131.

Lundström, A. (1984). Nature versus nurture in dento-facial variation. *The European Journal of Orthodontics*, *6*(1), 77-91.

L. R. Dermaut, F. van den Eynde, G. de Pauw, Skeletal and dento-alveolar changes as a result of headgear activator therapy related to different vertical growth patterns, *European Journal of Orthodontics*, Volume 14, Issue 2, April 1992, Pages 140–146.

Macari, A. T., & Hanna, A. E. (2013). Comparisons of soft tissue chin thickness in adult patients with various mandibular divergence patterns. *Angle Orthodontist*, *84*(4), 708-714.

Mangla R, Dua V, Khanna M, Singh N, Padmanabhan P. Evaluation of mandibular morphology in different facial types. Contemporary Clinical Dentistry. 2011;2(3):200.

Marshall, S.D., Low, L.E., Holton, N.E., Franciscus, R.G., Frazier, M., Qian, F., Mann, K., Schneider, G., Scott, J.E. and Southard, T.E., 2011. Chin development as a result of differential jaw growth. *American Journal of Orthodontics and Dentofacial Orthopedics*, *139*(4), pp.456-464.

McNamara, J. A., Brudon, W. L., & Kokich, V. G. (2001). *Orthodontics and dentofacial orthopedics*. Needham Press.

McNamara Jr, J. A. (1981). Components of Class II malocclusion in children 8–10 years of age. *The Angle orthodontist*, *51*(3), 177-202.

McNamara, J. A., Hinton, R. J., & Hoffman, D. L. (1982). Histologic analysis of temporomandibular joint adaptation to protrusive function in young adult rhesus monkeys (Macaca mulatta). *American journal of orthodontics*, *82*(4), 288-298.

Molina-Berlanga N, Llopis-Perez J, Flores-Mir C, Puigdollers A. Lower incisor dentoalveolar compensation and symphysis dimensions among Class I and III malocclusion patients with different facial vertical skeletal patterns. The Angle Orthodontist. 2013;83(6):948–55

Monirifard, M., Sadeghian, S., Afshari, Z., Rafiei, E. and Sichani, A.V., 2020. Relationship between cephalometric cranial base and anterior-posterior features in an Iranian population. Dental research journal, 17(1), p.60

Moorrees, C. F., & Kean, M. R. (1958). Natural head position, a basic consideration in the interpretation of cephalometric radiographs. *American Journal of Physical Anthropology*, *16*(2), 213-234.

Muretić, Ž., & Rak, D. (1991). Changes in the value of the mandibular angle and its segments during growth. *Acta stomatologica Croatica*, *25*(4), 219-224.

Nandaa R. The contributions of craniofacial growth to clinical orthodontics. American Journal of Orthodontics and Dentofacial Orthopedics. 2000;117(5):553–55

O'brien, K., Wright, J., Conboy, F., Appelbe, P., Davies, L., Connolly, I., ... & Sandler, J. (2009). Early treatment for Class II Division 1 malocclusion with the Twin-block appliance: a multi-center, randomized, controlled trial. *American Journal of Orthodontics and Dentofacial Orthopedics*, *135*(5), 573-579.

O'Brien, K., Wright, J., Conboy, F., Sanjie, Y., Mandall, N., Chadwick, S., ... & Harradine, N. (2003). Effectiveness of early orthodontic treatment with the Twin-block appliance: a multicenter, randomized, controlled trial. Part 1: dental and skeletal effects. *American Journal of Orthodontics and Dentofacial Orthopedics*, *124*(3), 234-243.

O'Brien, K., Wright, J., Conboy, F., Sanjie, Y., Mandall, N., Chadwick, S., ... & Harradine, N. (2003). Effectiveness of treatment for Class II malocclusion with the Herbst or Twin-block appliances: a randomized, controlled trial. *American Journal of Orthodontics and Dentofacial Orthopedics*, *124*(2), 128-137.

Park H, Ellis E, Fonseca R, Reynolds S, Mayo K. A retrospective study of advancement genioplasty. Oral Surgery Oral Medicine Oral Pathology. 1989;67(5):481–89.

Patel, H. P., Moseley, H. C., & Noar, J. H. (2002). Cephalometric determinants of successful functional appliance therapy. *The Angle orthodontist*, *72*(5), 410-417.

Pancherz, H., & Hägg, U. (1985). Dentofacial orthopedics in relation to somatic maturation: an analysis of 70 consecutive cases treated with the Herbst appliance. *American journal of orthodontics*, *88*(4), 273-287.

Peck, H., & Peck, S. (1970). A concept of facial esthetics. *The Angle orthodontist*, *40*(4), 284-317.

Power, G., Breckon, J., Sherriff, M., & McDonald, F. (2005). Dolphin Imaging Software: an analysis of the accuracy of cephalometric digitization and orthognathic prediction. *International journal of oral and maxillofacial surgery*, *34*(6), 619-626.

Proffit, W. R., Fields Jr, H. W., & Moray, L. J. (1997). Prevalence of malocclusion and orthodontic treatment need in the United States: estimates from the NHANES III survey. *The International journal of adult orthodontics and orthognathic surgery*, *13*(2), 97-106.

Proffit, W. R., Fields, H. W., & Sarver, D. M. (2014). *Contemporary Orthodontics-E-Book*. Elsevier Health Sciences.

Proffit, W. R., Vig, K. W., & Turvey, T. A. (1980). Early fracture of the mandibular condyles: frequently an unsuspected cause of growth disturbances. *American journal of orthodontics*, *78*(1), 1-24.

Rice, A.J., Carrillo, R., Campbell, P.M., Taylor, R.W. and Buschang, P.H., 2019. Do orthopedic corrections of growing retrognathic hyperdivergent patients produce stable results?. *The Angle Orthodontist*, *89*(4), pp.552-558.

Richmond, S., Shaw, W. C., O'brien, K. D., Buchanan, I. B., Jones, R., Stephens, C. D., & Andrews, M. (1992). The development of the PAR Index (Peer Assessment Rating): reliability and validity. *The European Journal of Orthodontics*, *14*(2), 125-139.

Ricketts, R. M. (1957). Planning treatment on the basis of the facial pattern and an estimate of its growth. *The Angle Orthodontist*, *27*(1), 14-37.
Ruf, S., & Pancherz, H. (1999). Dentoskeletal effects and facial profile changes in young adults treated with the Herbst appliance. *The Angle orthodontist*, *69*(3), 239-246.
Salzmann, J. A. (1950). *Principles of orthodontics*. Lippincott.

Robinson, L., 1913. The story of the chin. *Knowledge*, *36*, pp.410-420.

Rothstein, T. and Phan, X.L., 2001. Dental and facial skeletal characteristics and growth of females and males with Class II Division 1 malocclusion between the ages of 10 and 14 (revisited). Part II. Anteroposterior and vertical circumpubertal growth. *American Journal of Orthodontics and Dentofacial Orthopedics*, *120*(5), pp.542-555.

Schudy, F. F. (1965). The rotation of the mandible resulting from growth: its implications in orthodontic treatment. *The Angle orthodontist*, *35*(1), 36-50.

Schwartz, J.H. and Tattersall, I., 2000. The human chin revisited: what is it and who has it?. *Journal of human evolution*, *38*(3), pp.367-409

Shaughnessy, T., & Shire, L. H. (1988). Etiology of Class II malocclusions. *Pediatr Dent*, *10*(4), 336-338.

Siddegowda R, N R, B.M S. Mandibular morphological study using Bjorks signs. Saarbrücken: LAP LAMBERT Academic Publishing; 2013. p. 80

Sivakumar, A., & Valiathan, A. (2008). Cephalometric assessment of dentofacial vertical changes in Class I subjects treated with and without extraction. *American Journal of Orthodontics and Dentofacial Orthopedics*, *133*(6), 869-875.

Snyder, R., & Jerrold, L. (2007). Black, white, or gray: finding commonality on how orthodontists describe the areas between Angle's molar classifications. *American Journal of Orthodontics and Dentofacial Orthopedics*, *132*(3), 302-306.

Stahl, F., Baccetti, T., Franchi, L., & McNamara, J. A. (2008). Longitudinal growth changes in untreated subjects with Class II Division 1 malocclusion. *American Journal of Orthodontics and Dentofacial Orthopedics*, *134*(1), 125-137.

Steiner, C. C. (1959). Cephalometrics in clinical practice. *The Angle Orthodontist*, *29*(1), 8-29.

Taner, L., Gürsoy, G.M. and Uzuner, F.D., 2019. Does Gender Have an Effect on Craniofacial Measurements?. Turkish journal of orthodontics, 32(2), p.59.

Tulloch, J. C., Proffit, W. R., & Phillips, C. (1997). Influences on the outcome of early treatment for Class II malocclusion. *American Journal of Orthodontics and Dentofacial Orthopedics*, *111*(5), 533-542.

Tulloch, J. C., Proffit, W. R., & Phillips, C. (2004). Outcomes in a 2-phase randomized clinical trial of early Class II treatment. *American Journal of Orthodontics and Dentofacial Orthopedics*, *125*(6), 657-667.

Tulloch, J. F. C., Medland, W., & Tuncay, O. C. (1990). Methods used to evaluate growth modification in Class II malocclusion. *American Journal of Orthodontics and Dentofacial Orthopedics*, *98*(4), 340-347.

Varlık S, Demirbaş E, Orhan M. Influence of lower facial height changes on frontal facial attractiveness and perception of treatment need by lay people. The Angle Orthodontist. 2010;80(6):1159–64.

Varrela, J. (1998). Early developmental traits in Class II malocclusion. *Acta Odontologica Scandinavica*, *56*(6), 375-377.

Vásquez, M. J., Baccetti, T., Franchi, L., & McNamara, J. A. (2009). Dentofacial features of Class II malocclusion associated with maxillary skeletal protrusion: a longitudinal study at the circumpubertal growth period. *American Journal of Orthodontics and Dentofacial Orthopedics*, *135*(5), 568-e1.

Waterman T. The evolution of the chin. Am Nat 1916;50:237.

West, E. E. (1957). Analysis of early Class II, Division 1 treatment. *American Journal of Orthodontics*, *43*(10), 769-777.

Wilhelm, B. M., Beck, F. M., Lidral, A. C., & Vig, K. W. (2001). A comparison of cranial base growth in Class I and Class II skeletal patterns. *American Journal of Orthodontics and Dentofacial Orthopedics*, *119*(4), 401-405.

White TD. The anterior mandibular corpus of early African Hominidae: functional significance of size and shape [dissertation]. AnnArbor: University of Michigan; 1977