AMERICAN UNIVERSITY OF BEIRUT

COMPONENT ANALYSIS OF CRANIOFACIAL RELATIONS IN VARIOUS MALOCCLUSIONS

By

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To God

First and foremost for helping me achieve my goals and being a constant source of help and strength

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AN ABSTRACT OF THE THESIS OF

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Abstract

Linked principally to skeletal Class III malocclusion, mandibular macrognathism might exist in other malocclusions.

Aims: 1) Characterize the traits of Class III and Class II malocclusions compared to a control group of Class I malocclusion. 2) Explore the existence of mandibular macrognathism in all types of malocclusion and its prevalence in Class III and Class II division 2 types. 3) Demonstrate particular traits to Class II division 2 that set it apart from all other malocclusions.

Methods: 322 subjects were divided into 4 malocclusion Classes: I, II division 1, II division 2 (itself stratified into 4 subtypes), and III. Cephalometric linear and angular measurements gauged sizes and positions of the jaws and their relationships to each other. Statistics included a multivariate analysis of variance for group comparisons, frequency distribution, correlations, linear and logistic regressions.

Results: Components of Class II division 2 were distinct from other malocclusions: maxilla closer to Class II division 1, mandible closer to Class I and Class III. In adults, 13.88 % of Class III, 2.77% of Class II.2, 0% of Class II.1, had mandibular length (Co-Gn) beyond 1 standard deviation of the mean Class I mandibular length. In Class II.2 27.53% had mandibular length comparable to that of Class II.1, 56.56% comparable to that of Class I and 15.94% to Class III. ANB in Class II.2 in ~60% of the cases was comparable to Class I ANB (0-4.5˚), and ~40% to Class II.1 (4.6-10˚). Chin components were characteristic in Class II.2: increased anterior symphyseal angle and distance Go-Pog. **Conclusion**: The results indicate that Class II division 2 may be a dentoalveolar malocclusion grafted on skeletal patterns ranging across other types of malocclusion. Longitudinal research with a larger sample is warranted. Findings on other malocclusions corroborate previous knowledge.

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Abbreviations

Abbreviations of different points used in the study	
ABBREVIATION	**LANDMARK**
ANS	Anterior nasal spine
Ar	Articulare
A	A point
B	B point
Ba	Basion
Go	Gonion
Me	Menton
N	Nasion
R	Ramus (lowest inner point)
S	Sella
Pog	Pogonion
Po	Porion
OJ	Overjet
PNS	Posterior nasal spine

Abbreviations of different planes, angles and structures used in the study	
ABBREVIATION	**PLANE**
ANS-PNS	Length of the maxilla
Co-Go	Length of the ramus
Co-Go-Me	Jaw or gonial angle
B-Pog	Length from point B to pogonion
ASA	Anterior symphyseal angle
Go-Me	Length of the body of the mandible
H	True horizontal
LFH/TFH	Lower to total face height ratio
MP	Mandibular plane
PP	Palatal plane
R-B	Alveolar length
SN	Length of the anterior cranial base
S-Ar	Length of the posterior cranial base
SN-Ar	Saddle angle
U1	Most proclined maxillary incisor
L1	Most proclined mandibular incisor
U6	Maxillary first molar
L6	Mandibular first molar
U1/L1	Inter-incisal angle

CHAPTER I

INTRODUCTION

Whether a problem related to alignment of teeth, dental occlusion, jaw position problems or the combination, thereof malocclusion can also represent a significant issue in the frame of facial esthetics. Functional problems associated with malocclusion are directly proportional to the severity of the condition (Proffit et al. 2007). Depending on severity, functional and esthetic impact, treatment of malocclusion is usually solely orthodontic or in combination with orthognathic surgery.

True mandibular prognathism is a disproportionality at the skeletal level, often observed with a Class III malocclusion. Class III pattern ranges from mild incisal edge to edge to severe anterior cross-bite. This is a developmental condition throughout the process of eruption and beyond the adolescent growth spurt. This length of development contributes to a missed early diagnosis of skeletal Class III especially when macrognathism is not evident at an early age (Chang et al. 2006). The challenges to timely diagnosis and treatment of skeletal Class III relates to unspecified etiology and difficult prediction of future growth (amount, pathway, duration and prototype of craniofacial growth and mainly its cessation) (Haddad 2008).

Treatment of these skeletal discrepancies might be more coherent and effective if we could recognize different subgroups of skeletal malocclusions (possible through genetic typing) other than the existing phenotypical description. The use of dentofacial orthopedics for altering or redirecting facial growth in skeletal Class III is controversial

and the borderline decision between non-surgical (orthopedics) and surgical cases may be ill-defined.

A potential complication to the overall panorama of malocclusion is the possibilities of overlapping components about presumably well delineated malocclusions, for example mandibular macrognathism is observed in patients with Class II division 2 malocclusion, which is actually characterized by an overjet rather than an anterior crossbite as in Class III malocclusion.

In the sagittal direction, Class II division 2 malocclusions might be located between the Angle Class I and Class II division 1 malocclusions, in addition, vertical skeletal characteristics (Brezniak et al. 2002).

To sort out definite differences among all malocclusion types, particularly in relation to mandibular size, we undertook this cross-sectional investigation of difference malocclusions (Class III, Class II division 1 and division 2) along with a control group of Class I malocclusion.

The overall aim is to evaluate available information from previous studies and to analyze skeletal and dentoalveolar components of the spectrum of the malocclusions, particularly mandibular components and their potential clinical implications.

Specific aims:

1- To determine similarities and differences in mandibular characteristics between Class III and II malocclusions particularly Class II.2, compared to a control group of Class I malocclusion

2- To evaluate the possible presence of mandibular macrognathism, mostly related to Class III malocclusion, in the other malocclusions

3- To demonstrate particular traits to Class II division 2 that set it apart from all other malocclusions.

Hypothesis:

Mandibular macrognathism is more prevalent in Class III and Class II division 2, the latter skeletal components characteristics encompassing those of other malocclusions.

CHAPTER II

LITERATURE REVIEW

A. Normal occlusion versus malocclusion

A classification system is defined as the fact of grouping clinical conditions with similar appearance to create a reference for communication and comparison purposes. Classification does not mean diagnosis (Angle 1899).

The anatomist and surgeon John Hunter was the first author to describe normal occlusion in the 18th century. Later, Carabelli in the middle of the 19th century described for the first time abnormal occlusion as abnormal relationship between dental arches. Edge to edge and overbite were not included in his classification. In 1839, Le Foulon (France) was the first to coin the term "Orthodontics".

Edward H. Angle, considered the father of modern orthodontics, introduced in 1899 the three basic types of malocclusion in current use. They represent deviations of dental occlusion in the antero-posterior directions (figure II.1):

- Class I or normal occlusion: includes molar neutrocclusion, whereby the mesio-buccal cusp of the maxillary first molar occludes in the central groove of the first mandibular molar. While Class I may actually be accompanied with malocclusion usually in dentoalveolar conditions. The current prevalence of Class I malocclusion in the U.S. population is 50 – 55% (Proffit 2013).

- Class II division 1 malocclusion with distocclusion of the mandibular first molar, a forward position of the maxillary molar relative to the mandibular molar and an increased overjet between the anterior teeth (protrusion of the maxillary incisors). This malocclusion usually occurs in combination with a convex profile and retrognathic mandible (McNamara et al. 1981). The present occurrence of the population of the USA is nearly 15% (Proffit 2013).
- Class III: recognized by molar mesiocclusion where the mandibular molar is forward relative to the maxillary molar, it is associated with a concave profile, anterior crossbite, and prognathic mandible. Less than 1% of the U.S population is affected by this malocclusion (Proffit 2013).
- Defined at a later stage by Angle, Class II division 2 malocclusion was based on the clinical presentation of the dentoalveolar pattern (reduced overjet). The condition is rare (1.5-5 % in the USA).

Angle's classification contained various deficiencies (Simon 1926, Ackerman and Proffit 1969):

- One dimensional (A-P) stratification of three-dimensional malocclusions
- Limited to describing relations of teeth
- No clear differentiation between dento-alveolar and skeletal discrepancies
- No account for arch length discrepancies
- No indication of the complexity of the problem

  In addition, malocclusions with the same classification/ "Label" might not have the same common characteristics and could be treated differently.

Occlusion	Relation between Maxilla and Mandible	Facial Profile
Class I occlusion 	Orthognathic	Straight 
Class II division 1 	Maxillary prognathism and/or mandibular retrognathism	Convex 
Class II division 2 	Deep bite, normal overjet	Straight, concave subnasal profile 
Class III 	Maxillary retrognathism and/or mandibular prognathism	Concave 

Figure II.1. Simplified guide of occlusion and associated facial profile

Before the advent of cephalometrics, Angle's classification was based on the theory that the maxillary first permanent molar is the reference for occlusion. Subsequently cephalometric findings did not confirm this premise. Yet the simplicity of this classification insured its long lasting legacy, providing a common reference across the world.

In time, the canines were included in the same scheme of "class" description, when categorizing the occlusion of a patient to determine a more complete diagnosis of the malocclusion.

While Angle's classification is prominent in daily usage, many others have been advanced. Listed below are important attempts at improving or complementing Angle's categories for a more comprehensive diagnosis of malocclusion.

Simon (1922) was the first to relate teeth to the total face and the skull using the 3 planes of reference: vertical, antero-posterior and medio-lateral. He added and stressed on the orientation of the dental arch to the face and the cranium, separating dental from skeletal problems in 3 dimensions. However, his classification was confusing for regular utilization.

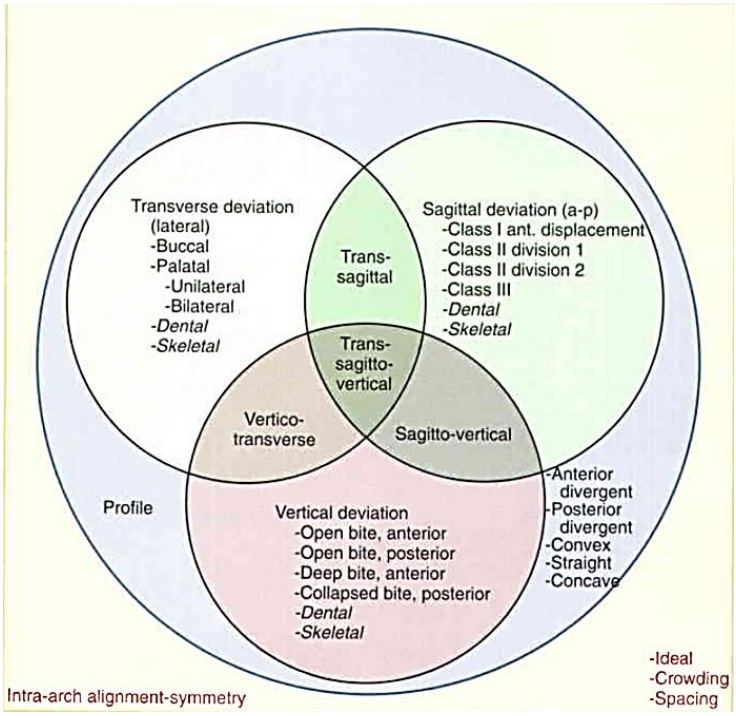

Figure II.2. Ackerman and Proffit malocclusion classification (1969).
(Proffit, W.R., Fields, H.W., 2013. Contemporary Orthodontics, 5th ed. Mosby, st Louis)

Ackerman and Proffit (1969) described 1 to 9 groups of malocclusion with five descriptive characteristics: intra-arch alignment, profile, transverse, sagittal and vertical. This classification reveals the complexities of malocclusions but has not gained popularity in clinical practice. The authors used Lisher's nomenclature for individual teeth malposition (e.g. by adding a suffix to the dental inclination such as distoversion, axioversion, infraversion, torsioversion) (Figure II.2).

Andrews (1972) introduced the six keys to normal occlusion complementing the description of normal dental relations: 1) a Class I molar relationship (distal cusp of maxillary first molar in contact with mesial cusp of mandibular second molar, and mesiolingual cusp of maxillary first molar in contact with central fossa of mandibular first molar); 2) the tip or crown angulation with the gingival portion tipped distally; 3) the torque or crown inclination (Anteriorly the gingival portion more lingual, gingival portion more buccal for maxillary posterior teeth, and progressively more buccal in mandibular posterior teeth); 4) absence of rotations; 5) tight contact points and 6) flat occlusal plane or minor curve of spee.

B. Etiology of malocclusions

Ackerman (2015) captured the complexity of etiology of malocclusion containing genetic and environmental components in an essay on the scientific foundation of orthodontics. He stipulated that for Darwin who studied facial expressions in "Animals and Man", malocclusion would probably be a "normal heritable morphologic variation as a result of evolution", and that well aligned teeth would induce

better function and enhance oral health. He noted that in the last century, no scientific evidence validated such original hypotheses, and that ideal occlusion remains the most essential model in orthodontics, awaiting a novel scientific standard to replace it. The role of muscles is not fully understood, albeit the assumption is that by exerting an abnormal force on the mandible, they may stimulate it to abnormal growth and malformation (Ackerman 2015).

1. Genetic and environmental etiologies for non-syndromic malocclusions

Among all malocclusions, skeletal Class III patterns have been more often linked to familial history. The Hapsburg family (ruling in Europe for 23 generations) had characteristically enlarged mandibles.

Many investigators have attempted to establish the genetic etiology of Class III malocclusion. Few studies have been done on families with a high incidence of skeletal Class III malocclusion to sort out genetic tendencies. After exploring the Class III malocclusion of 12 families, Bui et al. (2006) demonstrated that this phenotypical trait was inherited in an autosomal dominant mode (ARHGAP21 gene). The same had been already suggested by Mossey (1999). However, recognition of the genes associated with Class III still requires major undertakings.

Given the lack of a breakthrough in the genetic research of Class III, Ghafari (2004) advanced the possibility of genetic dominance in mandibular macrognathism, which should be the basis of inclusion criteria in genetic studies. This premise is reinforced by data supporting the potential for environmental causes behind maxillary retrognathism.

Nakasima et al. (1982) compared the craniofacial morphologic differences between parents with Class II children and those with Class III and analyzed the parent-children correlations within each of these malocclusions. They found a hereditary pattern of inheritance in both dysmorphologies. Harris and Kowalski (1976) also determined that familial similarities in Class II reveal some genetic features that may be used as predictors for future growth.

Although human research holds great potential, animal prototypes have directed the way. Numerous studies have been done in transgenic mice; specifically, the FGFR3 gene has been shown to regulate endochondral ossification through the mitogen-activated protein kinase pathway (Machicek et al. 2007). When inserted for an active MEK1 (MAPK kinase) mice, this gene created hypoplastic midface and nasal bone, in combination with mandibular prognathism (Murakami et al. 2004).

The Insulin-like Growth Factor 1 gene, mediating the growth hormone, acts on the growth of bones and muscles post-natal (Barton and Crowder 2010). Also Tomoyasu et al. (2009) stated that growth hormone receptor gene is associated with differences in mandibular ramus height.

The U.S. Human Genome Project which concentrates on the assembly of complete genetic maps for detecting and recognizing genes vulnerability to disease, illustrates the source of our knowledge of genetic diffusion. These improvements in genetics and molecular biology have offered accuracy in studying the genetics of craniofacial disorders, but have not yet yielded advanced knowledge on non-syndromic malocclusions.

Complexity surrounds etiologic definition of Class III malocclusion, as genetic and environmental interactions likely affect the oral-facial region.

Maxillary retrognathism may very well be of genetic origin, but it may also be due to environmental factors.The environment was found to influence the craniofacial complex in size and shape with lower genetic components (King et al. 1993). This finding suggests the possible minimization of full expression of Class III despite this malocclusion being the most likely deformity to run in families (Proffit et al. 2007). Ghafari et al. in 2004 suggested that an early anterior cross-bite associated with mandibular anterior position (particularly in deep bite) and sustained during a lengthy period of growth, might induce maxillary retrognathism that otherwise would not exist. This hypothesis of the environmental etiology of the retrognathic maxilla versus the genetic etiology of the prognathic mandible remains to be tested. The hypothesis is further reinforced by the finding (Ghafari et al. 2013 and Haddad, 2008) that maxillary retrognathism may be more prevalent than mandibular prognathism in Class III.

As Angle himself suggested when defining Class III malocclusion, nasal obstruction may be the cause of advancing the mandible to help clear the airway (Angle 1907). Indeed Angle's only justification for the etiology of Class III was: "Deformities under this Class begin at about the age of the eruption of the first permanent molars, or even much earlier, and are always associated at this age with enlarged tonsils and the habit of protruding the mandible, the latter probably affording relief in breathing." These concepts were supported by other authors (Macari and Ghafari 2006). Oral breathing has been shown as a primary etiology in association with various malocclusion traits: maxillary constriction, openbite, posterior crossbite (Souki et al. 2009). Various habits have also been incriminated as harmful to the normal development of the occlusion (Thomaz et al. 2012).

2. Genetic and environmental etiologies in syndrome-associated malocclusions

Certain syndromic conditions, with a genetic etiology, have been described in the literature as presenting a skeletal Class III malocclusion, they include:

- Crouzon syndrome (underdeveloped midface with receded cheekbones or bulging eyes)
- Achondroplasia (a hereditary condition with associated midface deficiency resulting from the failure development at the level of the cartilaginous nasal capsule or can only be an expression of normal morphologic variation (Litton et al. 1970). The condition is characterized by short limbs and a reduced face to skull ratio because of retarded ossification of cartilage resulting in disrupted growth of long bones.
- Acromegaly: abnormal growth of the hands, feet and face caused by a tumor of the anterior pituitary gland, leading to overproduction of the growth hormone, which in turn acts on the condylar cartilage creating an energetic mandibular growth. Post-pubertal overproduction of growth hormone leads to a disproportionate growth of the jaws and facial bones, resulting mostly from periosteal bone apposition due to reactivation of the sub-condylar growth zones. The most visible features of acromegaly include a larger ramus, prominent mandible, chin and lips.

Recent gene mapping and linkage analysis of individuals with achondroplasia and acromegaly have identified some of the responsible genes. Since skeletal Class III malocclusion is one of the manifestations of these two disorders, the genetic determinants of facial development in general and facial deformity in particular might be better understood in the future (Preising et al. 2003, Machicek et al. 2007, Yagi et al. 2004).

C. Components of malocclusion

1. Class III malocclusion

McNamara et al. (2006) did not find any difference in the sagittal position of the maxilla between Class III and Class I groups. However, the sagittal mandibular position and dimensions in Class III subjects were consistently larger than in the Class I group. The lower anterior facial height was significantly greater in Class III during the late developmental stages.

The restraint of forward maxillary growth, produced non-therapeutically, and named developmental growth modification or intragrowth orthopedics (Ghafari 2004), resembles that of a headgear that induces a clockwise rotation of the maxilla (PNS higher than ANS). In a finite element study of transfer of occlusal forces through maxillary molars, Cattaneo et al. (1996) demonstrated that distal molar displacement induces deformation of the posterior part of the maxilla through compression, and compensatory tensile stresses in the anterior part of the maxilla and at the zygomatic arch. The authors suggested that this force distribution might account for the backward rotation of the palatal plane. Following up on this concept, it is conceivable that a high position of Sella relative to Nasion might have resulted from the transfer of the same clockwise rotation discussed above (section B1) to the level of the cranial base (Ghafari et al. 2013).

Singh (1999) inferred that an acute cranial base angle is found in Class III subjects that may affect the articulation of the condyles in their glenoid fossae resulting in their forward displacement. He also inferred that the reduction in the anterior cranial base size may affect the position of the maxilla.

Components of Class III other than an increase in the cranial base flexure and or shorter anterior cranial base include:

- maxillary retrognathism with or without mandibular prognathism
- proclined maxillary incisors and retroclined mandibular incisors
- enlarged mandible relative to the maxilla
- small maxilla relative to the mandible
- forward rotation of the mandible, inducing a protrusive position of the chin and a reduced lower anterior facial height.

These descriptions imply a simplification of Class III definition (e.g. Angle's definition). In reality, much more complexity and severity in the problem is found according to cephalometric diagnosis in differentiating between macrognathism and prognathism of the mandible in reference to the dental and skeletal bases (Dhopaktar et al. 2002, Haddad 2008).

In addition to the difficulties in diagnosing Class III phenotypes, craniofacial growth, particularly mandibular growth, is highly variable, and is reported to continue into the late teens and well beyond the third decade of life (Behrents et al. 1986). Emphasis should be placed on characterizing the sources of individual variation including investigating the heritable patterns of mandibular macrognathism first, then the other skeletal characteristics.

2. Class II malocclusion and the distinction of Class II division 2

Wilhelm et al. (2001) found that the cranial base grows similarly in Class I and Class II, and no significant changes were found in cranial base angle between these groups. According to Dhopatkar et al. (2002), cranial base length was larger in Class II

and similar between Class I and Class III. The cranial base angle was larger in Class II division 1 but similar in the other malocclusions. Hopkin et al. (1968) reported that cranial base length differed significantly among all groups of malocclusion, and the cranial base angle showed smallest values in Class III and largest in Class II. In another comparison of all malocclusions, Kerr and Adams (1988) found a decreased cranial base length and angle, in sequence, among Class II division 1, division 2 and Class III groups.

Class II malocclusions, particularly Class II division 1 are associated with retrognathic mandibles (McNamara 1981), usually micrognathic but possibly of normal size. In orthodontics, Class II mandibles have long been recognized as retrognathic, if only as a group characteristic much like mandibular prognathism has been a trademark of Class III.

Facial patterns of skeletal Class II can be misleading. While the prevailing assumption is that a micrognathic mandible is responsible for discrepancy between the jaws, some patients, more specifically these with Class II division 2 malocclusion, have a skeletal Class II pattern combined with a strong chin and a concave subnasal profile (Isik 2006, Karlsen 1994).

According to some researchers (Brezniak et al. 2002), Class II division 2 malocclusion is associated with an orthognathic facial pattern and is related to dentoalveolar malocclusion. Others attribute different skeletal and dentoalveolar characteristics: orthognathic maxilla, short and retrognathic mandible, relatively prominent chin, hypodivergent facial pattern, acute gonial angle, distinctly retroclined maxillary central incisors, and deep overbite.

The genetic etiology of the skeletal Class II has been related to Class II division 2 (whether directly or indirectly) through the study of hypodontia. The increase in rate of missing teeth in Class II division 2 has been linked to specific genes (MSX1, AXIN2) (Hartsfield et al. 2012, Ghafari et al. 2013). Such association has not been found in Class II division 1 (Ast et al.1965; Mills 1966). Basdra et al. in 2001, examined the relationship between congenital tooth anomalies in Class III and Class II division 1. They concluded that there was no statistically significant difference in the prevalence of maxillary lateral incisor agenesis, peg-shaped laterals, impacted canines, or supernumerary teeth between these two malocclusions. When the occurrence rate of all congenital tooth anomalies was compared between the two malocclusions, Class III subjects showed significantly higher rates.

The linkage between dental and skeletal anatomy provides an interesting level for multifaceted albeit complex research.

3. Mandibular size among malocclusions

While mandibular macrognathism has been recognized in families and is concomitant with mandibular prognathism in Class III malocclusions, prognathism may exist without macrognathism. Macrognathia is classically defined as an enlargement of the jaw and is usually associated with a developmental deformation of the mandible.

McNamara et al. (2006) found that mandibular dimensions were larger in Class III compared to Class I subjects. The largest ‘‘increase’’ in mandibular length occurred on average 1 year later in Class III subjects compared to participants with normal occlusion (whether males or females). The same trend was also found in younger (13 to 14 years) and more mature (15 to 16 years) age groups.

Sayin and Turkkahraman (2005), comparing Class II division 1 non growing females to Class I group, found undersized and more retrognathic mandible, which was more downward and backward rotated due to a shorter ramus height and increased gonial angle. Gilmore (1950) also reported the mandible in Class II division 1 to be smaller compared to Class I malocclusion; while this finding was more prevalent in females, no gender difference was observed in the gonial angle.

On the other hand, Maj, Luzi, and Lucchese (1960) found that the total mandibular length in 96% of Class II was similar to that of normal individuals of corresponding age. Rothstein (1971) similarly concluded that the mandible most often was in the normal range comparing Class II division 1 to Class I.

Bishara (1998) found few consistent trends between Class II division 1 and Class I subjects: the differences in mandibular length and position were more evident in the early stages of development than at the later stages. The comparison of growth magnitude indicated the presence of greater skeletal facial convexity in Class II division 1, accompanied by a tendency for a more retruded mandible. The longitudinal comparisons of the growth profiles indicated that the growth trends were essentially similar between Class II division 1 and Class I. These findings were corroborated by other investigators who compared untreated Class I and Class II populations (Baccetti et al. 2008, 2009).

In a comparison with Class I and Class II division 1 groups, Brezniak et al. (2002) described the class II division 2 mandible as having relatively short and retrognathic parameters and relatively prominent chin. Karlsen (1994) found that patients with Class II division 2 have an underdeveloped distance between Gonion and B-point, the latter being retruded relative to both A-point and the cranial base. In

addition, B-point was retruded relative to Pogonion most probably due to the retrognathic position of the symphysis of these patients in the face. These variations in mandibular growth have been extensively explored by Bjork and Skieller (1972, 1983). The rotational growth resultant from the vertical and sagittal growth of the mandible was implicated in the development of chin prominence. Supporting these results, Baldridge (1941) found that in skeletal Class II division 2, the mandible may be in its normal position antero-posteriorly but may also be longer than the mandible of Class I individuals.

Blair (1954) described a more acute gonial angle with a shorter mandible in Class II division 2 patients when compared to the mandible in Class I patients, which present with a more forward position of the anterior portion of the mandible. Maj and Lucchese (1982) determined that the ramus and the chin are more developed in some patients, suggesting the segmenting of the mandible into anterior and posterior parts leading to different positions and lengths than the whole mandible when considered as a unit. Peck, Peck and Kataja (1998) stated that mandibular basal bone formation was increased in Class II division 2, leading to a stronger chin projection.

Comparisons between Class II division 2 and Class III are lacking. Emerging from this review on the mandible in the Class II.2 is a disparity of findings, possibly associated with variation in the jaw relations. In the sagittal direction, Class II division 2 malocclusion might be located between Class II division 1 and Class I, with unique vertical characteristics (Brezniak et. al 2002).

D. Rationale for the present study

Malocclusions represent a spectrum of phenotypes with potentially similar components, e.g.: hyper and hypodivergence, deep and openbite, transverse constriction (crossbite) or increased width. At the extreme poles Class II division1 and Class III differentiate through the fact that the dominant components of the malocclusions lie principally in mandibular retrognathism and/or micrognathism in Class II division1, and mandibular prognathism and/or macrognathism in Class III. Such differentiation may not be solid for Class I normal or mal-occlusion. More revealing and impacting on diagnosis and treatment is the fact that Class II division 2 malocclusion, supposedly within the domain of Class II dysmorphology, may have features closer to Class I and Class III, such as increased mandibular size.

This context will be a major part of this study. However, the mandibular components may not be singled out without their relations to other components, thus the scope of this investigation relates to component analysis of craniofacial relations in various malocclusions.

CHAPTER III

MATERIALS AND METHODS

A. Materials

1. General characteristics

The sample consisted of pre-treatment lateral cephalograms and panoramic radiographs of patients screened at the Division of Orthodontics and Dentofacial Orthopedics Clinics of the American University of Beirut Medical Center. IRB approval was granted before initiation of the study to evaluate the existing radiographs under specified regulations.

The power analysis indicated that a minimum number of 250 subjects was needed for this study. We were able to recruit 322 subjects who were stratified in 4 groups on the basis of malocclusion:

Group 1: Class I malocclusion (control group)

Group 2: Class II malocclusion division 1

Group 3: Class II Division 2

Group 4: Class III malocclusion

Each group was further divided into 2 age groups: growing and adult. The cutoff age between growers and adults was 16 years for females and 18 years for males.

2. Inclusion criteria

At least 2 criteria were used to differentiate malocclusions (Table III.1). ANB and OJ (overjet: the distance between maxillary and mandibular incisal edges in the sagittal plane) discriminated among Class I, Class II.1 and Class III but not for Class II.2, as the overbite (OB) was a unique characteristic that had to be included in the basic diagnosis of this malocclusion. OB was measured as the percentage overlap of the mandibular incisors by the maxillary incisors. It was set at a minimum of 80% for Class II.2. Given that Class II.2 has been described to include Class I molar occlusion or Class I skeletal pattern, and to avoid any overlap between Class I and Class II.2, all recruited Class I subjects had a maximal overbite of 30%. Accordingly, a fragment of Class I might have been excluded.

Table III.1. Sample selection and inclusion criteria

	Class I	**Class II.1**	**Class II.2**	**Class III**
OJ (mm)	2-3	≥5	2-3	≤0 (at least edge to edge)
OB (%)	30		≥80	
ANB (°)	0<ANB<3.5	≥4.5		<0

3. Exclusion criteria

Patients who had prior orthodontic treatment or a craniofacial anomaly were excluded from the study.

4. Group characteristics

a. Class I group

This group included 89 patients: 38 males (22 growing, 16 adults) and 51 females (31 growing, 20 adults) - Table III.2. A representative lateral cephalogram is shown in Figure III.1.

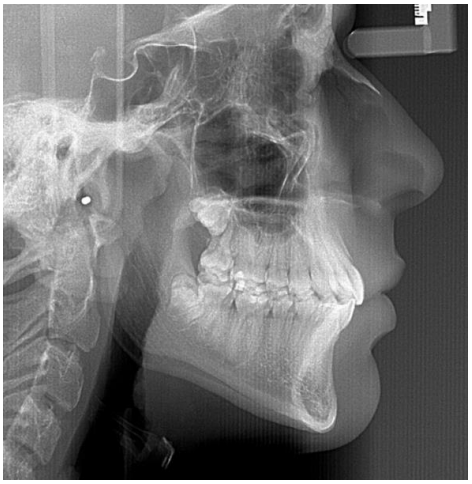

Figure III.1. Lateral cephalogram for a Class I individual

Table III.2. Class I group characteristics

		Males	**Females**
N	89	38	51
Growing	53	22	31
Adults	36	16	20
Age Mean Range		18.14 ± 7.45 [8.08 – 35.75 years]	16.62 ± 7.83 [7.75 - 34years]

b. Class II division 1 group

Of the 85 patients in this group, 41 were males (19 growing, 22 adults) and 44 females (21 growing, 23 adults) Table III.3. A representative lateral cephalogram is displayed in Figure III.2.

Figure III.2. A lateral cephalogram of a Class II division 1 individual

Table III.3. Class II division 1 group distribution

		Males	**Females**
N	85	41	44
Growing	40	19	21
Adults	45	22	23
Age Mean Range		17.65± 6.77 [9 - 33.66 years]	18.57 ± 8 [8.67 – 35.58 years]

c. Class II division 2 group

In this group, 69 patients were divided in gender subgroups of 32 males (16 growing, 16 adults) and 37 females (17 growing, 20 adults) - Table III.4. The characteristic features of the malocclusion appear in a representative cephalogram (Figure III.3).

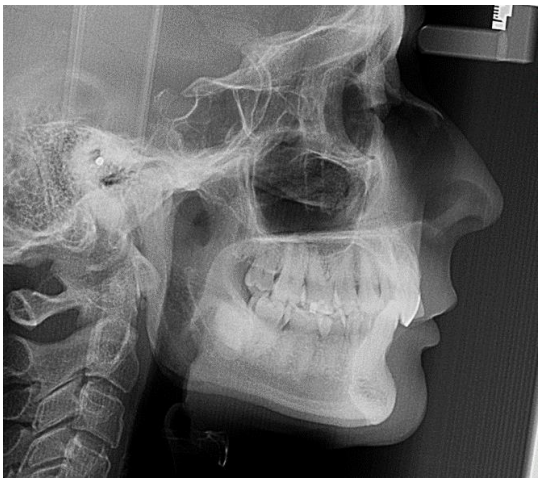

Figure III.3. Lateral cephalogram of a Class II division 2 individual

Table III.4. Class II division 2 group distribution

		Males	**Females**
N	69	32	37
Growing	33	16	17
Adults	36	16	20
Age Mean Range		19.02± 7.50 [8.25 – 35.1years]	19.22± 7.86 [8 - 35 years]

The Class II.2 group was further stratified into 4 subtypes 1A, 1B, 2A and 2B, as described by Ghafari and Street (1992): 1 and 2 on the basis of maxillary incisors retroclination (1: severely retroclined, 2: less retroclined), A and B according to mandibular plane inclination (A: increased hypodivergence, and B: closer to normal divergence) - Figure III.4.

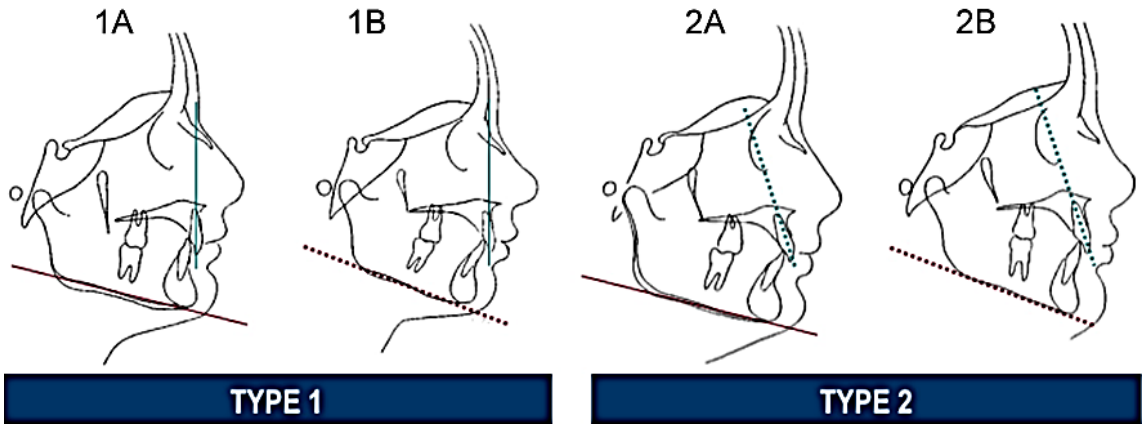

Figure III.4. Classification of Class II Division 2: representative tracings of types 1A, 1B, 2A, and 2B. (after Ghafari and Street 1992)

After gathering our Class II division 2 group and checking maxillary incisors inclination (U1/NA<12˚for group 1, and ≥12˚ for group 2) and the divergence (PP/MP<18˚ for A and ≥18˚ for B), it was distributed as the following in Table III.5.

Table III.5. Class II division 2 Subtypes distribution

Class II division 2 subtypes	**1A**	**1B**	**2A**	**2B**	Total
N	9	28	9	23	69

d. Class III group

This group included of 79 patients, with 43 males (25 growing, 18 adults) and 36 females (18 growing, 18 adults) - Table III.6. A typical profile outline is displayed in Figure III.5.

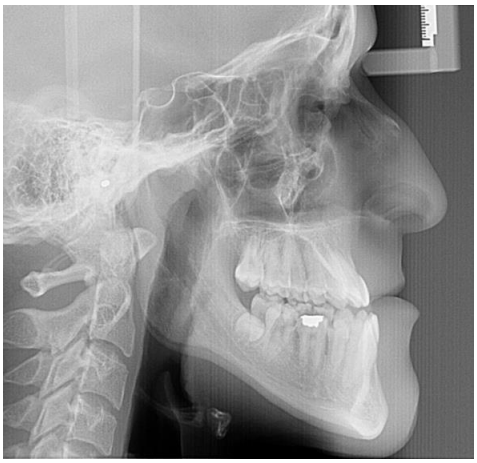

Figure III.5. Lateral cephalogram of a Class III individual

Table III.6. Class III group distribution

		Males	**Females**
N	79	43	36
Growing	43	25	18
Adult	36	18	18
Age Mean Range		17.55 ± 7.14 [7.58 -35.75years]	15.74 ± 7.08 [5.17 – 31.59 years]

B. Methods

All lateral cephalometric and panoramic radiographs were taken in the same digital machine (GE, Instrumentarium, Tuusula, Finland) following standardized procedures as per manufacturer's instructions. The body of the patient was covered with lead apron. The images were saved and stored in dedicated software (Cliniview 9.3).

1. Cephalometric evaluation

Lateral cephalometric radiographs were taken in natural head position (Moorrees et al. 1995) with the posterior teeth in occlusion and the lips touching gently. The lateral cephalograms were imported in an Imaging program (Dolphin Imaging and

Management Solutions, version 11.5, La Jolla, California, Figure III.6), and digitized, by one investigator (RT).

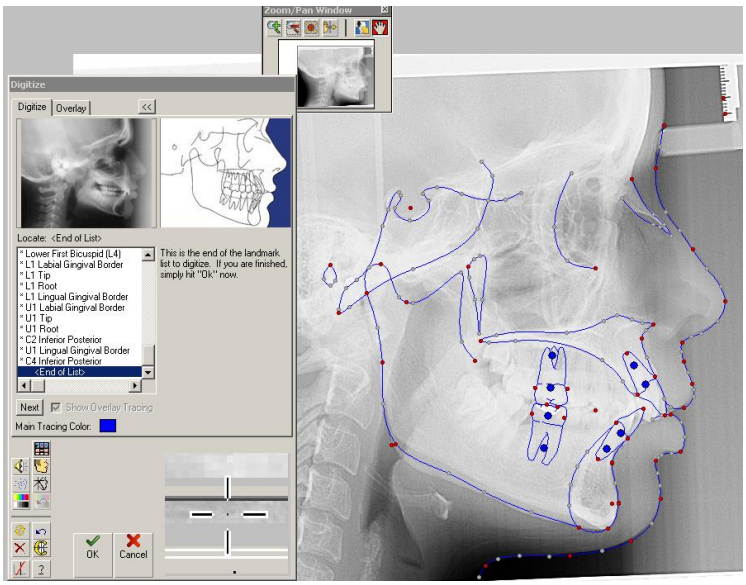

Figure III.6. Frame of view in computer while digitizing a lateral cephalogram using Dolphin Imaging program

Several advantages stem from using the imaging program:

- Options are available to enhance the digitized image for better identification of landmarks and adequate assessment of the bony and soft tissue structures.
- The computer software is consistent and minimizes operator time and efforts. Easily manipulated, it provides accurate measurements and instant reading of linear and angular measurements of corresponding landmarks that are transferred to the database.
- The program generates tracings of the digitized headfilms.

a. Cephalometric landmarks used in the digitization

The landmarks were selected to represent the structures needed for the comparisons of malocclusions. They included key points in the cranial base, maxilla and mandible (Figure.III.7). The definitions listed in the glossary of the American Association of Orthodontists were adopted (Tables III.7, 8, 9). Where two outlines of a structure (e.g. gonion landmarks and mandibular border) were present, the average landmark

(midpoint bisecting the distance between the two images) was selected.

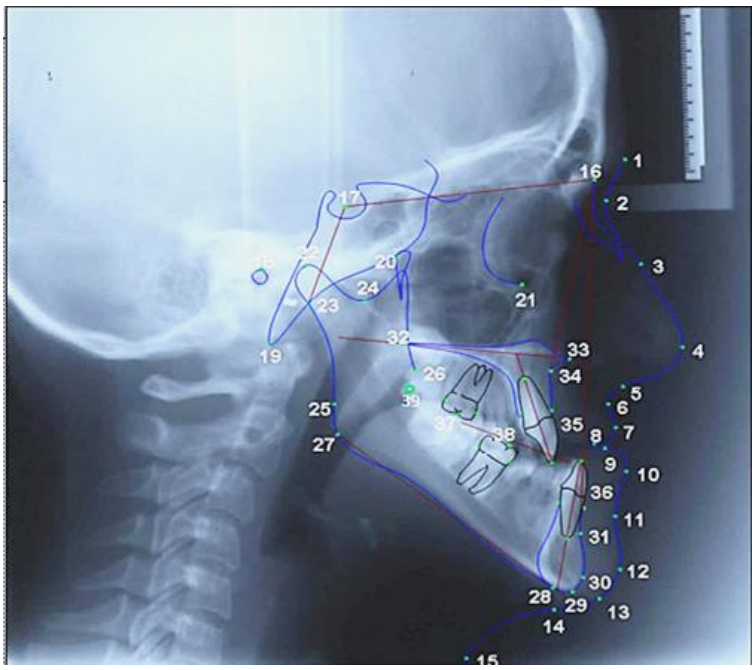

Figure III.7. Digitized lateral cephalogram with soft and hard tissue landmarks

Table III.7. Soft tissue landmarks

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

Table III.8. Hard tissue landmarks

Landmark	Number	Definition
Nasion (N)	16	The junction of the frontal and nasal bones
Sella (S)	17	The pituitary fossa. The center is used as a cephalometric landmark.
Porion (Po)	18	Highest point on the roof of the external auditory meatus
Basion (Ba)	19	Most inferior point on the anterior margin of the foramen magnum in the midsagittal plane
Pterygoid point (PT)	20	Most posterior point on the outline of the pterygopalatine fossa
Orbitale (Or)	21	Lowest point on the lower margin of the orbit.
Condylion (Co)	22	The highest point on the superior outline of the mandibular condyle.
Articulare (Ar)	23	A (Bjork) 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
Sigmoid notch	24	Deepest point on the sigmoid notch of the mandible
Ramus point	25	Most posterior point up the border of the ramus
Mid ramus	26	Most concave point of the inferior of the ramus
Gonion (Go)	27	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)
Menton (Me)	28	The most inferior point on the chin in the lateral view
Gnathion (Gn)	29	Lowest point of the Mandibular symphysis
Pogonion (Pog)	30	The most anterior point on the contour of the bony chin in the midsagittal plane
B point	31	The deepest (most posterior) midline point on the bony curvature of the anterior mandible, between infradentale and pogonion. Also called supramentale. (Downs)
Posterior nasal spine (PNS)	32	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.
Anterior nasal spine (ANS)	33	The tip of the bony anterior nasal spine at the inferior margin of the piriform aperture, in the midsagittal plane
A point	34	Subspinale, the deepest (most posterior) midline point on the curvature between the ANS and prosthion (dental alveolus) (Downs)
Ramus point (R)	39	Lowest inner point of the Ramus

Table III.9. Dental landmarks

Landmark	Number	Definition
U1	35	Most proclined maxillary incisor (at the incisal edge)
L1	36	Most proclined mandibular incisor (at the incisal edge) Infradentale: the highest and most forward point of the alveolar process between the mandibular central incisors
U6	37	Maxillary first molar
L6	38	Mandibular first molar

b. Specific data collected

Linear and angular measurements were performed to gauge the characteristics among cranial base, maxillary and mandibular structures. The planes used as references (e.g. SN) or to identify inclinations of structures (e.g. palatal and mandibular lines) are illustrated in Figure III.8, and the various measurements in Table III.10.

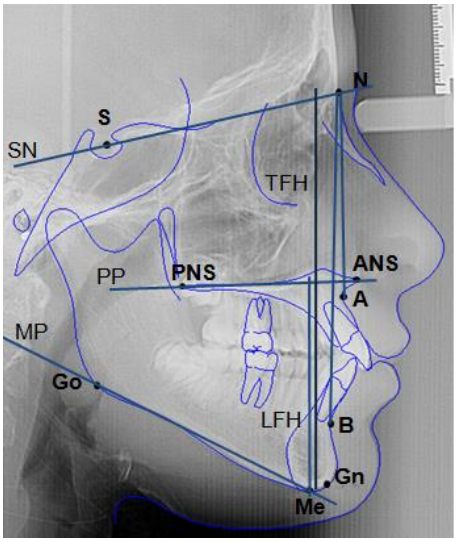

Figure III.8. Lateral cephalometric tracing with landmarks and angles used in this study to describe the relationship between jaws, cranial base, and horizontal

Table III.10. Definitions of cephalometric reference lines or planes

Lines	Definition
SN	Superior length of anterior cranial base from Sella to Nasion
Horizontal plane (H)	The true horizontal line passing through Sella
Palatal plane (PP)	Plane joining the anterior and posterior nasal spines (ANS-PNS)
Mandibular plane (MP)	Plane joining Gonion and Menton points (Go-Me)

The measurements encompassed relations among cranial base, jaws and teeth (Table III.11).

Table III.11. Measurements from lateral cephalogram tracing

	SAGITTAL	VERTICAL
Cranial base	**LENGTH** -SN (anterior cranial base) -S-Ar (posterior cranial base)	**INCLINATION** -SN/Horizontal *Depicts inclination of anterior cranial base in reference to natural head position* -Saddle angle : SN/Ar *Evaluates cant of anterior cranial base*
Relationship between jaws, cranial base, and horizontal	**POSITION** -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)*	**INCLINATION** -PP/Horizontal (H) *Depicts vertical inclination of the palatal plane (PP) to Horizontal (natural head position)* -MP/H; -SN/MP *Depicts vertical inclination of the mandible relative to Horizontal (natural head position) and to cranial base cant (SN)*
Relationship between jaws	-ANB *Angle between points A and B*	-Palatal/mandibular planes (PP/MP) *Depicts vertical relationship between the jaws through the angle between palatal plane and mandibular plane.* -Lower to total face height (LFH/TFH) *Projection of distance subnasale to menton in relation to total face height (Nasion-Menton)*
Jaw-specific measurements **Maxilla** **Mandible**	**SIZE** -ANS-PNS *Length of maxilla* Co-Go, Co- Gn, , Ar-Gn *Length of mandible* -body Go-Me, Go-B, Go-Pog -ramus (Ar-Go) *Length of mandibular components: body and ramus* -R-A, R-B, R-L1 *Mandibular alveolar length from mid-ramal point R to points A and B, and lower incisor* -Chin measurements: B-Pog *Mid-chin length*	**SHAPE** -Jaw angle (Ar-Go-Me, Co-Go-Me) *Measures opening of mandibular angle between ramus and body* - Shape of chin button : Anterior Symphyseal Angle ASA= between B-Pog and the vertical through B) *Measures cant of anterior slope of symphysis*
Relationship between teeth and jaws	-Maxillary incisors: U1/NA˚, U1-NAmm, U1/SN and U1/PP *Inclination of incisors to NA, SN and PP* -Mandibular incisors : L1/NB˚, L1-NBmm and L1/ MP *Inclination of incisors to NB and MP*	
Relationship between teeth	-Overjet (OJ) *Anterior projection of maxillary incisors relative to mandibular incisors* -Interincisal angle : U1/L1	-Overbite (OB) *Percent of overlap of mandibular incisors by maxillary incisors*

As clinical data were not available for classification, the overjet and overbite were measured on the cephalograms. Specifically for the overbite, the measure automatically computed in the software in millimeters. For the purpose of classification of Class II.2 on the basis of percent overlap of mandibular incisors by maxillary incisors, the mm value provided by the software, which measured the vertical distance between maxillary and mandibular incisors, was divided by the crown height of the mandibular incisor, measured from the mandibular incisor tip to infradentale.

2. Panoramic evaluation

Panoramic radiographs available for all the subjects were evaluated for missing teeth (Figure III.9). The patient was positioned with the Frankfort plane parallel to the ground and the median sagittal plane perpendicular to the ground. The patient's chin was positioned in a frontal chin cup with the incisors occluding on the plastic jig with the tongue resting against the palate.

Some films were excluded and accounted for as missing data in the analysis when it was not possible to confirm if teeth were missing or had been extracted (mostly in adult persons), or if it was early to assess (in young patients before the formation of all teeth buds).

Missing teeth were recorded for each eligible patient in 3 forms: 1- existence (0 not missing, 1 missing), 2- number of missing teeth, 3- actual teeth missing.

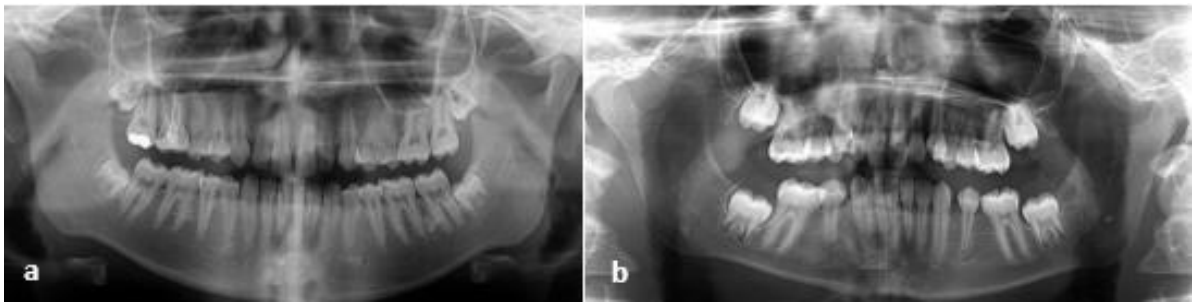

Figure III.9. a- Panoramic radiographs of a girl (14years 10 months) with complete dentition and b- panoramic of a boy (12years 11 months) with missing mandibular permanent second premolars

3. Repeated measurements

To gauge examiner reliability, 33 lateral cephalograms (10% of the total sample) were selected randomly from the total sample and processed through the same research procedures: they were digitized for landmark identification assessment and analyzed a second time for correspondence of measurement.

4. Statistical analysis

Various statistical analyses were applied:

a. The intraclass correlation coefficient gauged examiner reliability.

b. Descriptive statistics were generated for the total sample and for each group of malocclusion. The sample was then stratified by gender and age for further analysis. MANOVA (Multivariate analysis of variance) was conducted to assess the association among different malocclusions. When the MANOVA criteria were not satisfied (e.g. when the Levene's test was significant), independent t tests were applied between pairs of groups and the p value was multiplied by 6 (the number of associations). Also, the MANOVA test was performed comparing the 4 subtypes of Class II division 2 group.

c. A frequency analysis illustrated the distribution of missing teeth among different groups (with a chi-square for differences in missing teeth among malocclusions), also frequency distribution for mandibular size and alveolar length in each group.

d. A comparison of correlations among different malocclusions was conducted for mandibular variables.

e. A bivariate logistic regression helped to assess the effect of each covariate on the Class II division 2 malocclusion. Subsequently, a multivariate logistic regression was performed to model the outcome with the covariates that had a p-value <0.2.

f. A linear regression for Co-Gn with the clinically significant variables was performed in the total sample, at bi- and multivariate levels

All statistical tests were performed using SPSS and STATA as statistical packages, at a level of significance of $p \leq 0.05$.

CHAPTER IV

RESULTS

A. Examiner reliability

The interclass correlation coefficient test was performed for intra-class examiner and gave a coefficient ranging from 0.890 to 0.971. (Appendix1)

B. Differences among malocclusions

1. Total Sample

The total sample consisted of 322 individuals distributed as 89 Class I, 85 Class II division 1, 69 Class II division 2 and 79 Class III (Table IV.1).

a. Age differences

No statistically significant differences were found among the 4 groups (p=0.057).

b. Cranial base measurements

The anterior cranial base SN and the posterior cranial base S-Ar were similar in all groups. Statistically significant differences were observed in the following sets of variables (Tables IV.2.a, b):

- The inclination of the anterior cranial base SN to the true horizontal (p=0.014) between Class II.1 (12.16˚±3.76) and Class III (10.22˚±4.74).

- The saddle angle SN-Ar between Class III (123.60˚±6.62) and both Class II.1 (126.05˚±4.95) [p=0.026] and Class II.2 (127.15˚±4.86) [p=0.001]. The saddle angle was more acute in Class III compared to the Class II groups. Also it was different between Class I and Class II.2 (p=0.023) whereby it was more acute in Class I (124.62˚±5.26). The difference between Class III and Class I was not statistically significant.

c. Relationship between jaws and cranial base

The SNA and SNB angles were statistically significantly different among all groups except for Class II.2 (SNA: 81.27˚±3.77; SNB: 77.13˚±3.63). The latter was close to Class I (SNA: 80.11˚±3.53; SNB: 78.12˚±3.56) on one hand, and to Class II.1 (SNA: 82.36˚±3.37; SNB: 76˚±3.58) on the other hand, with average measurements located at midrange between Class I and Class II.1 (Tables IV.3.a,b).

The inclination of the palatal plane to the horizontal was different between Class II.1 and Class II.2 (p<0.001) and between Class II.1 and Class III (p=0.012). The palatal plane was rotated counter-clockwise in Class II.1 (-3.56˚±4.25), more than Class III (-1.14˚±3.69) and Class II.2 (-1.61˚±2.88).

The mandibular plane was flatter in the Class II.2 (MP/H: 24.36˚±5.61; MP/SN: 31.36˚±5.61) compared to Class I (MP/H: 29.91±5.95; MP/SN: 36.91˚±5.95˚), Class II.1 (MP/H: 29.99˚±6.66; MP/SN: 36.99˚±6.66) and Class III (MP/H: 29.00˚±6.75; MP/SN: 36˚±6.75) [p<0.001].

d. Inter-maxillary relationship

ANB was different among the 4 groups ($p<0.001$). The divergence angle between the two jaws PP/MP was different between Class II.2 and any other group ($p<0.001$), being reduced in Class II.2 (21.11˚±5.12) compared to Class I (26.82˚±5.83), Class II.1 (27.76˚±6.32) and Class III (26.34˚±5.84) (Tables IV.4.a, b). The same applies for the lower facial height that was decreased in Class II.2 (LFH/TFH: 53.71% ±2.11) compared to Class I (55.33% ±2.41), Class II.1 (55.66%±2.50) and Class III (55.57% ±2.62).

e. Jaw-specific measurements

The length of the maxilla (ANS-PNS) was different among all malocclusions except between Class II.1 and Class II.2. It was increased in Class II (Class II.1=49.97±4.46mm, Class II.2=49.95±3.80mm), compared to Class I (47.51±4.51mm) and the shortest in Class III (45.55±5.33mm). (Tables IV.5.a, b)

Mandibular length (Co-Gn) was statistically significantly different between Class III and both Class II malocclusions, Class II division 1 nevertheless having a smaller length than division 2. The vertical ramus height was not different between any 2 groups. The body of the mandible (Go-Me) was different between Class II.1 (61.02±5.75mm) and Class II.2 (64.35±7.57mm), and between Class II.1 and Class III (66.33±9.54mm). It was not different among Class I, Class II.1 and Class III. No statistically significant difference was found for Go-B among all malocclusions (Tables IV.5.a, b).

Go-Pog was statistically significantly different between Class III and Class I ($p=0.043$), and Class III and Class II.1 ($p<0.001$). The difference was not statistically

significant between Class II.2 and Class III, Class I and Class II, Class II.1 and Class II.2. Go-Pog in Class II.2 (68.41±6.65mm) fell between Class III (70.62±9.36) on one side and Class I (67.31±6.88)/ Class II.1 (64.96±8.48) on the other side.

The alveolar lengths R-B, and R-A where significant in all comparisons except Class II.1 and Class II.2: R-A was increased in Class II (Class II.1: 49.25±4.46mm, Class II.2: 49.87±4.71mm) compared to Class I (46.28±4.41mm) and Class III (43.54±4.12), whereas R-B was reduced in Class II (Class II.1: 48.4±4.64mm, Class II.2: 48.73±4.10mm) compared to Class I (50.70±4.53mm) and Class III (53.36±6.05mm). R-L1 was not different among malocclusions.

The chin prominence (ASA) was different between Class II.2 and all other malocclusions and between Class II.1 and Class III. The most increased angle was in Class II.2 (16.43˚±17.24) followed by Class III (10.17˚±7.66), then Class I (7.05˚±7.80), and the smallest in Class II.1 (5.48˚±8.25).

The gonial angle also was reduced in Class II.2 (Co-Go-Gn: 116.44˚±5.19, Ar-Go-Gn: 120.99˚±14.32) compared to Class II.1 (Co-Go-Gn: 121.56˚±5.76, Ar-Go-Gn: 127.88˚±5.92), Class I (Co-Go-Gn: 123.43˚±5.09, Ar-Go-Gn: 129.57˚±5.26), and Class III (Co-Go-Gn: 125.2˚±6.52, Ar-Go-Gn: 131.10˚±6.63) (Tables IV.5.a, b).

f. <u>Relationship between teeth and jaws</u>

The inclinations of the maxillary incisors to SN (U1/SN) and to palatal plane (U1/PP) were not different between Class III and Class I, and between Class III and Class II.1. No statistically significant difference was found for U1/NA when comparing Class II.1 and Class I, also to Class III. The maxillary incisors were retroclined in Class

II.2 (U1/NA= 11.75˚±5.45), proclined in Class II.1 (25.81˚±6.55) and more proclined in Class III (28.19˚±6.63).

The mandibular incisors were retroclined and retruded relative to NB in both Class III (19.90˚±6.14/ 3.28±2.22mm) and Class II.2 (21.71˚±6.99/ 3.19±2.18 mm), as well as to the mandibular plane. The mandibular incisors were similarly inclined to MP in Class II.2 (93.32˚±7.97) and Class I (90.97˚±7.18) (Tables IV.6.a, b).

g. Interdental relationship

The overjet and overbite were statistically significantly different in all comparisons: the least OJ and OB were in Class III (OJ= -1.8 ±2.83mm, OB=0.06±2.24mm), followed by the Class I (OJ=2.38±1.65mm, OB=1.29±1.53mm), Class II.1 had the largest OJ but closer to normal OB (OJ=6.58±1.74mm, OB=2.61±2.23mm). The Class II.2 had normal OJ and the largest OB (OJ=3.05±0.75mm, OB=5.31±1.13mm). The interincisal angle had a statistically significant difference ($p<0.001$) among all 4 groups. It was the most obtuse in Class II.2 group (142.80˚±10.79), followed by Class III (134.77˚±9.98), lesser in Class I (127.58˚±9.39) and the least in Class II.1 (117.41˚±9.10) (Tables IV.7.a, b).

h. Gender differences

Only the variables found to have statistically significant differences between males and females are displayed in the Table IV.8. LFH/TFH was greater ($p=0.021$) in males (55.65%±2.63) compared to females (54.91±2.32); SNB also was greater ($p=0.001$) in males (79.02˚±4.67) compared to females (77.14˚±3.83). PP/H the palatal

plane was tipped upward anteriorly more (p=0.034) in females (-2.46˚±4.11) than males (-1.39˚±3.60).

The linear measurements were all statistically significantly larger in males than in females: length of the palatal plane ANS-PNS (48.50±4.95mm and 46.80±4.67mm, respectively; p=0.006): mandibular length measurements Co-Go (53.74±8.04mm versus 50.83±6.16mm; p=0.001), Go-Me (64.13±7.93mm versus 61.76±6.96mm; p=0.013), Go-Pog (69.68±7.96mm versus 65.68±7.21mm; p<0.001), Ar-Gn (107.44±17.60mm versus 102.41±10.19mm; p=0.005), and Co-Gn (113.39±13.28mm versus 107.40±10.45mm; p<0.001). The opposite was found in the overjet OJ, were it was increased more in females (2.97± 2.92mm) compared to males (1.93±3.70mm; p=0.014).

2. Subgrouping by age and gender

Results are presented in this section on the 4 subgroups based on age and gender: growing females, growing males, adult females and adult males.

a. Growing female group (Table IV.9)

i. Cranial base measurements

SN/H and SN-Ar were statistically significant different between Class II.1 (SN/H=13.85˚± 3.15/ SN-Ar=127.18˚±5.28) and Class III (SN/H= 10.52˚± 3.22; SN-Ar= 122.56˚±5.48), showing a higher Sella and a more acute saddle angle in the Class III malocclusion (Tables IV.10.a, b).

ii. Relationship between jaws and cranial base

SNA was statistically significant different between Class II.2 and Class I (p=0.027), and between Class II.2 and Class III (p=0.031). The maxilla was more protrusive in Class II.2 (82.15˚± 3.49) compared to Class III (79.13˚± 2.69) and Class I (79.41˚± 3.33).

SNB was different in all combinations except between Class II.2 and Class I and between Class II.2 and Class III. The mandible in Class II.2 (78.51˚±3.63) was between Class I (77.58˚±3.25) and Class III (80.41˚±2.74), and comparatively deficient in Class II.1 (74.40˚±2.91) (Tables IV.11.a, b).

The palatal plane was tipped inferior-posteriorly (counter-clockwise) the most in Class II.1 group (-4.3˚±4.29) and the least in Class III (-0.61˚± 3.12) with a p=0.027.

The mandibular plane was the flattest in Class II.2 (MP/H=25.40˚±4.75, MP/SN=32.40˚±4.75), which was significantly different from Class I (MP/H= 29.96˚±5.05, MP/SN=36.96˚±5.05) and from Class II.1 (MP/H=31.66˚±4.57, MP/SN= 38.66˚±4.57), but not different from Class III (MP/H=27.49˚±5.99, MP/SN= 34.48˚±5.99).

iii. Inter-maxillary relationship

ANB was significantly different among all malocclusions (p<0.001). Although lower facial height was not different among malocclusions, PP/MP was different between Class II.1 (28.51˚±4.43) and Class II.2 (23.15˚±4.57) and between Class II.1 and Class III (23.90˚±5.76) (Tables IV.12.a, b).

iv. Jaw-specific measurements

The palate was the shortest in Class III (ANS-PNS= 41.98±3.43mm), and exhibited a statistically significant difference with all other malocclusions (Class I: 45.63±3.73, Class II.1: 47.47±3.24, Class II.2: 48.27±4.10).

In this subgroup, unlike the total sample, there was no difference in mandibular measurements among different malocclusions except for the mandibular alveolar length R-B which was smaller in Class II.1 (44.31±3.22mm) compared to all other malocclusions (Class II.2: 48.01±4.76mm, Class III: 48.22±3.75mm, and Class I: 48.41±3.47mm). The R-A distance was greater in the Class II.2 group (47.67±4.51mm) compared to Class I (43.53±2.91mm) and Class III (40.04±2.46mm).

Statistically significant differences in the gonial angle and the anterior symphyseal angle were found between Class II.2 and any other malocclusions: Class II.2 had the most acute gonial angle (Co-Go-Me=118.24˚± 3.89) and the largest ASA (12.51˚±6.51) (Tables IV.13.a, b).

v. Relationship between teeth and jaws

There was no difference between Class I and Class II.1 in any variable. Class II.2 had retroclined maxillary incisors (U1/NA=11.01˚±6.37, U1/SN=93.54˚±7.29) compared to all the other malocclusions. The mandibular incisors were retroclined in Class III (L1/NB= 19.42˚±8.48, L1/MP=84.52˚±8.18), followed by the Class II.2 (L1/NB=21.89˚±7.02, L1/MP=91.37˚±8.03), Class I (L1/NB=26.77˚±5.28, L1/MP=92.23˚±6.07), and were the most proclined in Class II.1 (L1/NB= 29.41˚±6.32, L1/MP=96.33˚±7.04) (Tables IV.14.a, b).

vi. Interdental relationship

The overjet was different among all malocclusions except between Class II.2 (3.03±0.78mm) and Class I (2.27±1.78mm), which exhibited the smaller values. The overjet was negative in Class III (-1.15±1.59mm) and greatest in Class II.1 (7.01±2.31mm). The overbite also was statistically significantly different among the groups except between Class I (1.22±1.53mm) and Class II.1 (2.31±2.33mm) from one side and between Class I and Class III (0.02±2.31mm) from the other side. The deepest OB was in Class II.2 (5.24±0.94mm).

Statistical significance for the interincisal angle also was observed among all groups except between Class II.2 and Class III; it was the most obtuse in Class II.2 (142.68˚±8.72), followed by Class III (137.22˚±14.18), normal in Class I (125.63˚±9.74) and acute in Class II division 1 (117.35˚±9.07) (Tables IV.15 a, b).

b. Growing male group (Table IV.16)

i. Cranial base measurements

At the cranial base level, the only statistically significant difference was found at the saddle angle between Class II.2 (SN-Ar=127.74˚±4.83) and Class III (122.74˚±4.83) with p=0.040. The Class II.1 (123.96˚±6.48) and Class I (123.58˚±4.78) saddle angles were in between (Tables IV.17.a, b).

ii. Relationship between jaws and cranial base

SNA was similar in Class II.2 (79.19˚±3.85), Class I (80.64˚±3.20) and Class III (78.20˚±3.41), the only significant difference was found between Class II.1 (81.62˚±3.21) and Class III (p=0.009). Yet SNB was different (p<0.001) between Class

III (81.22˚±4.88) and Class II.1 (75.29˚±3.39) but also between Class III and Class II.2 (75.55˚±3.82). No differences were found at the vertical level in this analysis (Tables IV.18.a, b).

iii. Inter-maxillary relationship

ANB was statistically significantly different among all groups except between Class II.2 and Class I. PP/MP was different between Class II.2 (21.79˚±4.40) and all other malocclusions (Class III=27.06˚±5.82, Class I=28.74˚±6.72, Class II.1= 28.06˚± 6.02). Likewise the LFH was: reduced in Class II.2 (53.22%±1.76) compared to all other malocclusions (Tables IV.19.a, b).

iv. Jaw-specific measurements

Class I measurements were located between Class II.1 and Class III; all the measurements in Class II.1 were smaller compared to Class I and Class III except for ANS-PNS, which was the largest in Class II.2 (48.99±3.32mm), followed by Class II.1 (48.42±4.53mm), Class III (44.69±4.46mm) and Class I (47.68±4.67mm). All the following mandibular variables were smaller in Class II.1 compared to Class III: R-A, R-B, Go-Pog, Co-Go-Me (Tables IV.20.a, b).

The gonial angle in Class II.2 was reduced compared to Class I. ASA was larger compared to Class I and Class II.1, but not to Class III. In Class III, R-A was decreased, R-B and Co-Go-Me were increased compared to Class II.1 and Class II.2.

v. Relationship between teeth and jaws

Statistically significant differences were found among all malocclusions except between Class I and Class II.1 in all variables, and among Class II.1, Class III and Class I in U1/SN and U1/PP. Maxillary incisors were proclined the most in Class III (U1/NA=29.07˚±6.36), followed by Class I and Class II.1, and retroclined in Class II.2 (U1/NA= 14.35˚±5.57). Mandibular incisors were retroclined in both Class III and Class II.2. The mandibular incisors were not different between Class II.2 and Class III (Tables IV.21.a, b).

vi. Interdental relationship

Overjet, overbite and interincisal angle were statistically significantly different between Class II.1 and Class III, and between Class II.1 and Class II.2. The OJ was similar between Class II.2 and Class I. The OB in Class I (1.37±1.68mm) was in between the means for Class II.1 (2.51±2.06mm) and Class III (0.40±1.99mm); it was the deepest bite in Class II.2 (5.05±0.48mm). The interincisal angle was normal in Class I (126.36˚±9.47) and Class II.1 (118.88˚±8.49), and obtuse in Class III (133.64˚±8.97) and Class II.2 (139.57˚±8.27) (Tables IV.22.a, b).

c. Adult female group (Table IV.23)

i. Cranial base measurements

No differences were noted in the adult female group among different malocclusions at the level of the cranial base (Tables IV.24.a, b).

ii. Relationship between jaws and cranial base

SNA and SNB showed statistically significant differences only between Class III and Class II. Maxillary position in Class II.2 (SNA=80.96˚±2.84) was close to Class I (79.92˚±4.33), retrognathic in Class III (76.55˚±5.09) and prognathic in Class II.1 (82.68˚±2.56). SNB had the highest value in Class III (79.66˚±5.07), followed by Class I (78.04˚±4.32), then Class II.2 (76.15˚±3.28) and the lowest was in Class II.1 (75.91˚±3.15).

Palatal plane was tipped up more counter-clockwise (p=0.020) in Class II.1 (-4.64˚±4.34) compared to Class I (-1.21˚±3.67). The mandible showed a difference only between Class II.1 and Class II.2 (p=0.035). MP/H and MP/SN were increased in Class II.1 (31.25˚±7.76/ 38.25˚±7.76) and decreased in Class II.2 (25.51˚±4.35/ 32.51˚±4.35) (Tables IV.25.a, b).

iii. Inter-maxillary relationship

ANB was different in all comparisons. Class II.2 showed a reduced lower facial height (LFH/TFH= 53.92%±1.82) compared to Class II.1 (56.71%±2.85), and a hypodivergent pattern (PP/MP= 21.21˚±4.16) in comparison with Class II.1 (29.04˚±8.40) and Class III (26.82˚±5.29) (Tables IV.26.a, b).

iv. Jaw-specific measurements

All mandibular measurements were not different among malocclusions except for the following: Go-Me was the longest in Class III (68.51±10.06mm) and the shortest in Class II.1 (61.21±4.44mm). The gonial angle was reduced in Class II.2 (Ar-Go-Me= 121.40˚±4.84/ Co-Go-Me=115.69˚±4.50) compared to all other malocclusion groups.

ASA was not statistically different in Class II.2 (15.43˚±9.50) and Class III (15.22˚±6.23), and was greater than Class II.1 (6.02˚±7.73) (Tables IV.27.a, b).

ANS-PNS was the shortest in Class III (45.48±6.06mm) compared to other malocclusions, and it was the longest in Class II.1 (49.66±3.45mm). These results coincide with the value of R-A which was also the longest in Class II.1 (50.17±3.42mm) and the shortest in Class III (44.60±2.83mm) with a $p<0.001$.

v. Relationship between teeth and jaws

Maxillary incisors measurements were different in all malocclusions except between Class I and Class II.1. They were retroclined in Class II.2 (10.99˚±5.50) and proclined in Class III (31.26˚±5.44). Mandibular incisors were not different among Class I, Class II.2 and Class III. They were proclined in Class II.1 (L1/NB=32.21˚± 5.43, L1/MP=98.06˚±8.13) (Tables IV.28.a, b).

vi. Interdental relationship

The OJ was different in all comparisons except between Class I (2.71±1.15mm) and Class II.2 (3.00±0.60mm). It was increased in Class II.1 (6.19±1.56mm) and decreased in Class III (-0.91±2.41mm). The overbite was increased in Class II.2 (5.22±1.50mm) compared to all other malocclusions, also it was reduced in Class III (0.12±0.92mm) compared to Class II.1 (1.92±2mm).

The interincisal angle also was statistically significantly different in all comparisons except between Class I (129.55˚±9.56) and Class III (130.80˚±4.81). The angle was obtuse in Class II.2 (144.48˚±14.01) and acute in Class II.1 (116.94˚±8.99) (Tables IV.29.a, b).

d. Adult male group (Table IV.30)

i. Cranial base measurements

The only significant difference within the cranial base measurements was found between Class I and Class II.2 (p=0.007) at the level of the saddle angle, the most obtuse occurring in the Class II.2 (SN-Ar=127.73˚±4.36) (Tables IV.31.a, b).

ii. Relationship between jaws and cranial base

SNA was different only between the 2 extreme malocclusions: the highest value (84.37˚±3.84) in Class II.1 and the lowest in Class III (80.25˚±4.00). SNB was statistically significantly different between any malocclusion and Class III, which had the highest value (84.01˚±4.40). MP/H was not different among malocclusions. The mandibular plane was different in Class II.2 compared to all other malocclusions, with the flattest inclination in Class II.2 (MP/H=20.20˚±5.97, MP/SN= 27.20˚±5.97) (Tables IV.32.a, b).

iii. Inter-maxillary relationship

ANB was different in all comparisons except between Class II.1 and Class II.2. Class II.2 had a significantly reduced PP/MP (18.11˚±6.40) compared to all other malocclusions, and exhibited reduced lower facial height (54.03%±3.01) compared to Class I (57.05%±2.85) and Class III (57.73%±2.01). LFH also was reduced in Class II.1 (55.45%±2.22) compared to Class III (Tables IV.33.a, b).

iv. Jaw-specific measurements

No differences were found between Class I and Class II, nor in Go-B and R-L1 among all malocclusions. ANS-PNS and Co-Go were different only between Class II.1 and Class III. ANS-PNS had the highest length in Class II.1 (54.04±3.67mm), and the lowest in Class III (50.40±3.77mm). In contrast, Co-Go that had the highest length in Class III (63.09±4.35mm) and the lowest in Class II.1 (57.96±4.76mm).

Mandibular length (Co-Gn) was significantly different among all malocclusions except between Class II.2 and Class II.1 on one hand, and between Class II.2 and Class I on the other. Co-Gn in Class II.2 (117.81±6.21mm) was between Class II.1 (116.76±4.68mm) and Class I (122.28±6.35mm), and was most increased in Class III (132.23±9.42mm). Go-Me was statistically significantly different between Class II.1 and Class II.2, also between Class II.1 and Class III. Go-Me was not significantly different among Class I (68.02±5.30mm), Class II.2 (72.38±8.10mm) and Class III (72.93±6.55mm), but it was reduced in Class II.1 (65.38±3.46mm).

In the chin, B-Pog and ASA differed between Class II.2 and each of Class II.1 to Class II.2. They were the most increased in Class II.2 (14.53±1.43mm; 17.84˚±10.13, respectively), followed by Class III (13.41±2.93mm; 10.91˚±7.98), Class I (10.22±2.13mm; 8.03˚±8.57) and Class II.1 (10.67±2.46mm; 7.41˚±9.09). Class II.2 had the strongest chin hard tissue structure (Tables IV.34.a, b).

v. Relationship between teeth and jaws

Class II.2 had retroclined/retruded maxillary incisors (U1/NA=10.93˚±3.59; 0.18±2.20mm) compared to all other malocclusions. Class II.1 had proclined mandibular incisors (L1/NB=29.96˚±7.08) compared to other malocclusions (Tables IV.35.a, b).

vi. Interdental relationship

The overjet was different in all comparisons except between Class II.2 (2.88±0.78mm) and Class I (2.59±1.11mm). Overjet was increased in Class II.1 (6.63±1.61mm) and decreased in Class III (-3.58±4mm). The OB also was different except between Class I (1.72±1.35mm) and Class III (-0.45±3.28mm). The deepest overbite was in Class II.2 (5.76±1.18mm) (Tables IV.36.a, b).

3. Class II division 2 subtypes

As indicated in the Methods section, Class II.2 radiographs were stratified into 4 subtypes based on the inclination of maxillary incisors and the divergence between maxilla and mandible (Tables IV.37.a, b).

For the cranial base measurements, the only statistically significant difference was observed between groups 1B and 2B at the level of SN/H (p=0.035), and Sella was lower relative to the horizontal in 1B subtype (SN/H=13.06˚±4.57) compared to 2B (10.07˚±2.74).

No statistically significant difference was found at the level of SNA; SNB was different between 1B and 2A (p=0.012), whereby the mandible was more retrognathic in 1B (75.78˚±3.87) compared to 2A (80.10˚±4.44). PP/H, MP/H and MP/SN were different in all comparisons between A and B within each of groups 1 and 2.

ANB showed a difference between 1B/2A (p=0.022) and 1B/2B (p=0.004); it was greater in 1B (5.28˚±2.39) compared to 2A (2.87˚±2.02) and 2B (3.18˚±1.86). PP/MP was different between subgroups A and B and the LFH/TFH was reduced in 1A (52.42% ±2.54) compared to 1B (54.55% ±1.92) (p=0.024).

The only jaw-specific difference was found at the level of Co-Go-Me between 1A/1B (p=0.018) and 1A/2B (p=0.039); the gonial angle was reduced in 1A (112.78˚±3.41) compared to 1B (118.09 ˚±4.64) and 2B (117.76˚±4.80).

The maxillary incisor inclination (U1/NA, U1-NA, U1/SN and U1/PP) was significantly different between 1 and 2 subtypes. No differences were found in the mandibular incisor inclination measurements (L1/MP, L1/NB), except for L1-NB, which was more protruded in 1B (4.09±2.33mm) and 1A (1.88±2mm) (p=0.045).

No differences were found in OJ and OB. U1/L1 were different between 1A/2A (p=0.012), 1A/2B (p<0.001), more obtuse in 1A (151.98˚±8.45) compared to 2A (138.13˚±11.19) and 2B (137.08˚±10.33), and between 1B/2B (p=0.029), more obtuse in 1B (144.96˚±8.83) compared to 2B.

C. Agenesis and mandibular length among malocclusions

1. Missing teeth and malocclusion

The data on missing teeth are presented at 4 levels: with and without the third molar.

At a first level, all suspected missing teeth were accounted for. Class II.2 group had the highest percentage (22.66%) of missing teeth, followed by Class III (20%), then Class I (16.66%), and the least percentage of missing teeth was found in the Class II.1 group (12.30%) (Table IV.38).

After excluding the subjects in whom we could not assess if the teeth were extracted rather than missing, or if it was early to confirm agenesis, Class II.2 (20.95%)

and Class III (17.72%) had the largest percentage of missing teeth, followed by the Class I (12.65%) and the lowest percentage remained in Class II.1 (7.05%).

Excluding the third molars, the percentage of missing teeth remained the lowest in Class II.1 (1.17%), followed by Class I (5.61%), Class III (15.18%) and Class II.2 (17.38%). The last level of evaluation included only the ascertained missing third molars. Chi-squares for the "ascertained missing" (2^{nd} level) and only third molars (4^{th} level) were not significant (p=0.107 and 0.627, respectively). A statistically significant difference was observed among the "ascertained missing teeth excluding third molars (p=0.001).

2. Mandibular length

a. Mandibular and alveolar length among all types of malocclusions

The mean and standard deviation (SD) for mandibular length (Co-Gn) were calculated in the Class I group for the total adult sample, adult male, adult female, total growing sample, growing male and growing female groups.

Frequencies of mandibular length greater than the mean of the Class I group (used as a reference) among all types of malocclusions in the same categories were obtained. Also frequencies of mandibular length greater than 1 SD of the Class I Co-Gn mean were calculated (Tables IV.39.a, b).

Among the total adult sample, 69.44% of Class I, 24.4% of Class II.1, 80% of Class III and 33.33% of Class II.2 had a Co-Gn greater than the mean Co-Gn of the Class I group; 13.88% of the Class III and 2.77% of the Class II.2 had Co-Gn beyond 1 SD of the mean Co-Gn of Class I group. While mandibular "macrognathism" was not

only found in Class III group but also in Class II.2 in a small percentage (2.77%), none were observed in the Class I and Class II.1 group had a Co-Gn greater than 1SD.

In the growing subjects, Class II.2 had the least percentage (6.06%) beyond 1 SD, followed by Class II.1 (10%), then Class I (16.98%) and the highest percentage was in the Class III group (25.58%).

In the female adult group, the percentage of macrognathic mandibles among Class II.2 was reduced compared to the female growing subjects (down to 5% compared with 11.76%). The same percentage increased among Class III (from 11.11 to 38.88%); a similar increase was observed in adult Class III males (72.22% compared to 36% in the younger group). A reverse trend was noted between the Class II.2 group, with an increase from 6.25 to 12.5%, and Class II.1 subjects, with a decrease from 5.26 to 0%.

The same computation for mandibular length was followed for the alveolar length (R-B) (Table IV.39.b). In the growing group Class II.2 presented a higher percentage (45.45%) of alveolar length (R-B) beyond the mean of growing Class I in comparison to Class II.1 (20%) and it was close to that of Class I (49.05%). Yet it was reduced later in the adult Class II.2 and its percentage was the lowest among all malocclusions (22.22%).

b. Mandibular length in Class II division 2 group

i. Class II division 2 total group

The length of Co-Gn in the total sample was 111.07±10.31mm in Class I, 108.41±9.46mm in Class II.1, and 116.34±16.24mm in Class III. ANB, SNA, SNB and

B-Pog of the Class II.2 population were distributed on the basis of correspondence between the Co-Gn of Class II.2 and other malocclusions in the total sample.
First, Class II.2 was divided into 3 categories: 1- Co-Gn within 1 SD of Class I Co-Gn (100.76- 121.38mm), 2- below 1SD (< 100.76) and 3- beyond 1SD (> 121.38) (Table IV.40.a). To be more comparable to the means of Class I, Class II.1 and Class III, half of the standard deviation of Co-Gn of the Class I was considered (Table IV.40.b).

Co-Gn in Class II.2 in the total sample was comparable to that of Class II.1 in 27.53% of the cases, to Class I in 56.52% and to Class III in 15.94%. The corresponding SNA, SNB and B-Pog increased with the increase in Co-Gn.

ii. Class II division 2 growing group

In the growing sample, Co-Gn was 116.79±9.58mm in Class I, 103.33±9.64mm in Class II.1, and 108.99±14.29mm in Class III.

The growing Class II.2 group was stratified in 3 categories: 1- Co-Gn within 1 SD of growing Class I Co-Gn (97.21-116.37mm), 2- below 1SD (< 97.21), 3- beyond 1SD (>116.37) (Table IV.41.a), and 4- half of the SD was considered (Table IV.41.b).

Mandibular length in growing Class II.2 subjects was comparable to that of Class II.1 in 24.24% of the cases, Class I in 57.57% and Class III in 18.18%. Also the corresponding SNA, SNB and B-Pog increased with the increase in Co-Gn.

iii. Class II division 2 adult group

The length of Co-Gn in the adult sample was 117.20±8.06mm in Class I, 112.93±6.63mm in Class II.1 and 125.12±14.04mm in Class III. The stratifications on Co-Gn included the following categories: 1- Co-Gn within 1SD of adult Class I Co-Gn

(109.14-125.26mm), 2- below 1SD (<109.14), 3- beyond 1SD (>121.23) (Table IV.42.a), and 4- half of the standard deviation of Co-Gn of the adult Class I was considered (Table IV.42.b).

Mandibular length in adult Class II.2 sample was comparable to that of Class II.1 in 61.11% of the cases, Class I in 25% and Class III in 13.88%. The corresponding SNA, SNB and B-Pog augmented with the increase in Co-Gn.

D. Correlations and regressions

1. Correlations between mandibular components among different malocclusions

The Pearson correlation test was conducted to check the presence of possible associations between mandibular variables within each malocclusion group (Appendix 2).

The statistically significant correlations are displayed in Table IV.43.

The main findings were the following:

a. Mandibular length (Co-Gn) was found to be significantly correlated with all mandibular components in all malocclusion groups except with gonial angle (Ar-Go-Me). It presented a moderate positive correlation with maxillary incisors' inclination only in Class II.1.
b. Mandibular position (SNB) was significantly correlated with all mandibular components in all malocclusion groups except for PP/MP in the Class III group and Ar-Go in the Class II.2 group.
c. Co-Go, Go-Pog and R-B were significantly correlated with all other mandibular components in all malocclusion groups. A high correlation is to be noted between R-B and RL1 in Class I and Class II and to a lesser degree in Class III.

2. Logistic regressions for Class II division 2 malocclusion

Taking into account the need to focus on the traits of mandibular macrognathism that were found in the Class II.2 group, a bivariate logistic regression followed by a multivariate regression were performed for Class II.2 taking as references each one of the three other malocclusions separately.

a. Class I malocclusion as a reference

The results of the bivariate logistic regression analysis for Class II.2 with Class I malocclusion as a reference were displayed in Table IV.44.a. 95% confidence intervals and the p-values were reported.

All covariates that had a $p<0.2$ at a bivariate level were included in the multivariate analysis. However, when significant variables that measure the same component were placed together in the same model, they distorted the effect of other covariates resulting in what is referred to as Simpson Paradox. Hence, we had to present the results under three different models.

In model 1, the remaining significant variables for Class II.2 compared to Class I, after adjusting for the effect of the other covariates were: SN-Ar (OR= 1.4, p=0.009), MP/H (OR=0.51, p=0.011), B-Pog (OR=1.96, p=0.041), U1-NA (OR=0.20, p=0.037), L1-NB mm (OR=4.01, p=0.040), U1/L1 (OR= 1.27, p=0.004), and the OJ (OR=4.50, p=0.023) (Table IV.44.b).

In model 2, we followed a previously described model by Ghafari et al. (2013) for component analysis that includes the following variables representing sagittal and vertical dimensions in addition to jaws and teeth measurements:

1. Cranial Base flexure: SN-Ar
2. Jaws relationship/position: Sagittal= ANB, SNB/ Vertical= PP/MP
3. Jaw-specific measurements: Maxilla= ANS-PNS, Mandible= Co-Gn, R-B, Chin= ASA, B-Pog
4. Dentoalveolar measurements: U1/NA, L1/NB, OJ and OB

In this model, the overbite (OB) was excluded from the multivariate analysis for displaying an error when added to the other covariates. This can be explained by the very high odds radio of the OB (OR=119.80, Table IV.44.a) obtained at bivariate level compared to other variables. This is due to the fact that the OB is one of the inclusion criteria upon which malocclusion groups were divided. The variables that remained significant after accounting for the effect of the other covariates in this model were: SN-Ar(OR=1.40, p=0.012), PP/MP (OR=0.70, p=0.032), ANS-PNS (OR=1.71, p=0.019), R-B (OR=0.43, p=0.021), ASA (OR=1.14, p=0.038) and U1/NA (OR=0.59, p=0.002) (Table IV.44.c).

In model 3, Go-B that was significant at a bivariate level, was included along with all the variables present in Model 2. The same results of the Model 2 were found in Model 3 except for ANS-PNS that did not remain significant. Moreover, Go-B lost its significance at the multivariate level (Table IV.44.d).

b. <u>Class II division 1 malocclusion as a reference</u>

The results of the bivariate logistic regression analysis for Class II.2 taking Class II.1 as reference were displayed in Table IV.45.a. All the covariates having a $p<0.2$ were included in the multivariate analysis (Table IV.45.b). The results of the

multivariate regression were also presented under 2 models for the same reasons described previously.

In model 1, the variables that remained significant for Class II.2 compared to Class II.1 were: OB (OR=2.65, p=0.001) and Ar-Go-Me (OR=0.63, p=0.046) (Table IV.45.b).

In model 2, none of the covariates included remained significant (Table IV.45.c).

c. Class III malocclusion as a reference

The results of the bivariate logistic regression analysis for Class II.2 compared to Class III are displayed in Table IV.46.a. For the multivariate analysis, the results were presented under two different models. It's important to note here that the variables OJ and OB, presenting high odds ratios at a bivariate level compared to the other covariates (OR=21.76 and OR=10.77 respectively) displayed an error when added in the multivariate analysis. Moreover, ANB also gave an error at a multivariate level because of the absence of overlapping measures between the Class II.2 and the Class III malocclusions. Hence, OJ, OB and ANB were excluded for the analysis.

In model 1, the significant predictors for Class II.2 compared to Class III were ANS-PNS (OR=4.09, p=0.009) and U1-NA (OR= 0.30, p=0.013) (Table IV.46.b).

In model 2, the variables that remained significant were: ANS-PNS (OR=2.24, p=0.017), in addition to U1/NA (OR=0.63, p=0.034) (Table IV.46.c).

3. Linear regression for the outcome mandibular length (Co-Gn)

A linear regression was conducted in the total sample to assess possible associations between Co-Gn and all the other variables included in the previously described model by Ghafari et al (2013).

At a bivariate level, Co-Gn was significantly correlated with all the variables of our model except with PP/MP (Table IV.47.a). The covariates having a $p<0.2$ were included in the multivariable linear regression. After adjusting for the effects of other covariates, ANB, ANS-PNS, R-B and B-Pog remained significant at a multivariate level ($p<0.001$) and the model presented a high significance ($p<0.001$) with $r^2=0.83$. Hence, for each 1degree of increase in ANB, corresponds 0.852mm decreases in Co-Gn; and for each 1 mm increase in R-B, corresponds 0.79 mm increase in Co-Gn; and for each 1 mm of increase in ANS-PNS corresponds 1.068 mm increase in Co-Gn; and finally for each 1 mm increase in B-Pog, corresponds 1.176 mm increase in Co-Gn.

In conclusion, in the total sample, 83% of the variability in Co-Gn is explained by the model that includes ANB, RB, ANS-PNS and B-Pog:
Co-Gn= - 0.852 ANB + 0.790 R-B + 1.068 ANS-PNS + 1.176 B-Pog (Table IV.47.b).

CHAPTER V

DISCUSSION

The results of this study comprise new concepts and support earlier findings. While much has been covered in the literature regarding malocclusion since Angle's classification, the hypothesis and research questions in this study allowed the formulation of additional tenets or clarification of existing ones. This outcome is facilitated by the research approach, through component analysis of the malocclusions, with a specific focus on singular characteristics of Class II division 2.

A. Nature of malocclusion

1. Cranial base

Although no statistically significant difference was found among the four malocclusions at the level of the anterior cranial base length (SN), a remarkable opposite trend in the cranial base flexure (SN-Ar) between Class III and Class II malocclusions was found. The findings that SN-Ar was more obtuse and the inferior cant of SN was more pronounced in Class II, compared with opposite angulations in Class III, corroborate prior results (Hopkin 1968, Kerr and Adams 1988, Dibbets 1996, Baccetti et al. 2005, Haddad 2008, Macari 2008, Ghafari et al. 2013).

The association between maxillary position and cranial base configuration has been investigated in past studies with differing results. Gilmore (1950) reported a shorter S-N length, while Wallis (1963) found a longer SN and a more obtuse SN-Ar in Class II malocclusion. Jarvinen (1980, 1984) stated a "topographic causation" between

cranial base flexure and SNA, with larger SN-Ar associated with decreased SNA. Also many authors suggested interaction between cranial base, maxilla and mandible (Bjork 1955, Enlow 1990, Jarabak et al.1942, Moorrees et al. 1995, Ghafari 2006). Ghafari et al. (2013) proposed that in Class III subjects the high position of Sella may be affected by anterior crossbite, which if sustained over time (generating a dental "lock" of maxillary teeth by mandibular teeth would result in maxillary retrognathism that otherwise, would not have existed. The occlusal forces, transferred through the maxilla to the basisphenoid, would contribute to a relatively higher position of Sella and flatter SN cant to the horizontal. This theory was reinforced by the superior-posterior tip of the palatal plane, a finding supported by the present study.

2. Maxillary-mandibular relationships

The average positions of the jaws (SNA and SNB) in Class II.2 lied nearly midpoint between Class I and Class II.1, and no basal mandibular retrognathism was found among Class II.2 subjects at the level of pogonion.

Other studies have reached similar conclusions regarding the intermediate value of the mandibular sagittal position in Class II.2 malocclusion (Leighton and Adams 1986, Brezniak et al. 2002, Isik et al. 2006). However, when pogonion was used as the mandibular anterior landmark, there was no statistically significant difference between the Class II.2 and Class I groups. In contrast, Pancherz et al. (1997) found mandibular retrusion in both Class II.1 and Class II.2, whereas Blair (1954) described a mild prognathic mandible. These discrepancies will be approached in a more encompassing discussion in the section on Class II.2 below.

Within the context of inter-jaw relations, the regression analyses revealed associations between mandibular length and other mandibular measurements but also maxillary components. Adjusting for the effects of other covariates, ANB, ANS-PNS, R-B and B-Pog remained significant ($p<0.001$) and the model presented a high significance ($p<0.001$) with $r^2=0.83$. Accordingly, 83% of the variability in Co-Gn is explained by ANB, RB, ANS-PNS and B-Pog: Co-Gn= - 0.852 ANB + 0.790 R-B + 1.068 ANS-PNS + 1.176 B-Pog.

The data actually suggest that for every 1 degree of increase in ANB, Co-Gn decreases by 1.038; for every 1 mm increase in ANS-PNS, Co-Gn increases by 0.852; for every 1 mm increase in R-B, Co-Gn increases by 0.79, and for each 1 mm increase in B-Pog, Co-Gn increases multiplied by 1.172 mm.

These findings support the concept of maxillo-mandibular interdependence whereby an induced change in one jaw indirectly affects the size and position of the other jaw. This premise is supported by various findings on the interactive effects between the jaws in dentofacial orthopedics: antero-inferior palatal rotation engendering a similar mandibular rotation with headgear treatment (Efstratiadis et al. 2005), maxillary retrognathism induced by sustained anterior crossbite (Ghafari, 2004, 2013), airway clearance and length of the maxilla effect on determining the length of the mandible (Macari 2008).

3. Jaw-specific measurements

Mandibular components encompassed an important focus of analysis, particularly that mandibular length constituted one of the specific aims of the research. We had stipulated that the largest mandibles would likely be found in Class III and Class

II.2 malocclusions. This hypothesis stemmed from observations of increased mandibular length in Class II.2 patients. On the assumption that mandibular size greater than one standard deviation of the mean control Class I group would fit the definition of "large mandible", Class II.2 partially met this criterion in adult males (Table IV.39.a).

In males, the higher prevalence of largest mandibles was in Class III (72.22%), followed equally by Class II.2 and Class I (12.5% each), then Class II.1 (0%). In females, the largest mandibles were in Class III (~39%), then Class I (~10%), Class II.2 (5%) and Class II.1 (4.34%). Accordingly, it seems that a gender difference exists, suggesting that larger mandibles, when present in males with Class II.2, would resemble Class I, while in females they would resemble Class II.1. This finding is particularly noteworthy when considering the span of Class II.2 across both Class I and Class II.1 skeletal discrepancies (section B below). One possible explanation beyond the already established finding of gender dimorphism of mandibular size (Baccetti et al. 2007) is the fact that the mandible augments over a longer period of growth in males than females. The same rationale would apply to Class III, in whom the rate of larger mandibles (greater than 1SD of Class I average) was nearly double (~72%) in males that in females (39%).

Maxillary length (ANS-PNS) was the largest in both Class II malocclusions (Class II.1: 49.97±4.46mm, and Class II.2: 49.95±3.80mm), and the shortest in Class III (45.55±5.33). Also, mandibular length was not statistically significantly different between Class II.1 and either Class I or Class II.2. In the context of the mandible being most retrognathic in Class II.1, this finding indicates that retrognathism is not, on average, associated with micrognathism. Further scrutiny is warranted of Class II.1 components.

Nevertheless, in the adult sample, mandibular length was similar in Class II.2 and Class I, possibly indicating that further growth brought the Class II.2 mandible closer

to normal, another reason why this malocclusion may be differentiated from the other malocclusions less for skeletal and more for dentoalveolar components.

The alveolar length (R-B) was different among all malocclusions except between Class II division 1 and 2, both of which being the shortest in the total sample, but only Class II.2 having the shortest R-B and R-L1 in the adult group (Table IV.27.a), shielded from the changes of growth. Given that mandibular body (Go-Pog) was shorter in Class II.2, alveolar length may be considered relatively shorter in this malocclusion at all ages. Also, Class II.2 had features away from the "Class II phenotype", as well as from Class I and Class III with a more acute gonial angle, a reduced lower anterior facial height, and an increased anterior symphyseal angle (ASA), compared to all these malocclusions. The finding on ASA is new, as it was not researched earlier, indicating that chin form is best delineated (on average) in Class II.2, followed by Class III. Reasons for such definitions may be the differential growth between the dentition and chin in Class II.2, and the larger mandibular size and growth in Class III.

Fischer-Brandies et al. (1985) found in adult Class II.2 subjects a retroposition of the alveolar bone (B point area), whereas the chin (pogonion) was in a more normal position. But they did not find statistically significant differences in the gonial angle between Class II.2 and Class I malocclusions. Blair (1954) and Wallis (1963) reported as characteristics of Class II.2 mal-alignments a smaller gonial angle with an anterior position of the mandibular body. In a study by Pancherz et al. (1997) short lower facial heights were consistent findings in both Class II divisions 1 and 2.

Brezniak et al. (2002) summarized the characteristics of Class II.2 malocclusions as follows: similar sagittal position and length of maxilla as Class I, retruded and short mandible, prominent chin, enlarged posterior facial height, and acute gonial angle. The

disparities among researchers are explained in a hypothesis advanced by Ghafari and Haddad (2014) and further exposed in section B below.

Finally, with respect to mandibular components, a series of correlations (Pearson) were tested to determine related associations. Alveolar length parameters (Ramus point to point B and to lower incisor L1) were highly correlated in Class I (r=0.89) and Class II divisions 1 (r=0.92) and 2 (r=0.89), but the correlation was smaller (though still significant) in Class III (r=0.59), possibly indicating lesser influence of tooth position on that of point B in this malocclusion.

Not surprisingly, the length of the mandible (Co-Gn), in all malocclusions, correlated with all mandibular components of mandible, including alveolar length (R-B), but not with the gonial angle or the mandibular incisor position. This finding may be related to the variation in the gonial angle across malocclusions, characteristically more acute in Class II.2. In a related component, the angle of divergence PP/MP was associated with the sagittal position of the mandible (SNB) but exhibited a low correlation (r=-0.17) in Class III. This result may indicate that Class III malocclusion encompasses more individual variation in vertical intermaxillary relations.

Except for Class II.1, ramus height (Co-Go) correlated with mid-chin length (B-Pog) and mandibular corpus short length (Go-B) but the correlation was highest in Class II.2 and Class III. Also delineating a "weaker" chin extension in Class II.1 is the finding of higher correlations between Go-Pog and B-Pog in all malocclusions (r= 0.47 in Class I and Class II.1; r=0.6 in Class III) but in Class II.1 (r=0.27).

4. Gender differences

Smaller variables found in this study in females compared to males (SNB, ANS-PNS, Co-Go, Go-Me, Go-Pog, Ar-Gn and Co-Gn) underscore the existence of sexual dimorphism found by other authors throughout the literature and across malocclusions (Baccetti et al. 2005). Nevertheless, the nature of dysmorphology remains similar. As above-mentioned, the tendency for males to have a more severe expression of the problem may be related to the fact that they grow over longer periods of time than girls, both before and after a more potent growth spurt.

Baccetti et al. (2008, 2009) showed a significant degree of sexual dimorphism in craniofacial features in various malocclusions. Specifically in Class III dysmorphology, female subjects presented smaller linear dimensions in the maxilla, mandible, and anterior facial heights than male subjects (Baccetti et al. 2005, 2007). The increase in mandibular growth was three times greater in males with Class III than in subjects with normal occlusion.

B. Class II division 2

1. Findings supporting the theory of dentoalveolar dominance

Class II.2 presented a reduced alveolar length (RB and RL1) and an increased Go-pog measurement. This finding supports the hypothesis regarding Class II.2 representing mainly a dentoalveolar malocclusion, as if the mandibular arch was restrained by the maxillary arch (retroclined incisors, Figure V.1) while the mandible grew forward (Ghafari et al. 2014). The growing chin would displace away from the self-restricting dentolaveolar complexes, leading to the characteristic Class II.2 chin

button. Further supporting this theory is the finding, on average, of largest anterior symphyseal angle in Class II.2 than in any other malocclusion.

Figure V.1. Intraoral lateral photograph for a Class II.2 malocclusion
(after Ghafari and Haddad 2014)

Class II.2 also stands out from the other malocclusions in the fact that it is described anteroposteriorly but recognized as a malocclusion with a prevalent and dominant vertical hypodivergence (Figure V.2).

Figure V.2. Lateral cephalogram for a Class II.2 malocclusion indicating the prevalent vertical dominant components: reduced lower facial height, flat mandibular plane and lower face hypodivergence *(after Ghafari and Haddad 2014*).

As originally defined by Angle, Class I, Class II division 1, and Class III malocclusions are distinct separate entities with recognizable sagittal differences. The

vertical variations observed in these entities do not overcome the sagittal variations. However, the Class II division 2 entity stands out by the fact that the associated sagittal component can be Class II.1, Class I and in extreme cases Class III according to the findings on range of ANB and mandibular length associated with Class II.2.

In Figure V.3 are displayed the ranges of ANB recorded in this research for the 4 malocclusion groupings. Although ANB was an inherent inclusion criterion that discriminated between Class I, Class II.1 and Class III, it was not for Class II.2. This differentiation was significant in that it disclosed the spectrum of Class II.2 skeletal relations when the malocclusion was identified by its original descriptors: deep overbite and reduced overjet (related to the upright maxillary incisors). In further analysis, the ANB angle within Class II.2 was in nearly 40% of subjects within the Class II domain, the majority ranking in the Class I domain, in which is included the Class I range (0-3.5º) and the intermediate range (3.5-4.5º), albeit the latter lies beyond one standard deviation from the ANB norm of 2±1.5º (Table V.1).

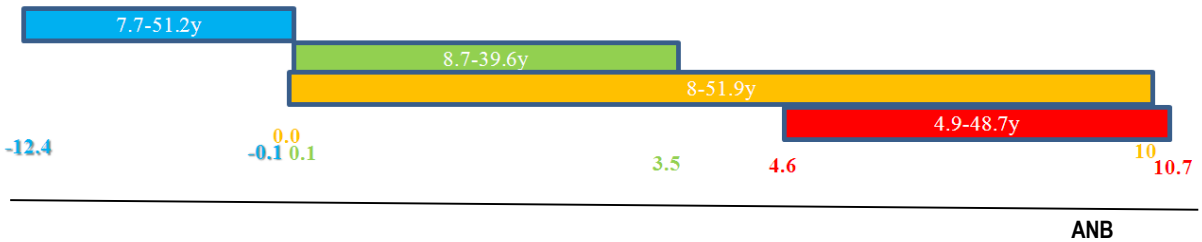

Figure V.3. ANB distribution among different malocclusions (Blue: Class III, green: Class I, yellow: Class II.2, red: Class II.1). Note the expanded range of ANB in Class II, division 2.

Table V.1. Distribution of Class II division 2 according to ANB: prevalence within Class I and Class II domains

CLASS I DOMAIN				CLASS II DOMAIN	
Class I range		Middle range		Class II range	
n	%	n	%	n	%
29	42.02	14	20.28	26	37.68

In summary of the above-related hypothesis, the deep overbite would generate or worsen the self-restricting dentoalveolar "lock", holding the mandibular teeth back with limited alveolar growth, while the chin continued its forward growth. "Unlocking" the dentoalveolar "curtain" at an early stage could prevent the development or worsening of the Class II.2 features.

Class II.2 is a unique malocclusion, characterized in various classifications probably because of the variety in the underlying skeletal pattern as determined in our research. While categorizations were based on the maxillary arch (3 types: Van der Linder 1983) and skeletal and dental parameters (4 types: Jarabak and Fizzell 1972, Ghafari and Street 1992), our data shed light on why even a "Class I division 2" was described (Jarabak and Fizzell 1972). The distribution of our sample according to Ghafari and Street's typing revealed a higher percentage (51/69=73.91%) with mandibular plane closer to normal, and a smaller incidence of severely flat mandibular plane (18/69=26.08%). Confirmation of these findings warrants a larger study sample.

2. *Dentoalveolar components*

In Class II.1 and Class III, incisal overjet matches the "molar overjet" (Ghafari and Haddad 2014): both are advanced in the maxilla in Class II.1, and forward in the mandible of Class III subjects. However, in Class II.2, maxillary molars and incisors are in different directions (Figure V.4), while maintaining the vertical commonality of hypodivergence. The other malocclusions, distinct in the horizontal plane, but may present with various vertical traits.

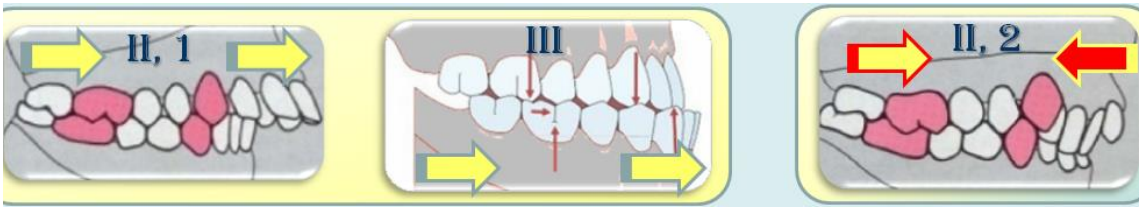

Figure V.4. Graphic representation for the opposite directions of maxillary incisors and molars in Class II division 2, compared to Class II division 1 and Class III malocclusions *(courtesy of JG Ghafari with permission).*

The findings on missing teeth are revealing, with the highest incidences in Class II.2 and Class III (Table IV.38), the prevalence being statistically significant when the third molars were not accounted for (Class II.2, 17.38%; Class III, 15.18%; Class II.1, 1.17%; Class I, 5.61%). Reports are well established of strong associations of Class II.2 with dental developmental anomalies, higher than in other malocclusions (Basdra et al. 2000, 2001; Hartsfield 2012). Excluding third molars, agenesis of other teeth was at least 3 times more seen in Class II.2 subjects than in other malocclusions. Nearly 57% of Class II division 2 patients exhibited developmental tooth anomalies comprising hypodontia as compared to as many as 35% of the total population presenting an agenesis of at least one tooth.

While the absence of clinical examination and records precluded the demonstration of dental anomalies in our study, the findings on missing teeth from the panoramic radiographs support the reports on hypodontia. Hartsfield (2011, 2012) reported that the genetic background related to missing teeth in Class II.2 may reinforce claims that the malocclusion has genetic origins.

Providing a different interpretation and support for their dentoalveolar hypothesis in Class II.2 malocclusions, Ghafari and Haddad (2014) stated that dental anomalies may not indicate the primacy of genetic etiology of the malocclusion but can

contribute to a “constriction” of the dental arches, further holding the mandibular arch with the enfolding maxillary dentition (retroclined incisors), resulting in severe malocclusions into a dentoalveolar collapse and increased lower face concavity.

C. Component analysis (importance and dominance)

The component analysis facilitated discriminating among malocclusions, with differential dominance of certain components specific to malocclusion. In Class III, maxillary retrognathism and the largest mandibles (macrognathism) may be the dominant components. In Class II division 1, dominance is found with the mandibular retrognathism and size. Class II division 2 dominance is in the position of the maxillary incisors and the deep overbite. Finally the Class I dominant component is the close to normal relationship between jaws (ANB) and teeth. Grafted on these specific delineations may be similar or differing components in different planes of space (width of maxilla and mandible; variation in vertical divergence- albeit a dominant domain of Class II.2).

In the context of these discriminating components, a hypothesis may be enunciated regarding the correction of the malocclusion: the achievement of Class I dental relations, sought in all malocclusions, is most compatible with the Class I phenotype, as an element of compensation is necessarily prevalent in the transformation of deviant occlusions (Class III, II.1 and II.2) to neutroclusion (Ghafari and Macari 2014). The exception to this rationale would be surgical correction of severe skeletal dysplasia, whereby bone movement aims at restoring a normal relationship between the jaws.

To illustrate the importance of component assessments in differentiating phenotypes, the Class II.2 variables were evaluated through their "location" relative to the other malocclusions (Figure V.5). In those measurements related to position of maxilla and mandible, and intermaxillary relations (ANB), Class II.2 was between Class I and Class II.1. In measurements disclosing vertical (hypodivergency) and dentoalveolar relations (particularly maxillary incisor retroclination), as well as mandibular shape (gonial angle, symphyseal angle ASA), Class II.2 was set apart from all other malocclusions, scoring either the highest or lowest values.

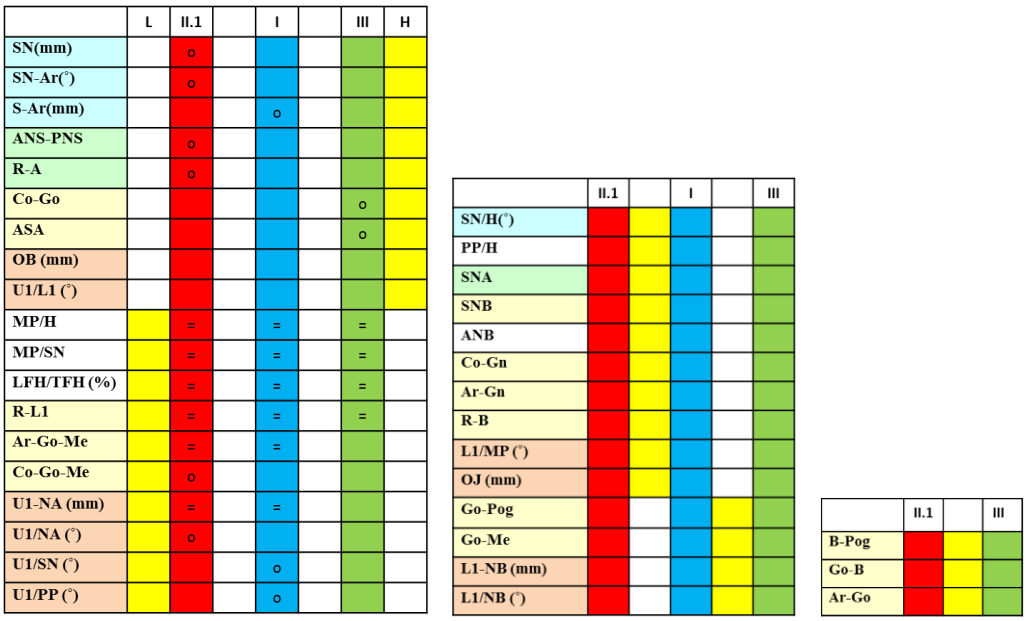

Figure V.5. Location of Class II division 2 measurements (yellow) relative to Class I (blue), Class II division 1 (red), and Class III (green) malocclusions.

This aspect of the component analysis reinforced the preceding discussion that Class II.2 is more of a dentoalveolar malocclusion that is readily identified with its vertical rather than its sagittal traits. While our findings support a theory by Brezniak et

al. (2002) regarding Class II.2 being possibly located between Class II.1 and Class I, with distinct vertical traits, having relatively short and retrognathic parameters and relatively prominent chin, our analysis qualifies these authors' conclusion, as only a number of parameters, albeit important, fit this description.

The outcome of treatment or growth cannot be predicted on the basis of cephalometric imaging. Instead, the various components of the hard and soft tissues contribute to the outcome. As a major facial component, soft tissue may worsen or mask the underlying hard tissue structures. While technological advances in 3-dimensional radiography of the face and dentition are within reach (Ghafari 1997, 2006), treatment and growth outcome will still require the assessment of both angular-linear measurements in addition to regional superimpositions (Ghafari et al. 1998c).

D. Clinical significance

The results of the study have immediate clinical implications regarding the timing and modality of treatment of malocclusions. The differences found between the growing and adult groups, with more accentuated malocclusion in the older group, suggest that the early treatment of malocclusion would favor the normal development of the dentofacial complex, particularly the direction of growth of the jaws, if not entirely impacting the amount of development (Ghafari 2004).

This premise may not be applied without judicious assessment of the components of the developing malocclusion, as the early treatment may encounter the limitations of growth potential within a specific malocclusion (Ghafari and Haddad 2014, Ghafari and Macari 2014).

Early correction would include addressing the dominant component in each malocclusion. In Class III and Class II.2, earlier intervention might target the potential interference of an anterior crossbite or overbite, respectively, by eliminating the vertical "dental curtain" in Class II.2 and anterior dental "lock" in Class III, in essence "getting the teeth away from the path of maxillary mandibular forward displacement in Class II.2 and maxillary growth in Class III. In Class I, the focus of early treatment might be on crowding and vertical control. In Class II division 1, early treatment would target favoring mandibular growth by stimulating differential growth and reducing the risk of trauma to maxillary incisors.

The psychological benefit from early treatment may not be discounted, particularly in severe conditions of increased overjet (mostly in Class II.1) or anterior crossbite prominent chin (Class III).

The early elimination of a probable cause of a developing skeletal dysmorphology may reduce future treatment to a simpler orthodontic treatment (aligning teeth). Early treatment becomes questionable when the patient ends up undergoing surgery at an older age. Yet early treatment may reduce the severity of the malocclusion by minimizing associated problems. If left uncorrected, this problem may have to be treated later by tooth extractions and/or orthognathic surgery (in one or both jaws). In early corrected cases, the surgery if needed later, might be limited either to a one jaw surgery or in extreme cases to two jaws but with reduced severity.

E. Research considerations and future directions of study

From both the educational and diagnostic perspectives, knowledge about growth and development of the craniofacial complex shall be enhanced by many of our

findings, particularly regarding Class II division 2. Further studies in molecular biology would also identify the gene–environment interactions associated with the phenotypic diversity of mandibular size and the heterogenic developmental mechanisms thought to be responsible for them.

Establishing the genetic etiology of each malocclusion may provide additional insights and tools to improve the management of particularly the more severe malocclusions. Molecular genetic information may be used in the future particularly to accurately predict long-term growth changes, and may ultimately lead to the utilization of gene therapy. Understanding the specific genetic factors contributing to the risk for mandibular prognathism would be a major advancement in dentofacial orthopedics and potentially reduce the need for oral and maxillofacial surgery.

We did not have available clinical records to help related the occlusion to the cephalometric record. Certain cephalometrically-defined malocclusions may translate in a molar relationship between two malocclusions, such as an end/on molar relation in an otherwise Class II malocclusion. However, the stringent criteria defining Class II and Class III malocclusions set out such "grey-zone" dysmorphologies and likely eliminate them. Also, the cut-off ages differentiating between growing and adult subjects, albeit taking into account gender differences, may not be solid across the sample, as bone age may have differed from chronologic age. Nevertheless, the differentiation helped establish trends of development and relations. We emphasized the significance of findings in adulthood as the influence of growth has faded.

Malocclusions have been analyzed for decades and actually centuries. The fact that more information may be drawn from yet another study is in itself remarkable. The inclusion of an "ideal" occlusion Class I group would have been more optimal, but it is

doubtful that the comparisons with other malocclusion groups would have been different at least in central tendencies. Also, research would be optimal on longitudinal samples, but they should ideally be of untreated individuals in the various malocclusions. Such undertaking would need to pass the scrutiny of more demanding IRB thresholds.

Finally, the conduct of comparisons using 3D technology might be more accurate and possibly more revealing. However, recent comparisons of various facial structures between 3D and 2D images have not yielded changes in long-established basic knowledge of growth and development.

CHAPTER VI

CONCLUSION

We set to explore malocclusions through a component analysis, with particular focus on the mandible. Previous studies that have explored malocclusions have emphasized that Class III malocclusion contains a genetic etiology. This theory has yet to be fully proven, as it may hold true in the presence of macrognathic mandibles and not necessarily all retrognathic maxillae. Our findings supported the presence of macrognathism mostly in Class III malocclusions, more particularly in males, possible due to the fact that their growth lasts over a greater number of years than in girls.

Both Class III and Class II division 1 malocclusions stand as dysmorphologies with opposite maxillary and mandibular problems. Class II division 2 malocclusion has a unique dental appearance that sets it apart from the two others. While defined like Class II.1 and Class III as a sagittal problem, only maxillary incisor retroclination is a sagittal characteristic, the other unique defining feature being in the vertical plane: deep overbite.

Our study corroborated prior findings on Class II division 2: flat mandibular plane, retroclined maxillary central incisors, obtuse interincisal angle, deep overbite, prominent chin, and deficient anterior facial height (due to a decrease in lower facial height). Yet the finding underscored that Class II division 2 is set apart from the other malocclusions as having a distinct dentoalveolar problem that may have various underlying skeletal components, ranging from Class I to Class II discrepancies, all the way even to approaching Class III, if only as the closest malocclusion to have the larger

size mandible. Moreover, the findings reinforced a prior hypothesis we enunciated regarding the growth of the mandible away from a self-restricting anterior deep bite, yielding the characteristic "chin button" described in Class II.2. Further research is warranted, particularly, if possible, in a longitudinal setting.

The immediate implication from these findings is the early treatment during the development of the Class II.2 malocclusion, relieving the "self-restricting" anterior deep bite that would allow redirecting mandibular growth in a more normal pathway. However, recognition of Class II.2 characteristics may not be until the onset of the late mixed dentition or later. Research should also explore this aspect of development. Nevertheless, early treatment should at least reduce the severity of the malocclusion, particularly if favorable growth occurs during treatment.

Improved knowledge of the various dento-skeletal components of different malocclusions, rather than generic descriptions and assumptions, would help establish more precise treatment goals and successful treatment. Outcome studies should be evaluated in the changes within those components to build a wider body of evidence in turn more applicable to individual conditions. The clinician's responsibility is to adhere to the scientific basis of treatment, weigh the evidence for more effective, stable and predictable treatment" (Huang 2004).

TABLES

Table IV.1. Age distribution in the malocclusion groups in the total sample

	Class I		Class II				Class III		Total	
			Division 1		Division 2					
N	89		85		69		79		322	
Age	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
	17.27	7.66	18.1	7.40	19.12	7.64	16.73	7.13	17.76	7.48

Table IV.2.a. Cranial base measurements in the total sample

	Class I		Class II				Class III		Total	
			Division 1		Division 2					
Variables	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
SN(mm)	64.91	5.08	65.83	4.41	66.28	4.22	64.59	5.92	65.37	4.99
SN/H(°)	11.00	3.71	12.16	3.76	11.23	3.85	10.22	4.74	11.16	4.07
SN-Ar(°)	124.62	5.26	126.05	4.95	127.15	4.86	123.60	6.62	125.29	5.60
S-Ar(mm)	31.09	3.66	30.91	3.75	31.53	3.75	30.64	4.30	31.03	3.86

Table IV.2.b. Values of corresponding MANOVA or independent t tests for cranial base measurements in the total sample

	CI/ II.1	**CI/II.2**	**CI/III**	**CII.1/II.2**	**CII.1/III**	**CIII/II.2**
SN	1.000	0.513	1.000	1.000	0.670	0.237
SN/H	0.351	1.000	1.000	0.947	0.014	0.755
SN-Ar	0.505	0.023	1.000	1.000	0.026	0.001
S-Ar	1.000	1.000	1.000	1.000	1.000	0.970

Table IV.3.a. Measurements of the relationship between jaws and cranial base in the total sample

	Class I		Class II				Class III		Total	
			Division 1		Division 2					
Variables(°)	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Sagittal										
SNA	80.11	3.53	82.36	3.37	81.27	3.77	78.50	4.00	80.56	3.92
SNB	78.12	3.56	76.00	3.58	77.13	3.63	81.31	4.61	78.13	4.32
Vertical										
PP/H	-1.50	3.70	-3.56	4.25	-1.61	2.88	-1.14	3.69	-1.98	3.80
MP/H	29.91	5.95	29.99	6.66	24.36	5.61	29.00	6.75	28.51	6.63
MP/SN	36.91	5.95	36.99	6.66	31.36	5.61	36.00	6.75	35.51	6.63

Table IV.3.b. p-values of corresponding MANOVA or independent t tests between jaws and cranial base in the total sample

	CI/ II.1	CI/II.2	CI/III	CII.1/II.2	CII.1/III	CIII/II.2
Sagittal						
SNA	<0.001	0.285	0.028	0.403	<0.001	<0.001
SNB	0.002	0.648	<0.001	0.435	<0.001	<0.001
Vertical						
PP/H	0.006	0.711	0.501	0.012	<0.001	0.290
MP/H	1.000	<0.001	1.000	<0.001	1.000	<0.001
MP/SN	1.000	<0.001	1.000	<0.001	0.716	<0.001

Table IV.4.a. Measurements of maxilla-mandibular relationships in the total sample

	Class I		Class II				Class III		Total	
			Division 1		Division 2					
Variables	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
ANB(°)	1.98	1.01	6.34	1.65	4.14	2.26	-2.83	2.51	2.41	3.88
PP/MP(°)	26.82	5.83	27.76	6.32	21.11	5.12	26.34	5.84	25.71	6.30
LFH/TFH (%)	55.33	2.41	55.66	2.50	53.71	2.11	55.57	2.62	55.13	2.53

Table IV.4.b. p-values of corresponding MANOVA or independent t tests for maxilla-mandibular relationships in the total sample

	CI/ II.1	CI/II.2	CI/III	CII.1/II.2	CII.1/III	CIII/II.2
ANB	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
PP/MP	1.000	<0.001	1.000	<0.001	0.716	<0.001
LFH/TFH	1.000	<0.001	1.000	<0.001	1.000	<0.001

Table IV.5.a. Jaw-specific measurements in the total sample

		Class I		Class II				Class III		Total	
				Division 1		Division 2					
Variables		**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Maxilla(mm)											
ANS-PNS		47.51	4.51	49.97	4.46	49.95	3.80	45.55	5.33	48.21	4.90
R-A		46.28	4.41	49.25	4.46	49.87	4.71	43.54	4.12	47.18	5.06
Mandible											
Distances (mm)	**Co-Go**	52.29	6.88	51.95	6.71	54.42	6.56	53.38	8.23	52.93	7.16
	Co-Gn	111.07	10.31	108.41	9.46	109.25	8.62	116.34	16.24	111.27	11.89
	Ar-Gn	105.55	9.90	102.56	12.85	104.74	8.32	110.68	18.71	105.84	13.35
	Go-Me	63.30	6.06	61.02	5.75	64.35	7.57	66.33	9.54	63.66	7.53
	Go-B	56.44	6.62	65.22	5.55	66.73	5.90	67.91	8.22	66.26	6.71
	Ar-Go	42.38	6.16	42.70	5.90	44.76	6.11	45.03	7.49	43.62	6.51
	R-B	50.70	4.53	48.4	4.64	48.73	4.10	53.36	6.05	50.32	5.24
	R-L1	48.20	4.81	48.9	5.09	47.8	4.56	48.84	7.77	48.46	5.68
	B-Pog	10.28	2.40	11.32	2.11	10.81	2.18	11.22	2.94	10.90	2.46
	Go-Pog	67.31	6.88	64.96	8.48	68.31	6.65	70.62	9.36	67.72	8.16
Angles (°)	**Ar-Go-Me**	129.57	5.26	127.88	5.92	120.99	14.32	131.10	6.63	127.64	9.20
	Co-Go-Me	123.43	5.09	121.56	5.76	116.44	5.19	125.2	6.52	121.87	6.45
	ASA	7.05	7.80	5.48	8.25	16.43	17.24	10.17	7.66	9.42	11.34

Table IV.5.b. p-values of corresponding MANOVA or independent t tests for jaw-specific measurements in the total sample

		CI/ II.1	CI/II.2	CI/III	CII.1/II.2	CII.1/III	CIII/II.2
Maxilla(mm)							
ANS-PNS		0.004	0.003	0.036	1.000	0.004	<0.001
R-A		<0.001	<0.001	<0.001	1.000	<0.001	<0.001
Mandible							
Distances (mm)	**Co-Go**	0.752	0.216	0.347	0.096	0.227	0.339
	Co-Gn	0.468	0.355	0.09	0.413	<0.001	0.012
	Ar-Gn	0.576	0.810	0.174	0.159	0.012	0.120
	Go-Me	0.096	0.222	0.084	0.006	<0.001	0.206
	Go-B	0.878	0.128	0.168	0.438	0.102	0.405
	Ar-Go	1.000	0.126	0.048	0.289	0.012	1.000
	R-B	0.006	0.030	0.012	0.639	<0.001	<0.001
	R-L1	0.355	0.627	0.532	0.173	0.952	0.334
	B-Pog	0.018	0.594	0.138	0.219	0.796	0.437
	Go-Pog	0.306	1.000	0.043	0.056	<0.001	0.459
Angles (°)	**Ar-Go-Me**	1.000	<0.001	1.000	<0.001	0.095	<0.001
	Co-Go-Me	0.177	<0.001	0.242	<0.001	<0.001	<0.001
	ASA	1.000	<0.001	0.349	<0.001	0.031	0.002

Table IV.6.a. Measurements of the relationship between teeth and jaws in the total sample

	Class I		Class II				Class III		Total	
			Division 1		Division 2					
Variables	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Maxilla										
U1-NA (mm)	4.45	2.03	4.61	2.25	0.49	2.39	5.87	2.60	3.98	2.99
U1/NA (°)	24.29	5.86	25.81	6.55	11.75	5.45	28.19	6.63	22.93	8.61
U1/SN (°)	104.42	6.46	108.12	7.24	92.13	7.75	106.72	7.25	103.29	9.33
U1/PP (°)	113.92	6.84	116.72	7.01	101.75	7.20	115.81	6.70	112.48	8.98
Mandible										
L1-NB (mm)	4.76	1.93	6.56	2.32	3.19	2.18	3.28	2.22	4.53	2.55
L1/NB (°)	25.98	5.64	30.47	5.95	21.71	6.99	19.90	6.14	24.75	7.37
L1/MP (°)	90.97	7.18	97.46	7.17	93.32	7.97	82.58	7.91	91.13	9.26

Table IV.6.b. p-values of corresponding MANOVA or independent t tests for the relationship between teeth and jaws in the total sample

	CI/ II.1	**CI/II.2**	**CI/III**	**CII.1/II.2**	**CII.1/III**	**CIII/II.2**
Maxilla						
U1-NA	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
U1/NA	0.619	<0.001	<0.001	<0.001	0.084	<0.001
U1/SN	0.004	<0.001	0.229	<0.001	1.000	<0.001
U1/PP	0.049	<0.001	0.476	<0.001	1.000	<0.001
Mandible						
L1-NB	<0.001	<0.001	<0.001	<0.001	<0.001	1.000
L1/NB	<0.001	<0.001	<0.001	<0.001	<0.001	0.449
L1/MP	<0.001	0.306	<0.001	0.004	<0.001	<0.001

Table IV.7.a. Measurements of interdental relationship in the total sample

	Class I		Class II				Class III		Total	
			Division 1		Division 2					
Variables	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
OJ (mm)	2.38	1.65	6.58	1.74	3.05	0.75	-1.81	2.83	2.60	3.55
OB (mm)	1.29	1.53	2.61	2.23	5.31	1.13	0.06	2.24	2.20	2.63
U1/L1 (°)	127.58	9.39	117.41	9.10	142.80	10.79	134.77	9.98	129.95	13.38

Table IV.7.b. p-values of corresponding MANOVA or independent t tests for interdental relationship in the total sample

	CI/ II.1	**CI/II.2**	**CI/III**	**CII.1/II.2**	**CII.1/III**	**CIII/II.2**
OJ	<0.001	0.006	<0.001	<0.001	<0.001	<0.001
OB	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
U1/L1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Table IV.8. Gender differences in the total sample

Variables	Females		Males		p
	Mean	SD	Mean	SD	
LFH_TFH	54.91	2.32	55.65	2.63	0.021
ANS_PNS	46.80	4.67	48.50	4.95	0.006
PP_H	-2.46	4.11	-1.39	3.60	0.034
SNB	77.14	3.83	79.02	4.67	0.001
Go-Pog	65.68	7.21	69.68	7.96	<0.001
Co-Gn	107.40	10.45	113.39	13.28	<0.001
Ar-Gn	102.41	10.19	107.44	17.60	0.005
Go-Me	61.76	6.96	64.13	7.93	0.013
Co-Go	50.83	6.16	53.74	8.04	0.001
OJ	2.97	2.92	1.93	3.70	0.014

Table IV.9. Age distribution in the malocclusion groups in growing females

	Class I		Class II				Class III		Total	
			Division 1		Division 2					
N	31		21		17		18		87	
Age	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
	11.29	2.02	11.05	1.83	12.65	1.86	10.13	2.95	11.26	2.29

Table IV.10.a. Cranial base measurements in growing females

	Class I		Class II				Class III		Total	
			Division 1		Division 2					
Variables	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
SN (mm)	62.39	3.39	63.82	5.09	63.95	4.78	61.24	4.50	62.80	4.40
SN/H (°)	11.33	3.24	13.85	3.15	11.20	3.78	10.52	3.22	11.75	3.49
SN-Ar (°)	125.66	4.67	127.18	5.28	124.88	5.10	122.56	5.48	125.23	5.23
S-Ar (mm)	29.23	2.72	28.76	2.55	30.58	4.56	27.96	2.84	29.12	3.21

Table IV.10.b. p-values of corresponding MANOVA or independent t tests for cranial base measurements in growing females

	CI/ II.1	CI/II.2	CI/III	CII.1/II.2	CII.1/III	CIII/II.2
SN	1.000	1.000	1.000	1.000	0.414	0.418
SN/H	0.055	1.000	1.000	0.103	0.016	1.000
SN-Ar	1.000	1.000	0.255	1.000	0.035	1.000
S-Ar	0.532	0.277	0.576	0.930	0.357	0.288

Table IV.11.a. Measurements of the relationship between jaws and cranial base in growing females

	Class I		Class II				Class III		Total	
			Division 1		Division 2					
Variables (˚)	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Sagittal										
SNA	79.41	3.33	80.57	2.73	82.15	3.49	79.13	2.69	80.17	3.25
SNB	77.58	3.25	74.40	2.91	78.51	3.63	80.41	2.74	77.58	3.73
Vertical										
PP/H	-1.55	4.38	-4.31	4.29	-2.61	3.36	-0.61	3.12	-2.23	4.10
MP/H	29.96	5.05	31.66	4.57	25.40	4.75	27.49	5.99	28.97	5.49
MP/SN	36.96	5.05	38.66	4.57	32.40	4.75	34.48	5.99	35.97	5.49

Table IV.11.b. p-values of corresponding MANOVA or independent t tests between jaws and cranial base in growing females

	CI/ II.1	CI/II.2	CI/III	CII.1/II.2	CII.1/III	CIII/II.2
Sagittal						
SNA	1.000	0.027	1.000	0.736	0.915	0.031
SNB	0.004	1.000	0.020	0.001	<0.001	0.479
Vertical						
PP/H	0.091	1.000	1.000	1.000	0.027	0.834
MP/H	1.000	0.024	0.635	0.002	0.076	1.000
MP/SN	1.000	0.024	0.625	0.002	0.075	1.000

Table IV.12.a. Measurements of maxillo-mandibular relationships in growing females

	Class I		Class II				Class III		Total	
			Division 1		Division 2					
Variables	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
ANB (˚)	1.81	0.92	6.13	1.60	3.64	2.12	-1.35	1.46	2.56	2.98
PP/MP (˚)	26.39	4.53	28.51	4.43	23.15	4.57	23.90	5.76	25.76	5.12
LFH/TFH (%)	54.41	1.94	54.72	2.18	53.61	1.81	53.80	2.16	54.20	2.03

Table IV.12.b. p-values of corresponding MANOVA or independent t tests for maxillo-mandibular relationships in growing females

	CI/ II.1	CI/II.2	CI/III	CII.1/II.2	CII.1/III	CIII/II.2
ANB	<0.001	0.001	<0.001	<0.001	<0.001	<0.001
PP/MP	0.729	0.167	0.501	0.006	0.022	1.000
LFH/TFH	1.000	1.000	1.000	0.579	0.974	1.000

Table IV.13.a. Jaw-specific measurements in growing females

		Class I		Class II				Class III		Total	
				Division 1		Division 2					
Variables		**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Maxilla (mm)											
ANS-PNS		45.63	3.73	47.47	3.24	48.27	4.10	41.98	3.43	45.83	4.21
R-A		43.53	2.91	45.41	3.08	47.67	4.51	40.04	2.46	44.07	4.08
Mandible											
Distances (mm)	**Co-Go**	48.18	5.33	47.27	5.41	49.50	4.18	46.45	4.43	47.86	4.99
	Co-Gn	104.44	8.36	101.71	9.75	104.68	9.39	102.08	9.81	103.34	9.15
	Ar-Gn	99.35	8.23	97.15	8.98	99.61	8.92	98.15	10.18	98.62	8.87
	Go-Me	60.70	5.24	58.02	5.48	61.18	6.45	58.78	6.35	59.75	5.82
	Go-B	63.11	4.60	61.40	3.98	56.21	6.63	62.01	5.49	65.21	6.63
	Ar-Go	38.84	5.01	38.57	4.87	39.49	3.87	38.86	4.49	38.91	4.60
	R-B	48.41	3.47	44.31	3.22	48.01	4.76	48.22	3.75	47.31	4.06
	R-L1	45.62	3.23	44.06	3.47	46.27	3.91	44.27	3.91	45.11	3.70
	B-Pog	8.66	1.55	10.67	1.84	9.38	1.64	8.82	2.17	9.32	1.93
	Go-Pog	65.02	5.52	61.97	6.12	65.48	7.48	63.03	6.49	63.96	6.33
Angles (°)	**Ar-Go-Me**	129.55	4.46	129.71	5.04	124.58	4.12	130.42	6.02	128.80	5.26
	Co-Go-Me	123.20	4.45	123.15	5.34	118.24	3.89	124.51	5.87	122.49	5.28
	ASA	5.83	8.43	5.01	5.97	12.51	6.51	5.08	8.77	6.78	8.02

Table IV.13.b. p-values of corresponding MANOVA or independent t tests for jaw-specific measurements in growing females

		CI/ II.1	CI/II.2	CI/III	CII.1/II.2	CII.1/III	CIII/II.2
Maxilla(mm)							
ANS-PNS		0.465	0.110	0.007	1.000	<0.001	<0.001
R-A		0.258	<0.001	0.003	0.216	<0.001	<0.001
Mandible							
Distances (mm)	**Co-Go**	1.000	1.000	1.000	1.000	1.000	0.441
	Co-Gn	1.000	1.000	1.000	1.000	1.000	1.000
	Ar-Gn	1.000	1.000	1.000	1.000	1.000	1.000
	Go-Me	0.637	1.000	1.000	0.592	1.000	1.000
	Go-B	1.000	1.000	1.000	0.151	1.000	0.407
	Ar-Go	1.000	1.000	1.000	1.000	1.000	1.000
	R-B	0.001	1.000	1.000	0.020	0.011	1.000
	R-L1	0.805	1.000	1.000	0.332	1.000	0.553
	B-Pog	0.001	1.000	1.000	0.174	0.010	1.000
	Go-Pog	0.537	1.000	1.000	0.547	1.000	1.000
Angles (°)	**Ar-Go-Me**	1.000	0.007	1.000	0.011	1.000	0.004
	Co-Go-Me	1.000	0.007	1.000	0.017	1.000	0.002
	ASA	1.000	0.029	1.000	0.021	1.000	0.030

Table IV.14.a. Measurements of the relationship between teeth and jaws in growing females

	Class I		Class II				Class III		Total	
			Division 1		Division 2					
Variables (˚)	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Maxilla										
U1-NA (mm)	4.33	1.99	4.76	2.24	0.29	1.99	4.15	2.80	3.61	2.75
U1/NA (˚)	25.75	6.65	27.08	5.59	11.01	6.37	24.62	8.36	22.96	8.93
U1/SN (˚)	105.17	6.52	107.62	6.73	93.54	7.29	103.76	8.30	103.20	8.58
U1/PP (˚)	114.96	7.82	117.16	7.17	102.15	7.33	113.70	7.45	112.73	9.12
Mandible										
L1-NB (mm)	4.54	1.43	5.75	2.10	3.06	1.99	2.72	2.66	4.16	2.28
L1/NB (˚)	26.77	5.28	29.41	6.32	21.89	7.02	19.42	8.48	24.93	7.53
L1/MP (˚)	92.23	6.07	96.33	7.04	91.37	8.03	84.52	8.18	91.46	8.10

Table IV.14.b. p-values of corresponding following MANOVA or independent t tests for the relationship between teeth and jaws in growing females

	CI/ II.1	**CI/II.2**	**CI/III**	**CII.1/II.2**	**CII.1/III**	**CIII/II.2**
Maxilla						
U1-NA	1.000	<0.001	1.000	<0.001	1.000	<0.001
U1/NA	1.000	<0.001	1.000	<0.001	1.000	<0.001
U1/SN	1.000	<0.001	1.000	<0.001	0.568	<0.001
U1/PP	1.000	<0.001	1.000	<0.001	0.928	<0.001
Mandible						
L1-NB	0.216	0.102	0.018	0.001	<0.001	1.000
L1/NB	0.973	0.102	0.002	0.005	<0.001	1.000
L1/MP	0.276	1.000	0.003	0.221	<0.001	0.036

Table IV.15.a. Measurements of interdental relationships in growing females

	Class I		Class II				Class III		Total	
			Division 1		Division 2					
Variables	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
OJ (mm)	2.27	1.78	7.01	2.31	3.03	0.78	-1.15	1.59	2.85	3.27
OB (mm)	1.22	1.53	2.31	2.33	5.24	0.94	0.02	2.31	2.02	2.53
U1/L1(˚)	125.63	9.74	117.35	9.07	142.68	8.72	137.22	14.18	129.36	13.94

Table IV.15.b. p-values of corresponding MANOVA or independent t tests for interdental relationship in growing females

	CI/ II.1	**CI/II.2**	**CI/III**	**CII.1/II.2**	**CII.1/III**	**CIII/II.2**
OJ	<0.001	0.276	<0.001	<0.001	<0.001	<0.001
OB	0.282	<0.001	0.204	<0.001	0.024	<0.001
U1/L1	0.039	<0.001	<0.001	<0.001	<0.001	0.766

Table IV.16. Age distribution in the malocclusion groups in growing males

	Class I		Class II				Class III		Total	
			Division 1		Division 2					
N	22		19		16		25		82	
Age	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
	13.02	2.09	11.54	1.79	12.44	2.62	13.00	3.28	12.56	2.78

Table IV.17.a. Cranial base measurements in growing males

	Class I		Class II				Class III		Total	
			Division 1		Division 2					
Variables	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
SN (mm)	65.80	5.35	66.34	3.54	66.43	3.21	64.42	5.16	65.63	4.55
SN/H (°)	10.28	3.33	11.70	3.68	11.55	4.51	9.90	5.37	10.74	4.34
SN-Ar (°)	123.58	4.78	123.96	6.48	127.74	4.83	122.74	4.83	124.21	5.83
S-Ar (mm)	30.64	3.29	30.51	4.43	32.06	3.87	30.26	4.18	30.77	3.94

Table IV.17.b. p-values of corresponding following MANOVA or independent t tests for cranial base measurements in growing males

	CI/ II.1	**CI/II.2**	**CI/III**	**CII.1/II.2**	**CII.1/III**	**CIII/II.2**
SN	1.000	1.000	1.000	1.000	1.000	1.000
SN/H	1.000	1.000	1.000	1.000	1.000	1.000
SN-Ar	1.000	0.168	1.000	0.313	1.000	0.040
S-Ar	1.000	1.000	1.000	1.000	1.000	0.952

Table IV.18.a. Measurements of the relationship between jaws and cranial base in growing males

	Class I		Class II				Class III		Total	
			Division 1		Division 2					
Variables (˚)	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Sagittal										
SNA	80.64	3.20	81.62	3.21	79.19	3.85	78.20	3.41	79.84	3.60
SNB	78.30	3.27	75.29	3.39	75.55	3.82	81.22	4.88	77.96	4.61
Vertical										
PP/H	-1.94	2.89	-2.78	4.21	-1.08	2.02	-0.912	4.17	-1.65	3.54
MP/H	30.55	6.24	30.52	6.25	25.90	5.98	29.75	6.93	29.39	6.54
MP/SN	37.55	6.24	37.52	6.25	32.90	5.98	36.75	6.93	36.39	6.54

Table IV.18.b. p-values of corresponding MANOVA or independent t tests between jaws and cranial base in growing males

	CI/ II.1	CI/II.2	CI/III	CII.1/II.2	CII.1/III	CIII/II.2
Sagittal						
SNA	1.000	1.000	0.098	0.231	0.009	1.000
SNB	0.105	0.226	0.084	1.000	<0.001	<0.001
Vertical						
PP/H	1.000	1.000	1.000	0.959	0.515	1.000
MP/H	1.000	0.182	1.000	0.224	1.000	0.389
MP/SN	1.000	0.182	1.000	0.224	1.000	0.389

Table IV.19.a. Measurements of maxilla-mandibular relationships in growing males

	Class I		Class II				Class III		Total	
			Division 1		Division 2					
Variables	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
ANB (˚)	2.34	0.89	6.32	1.62	3.64	1.75	-3.02	2.73	1.88	4.03
PP/MP (˚)	28.74	6.72	28.06	6.02	21.79	4.40	27.06	5.82	26.72	6.30
LFH/TFH (%)	55.81	2.56	55.66	2.42	53.22	1.76	55.26	2.50	55.11	2.52

Table IV.19.b. p-values of corresponding MANOVA or independent t tests for maxilla-mandibular relationships in growing males

	CI/ II.1	CI/II.2	CI/III	CII.1/II.2	CII.1/III	CIII/II.2
ANB	<0.001	0.258	<0.001	0.001	<0.001	<0.001
PP/MP	1.000	0.003	1.000	0.014	1.000	0.039
LFH/TFH	1.000	0.008	1.000	0.020	1.000	0.043

Table IV.20.a. Jaw-specific measurements in growing males

		Class I		Class II				Class III		Total	
				Division 1		Division 2					
Variables		**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Maxilla (mm)											
ANS-PNS		47.68	4.67	48.42	4.53	48.99	3.32	44.69	4.46	47.20	4.60
R-A		45.37	4.17	47.52	4.37	47.70	3.90	43.19	4.14	45.66	4.49
Mandible											
Distances (mm)	**Co-Go**	50.42	7.06	49.77	6.10	52.28	5.90	50.94	7.35	65.26	6.12
	Co-Gn	110.11	10.37	105.12	9.46	106.53	8.57	113.96	15.09	109.43	11.89
	Ar-Gn	105.23	10.26	100.61	8.98	102.34	7.06	105.90	22.62	103.80	14.52
	Go-Me	62.43	6.18	59.04	6.72	60.58	5.46	65.44	9.25	62.20	7.54
	Go-B	65.47	5.67	63.78	5.50	64.28	4.88	66.83	7.47	65.26	6.12
	Ar-Go	41.47	6.27	40.66	4.93	43.18	4.76	43.39	6.36	42.20	5.76
	R-B	50.08	4.19	47.39	4.13	47.36	3.60	53.54	6.90	49.98	5.63
	R-L1	47.70	4.96	47.34	4.09	46.41	4.27	49.44	6.55	47.89	5.24
	B-Pog	10.85	2.49	10.60	1.59	10.24	1.96	10.57	2.38	10.59	2.14
	Go-Pog	66.84	5.63	64.48	7.40	66.12	5.48	70.43	7.73	67.25	6.99
Angles (°)	**Ar-Go-Me**	131.83	5.45	128.90	4.97	118.45	28.85	132.60	5.18	128.77	14.26
	Co-Go-Me	125.48	5.01	122.36	4.53	119.04	4.98	126.90	4.88	123.93	5.60
	ASA	4.01	6.07	3.09	9.87	20.52	32.56	9.66	4.94	8.74	16.61

Table IV.20.b. p-values of corresponding MANOVA or independent t tests for jaw-specific measurements in growing males

		CI/ II.1	CI/II.2	CI/III	CII.1/II.2	CII.1/III	CIII/II.2
Maxilla(mm)							
ANS-PNS		1.000	1.000	0.127	1.000	0.037	0.017
R-A		0.619	0.551	0.461	1.000	0.006	0.007
Mandible							
Distances (mm)	**Co-Go**	1.000	1.000	1.000	1.000	1.000	1.000
	Co-Gn	0.708	0.268	0.309	0.648	0.132	0.312
	Ar-Gn	0.136	0.310	0.900	0.536	0.342	0.470
	Go-Me	0.606	0.346	0.203	0.468	0.090	0.309
	Go-B	1.000	1.000	1.000	1.000	0.635	1.000
	Ar-Go	1.000	1.000	1.000	1.000	0.735	1.000
	R-B	0.276	0.264	0.252	0.984	0.006	0.006
	R-L1	1.000	1.000	1.000	1.000	1.000	0.444
	B-Pog	1.000	1.000	1.000	1.000	1.000	1.000
	Go-Pog	1.000	1.000	0.433	1.000	0.029	1.000
Angles (°)	**Ar-Go-Me**	0.486	0.240	0.623	0.780	0.126	0.126
	Co-Go-Me	0.263	0.001	1.000	0.286	0.018	<0.001
	ASA	1.000	0.011	1.000	0.009	1.000	0.197

Table IV.21.a. Measurements of the relationship between teeth and jaws in growing males

	Class I		Class II				Class III		Total	
			Division 1		Division 2					
Variables	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Maxilla										
U1-NA (mm)	4.26	2.11	4.30	2.62	1.82	1.78	6.46	2.84	4.46	2.88
U1/NA (°)	23.64	5.37	24.64	7.28	14.35	5.57	29.07	6.36	23.69	7.96
U1/SN (°)	104.20	6.06	106.26	7.03	93.55	6.25	107.32	8.00	103.55	8.52
U1/PP (°)	112.57	5.79	115.18	5.34	104.03	4.77	116.32	7.76	112.65	7.58
Mandible										
L1-NB (mm)	5.40	2.41	6.45	2.13	3.31	1.44	3.41	2.29	4.63	2.49
L1/NB (°)	27.66	5.48	30.13	4.58	22.41	5.71	20.51	5.63	25.03	6.59
L1/MP (°)	91.85	6.70	97.31	6.28	93.96	8.64	82.55	7.37	90.69	9.14

Table IV.21.b. p-values of corresponding MANOVA or independent t tests for the relationship between teeth and jaws in growing males

	CI/ II.1	**CI/II.2**	**CI/III**	**CII.1/II.2**	**CII.1/III**	**CIII/II.2**
Maxilla						
U1-NA	1.000	0.018	0.016	0.021	0.027	<0.001
U1/NA	1.000	<0.001	0.019	<0.001	0.128	<0.001
U1/SN	1.000	<0.001	0.779	<0.001	1.000	<0.001
U1/PP	1.000	<0.001	0.251	<0.001	1.000	<0.001
Mandible						
L1-NB	0.725	0.026	0.014	<0.001	<0.001	1.000
L1/NB	0.889	0.024	<0.001	<0.001	<0.001	1.000
L1/MP	0.110	1.000	<0.001	1.000	<0.001	<0.001

Table IV.22.a. Measurements of interdental relationship in growing males

	Class I		Class II				Class III		Total	
			Division 1		Division 2					
Variables	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
OJ (mm)	2.07	2.14	6.50	1.35	3.33	0.84	-1.67	2.36	2.20	3.55
OB (mm)	1.37	1.68	2.51	2.06	5.05	0.48	0.40	1.99	2.06	2.38
U1/L1 (°)	126.36	9.47	118.88	8.49	139.57	8.27	133.64	8.97	129.42	11.41

Table IV.22.b. p-values of corresponding MANOVA or independent t tests for interdental relationship in growing males

	CI/ II.1	**CI/II.2**	**CI/III**	**CII.1/II.2**	**CII.1/III**	**CIII/II.2**
OJ	<0.001	0.108	<0.001	<0.001	<0.001	<0.001
OB	0.360	<0.001	0.480	<0.001	0.006	<0.001
U1/L1	0.052	<0.001	0.038	<0.001	<0.001	0.242

Table.IV.23. Age distribution in the malocclusion groups in adult females

	Class I		Class II				Class III		Total	
			Division 1		Division 2					
N	20		23		20		18		81	
Age	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
	27.57	10.05	25.83	5.33	24.79	6.39	21.22	5.64	24.97	6.82

Table IV.24.a. Cranial base measurements in adult females

	Class I		Class II				Class III		Total	
			Division 1		Division 2					
Variables	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
SN (mm)	63.37	4.51	64.28	4.13	65.03	3.31	64.49	7.45	64.28	4.91
SN/H (˚)	12.39	4.69	13.00	3.59	12.70	3.70	11.44	4.99	12.43	4.20
SN-Ar (˚)	126.49	5.52	127.71	3.56	128.11	4.79	126.47	7.68	127.24	5.40
S-Ar (mm)	31.32	3.19	30.58	3.60	30.32	2.27	30.98	3.93	30.79	3.25

Table IV.24.b. p-values of corresponding MANOVA or independent t tests for cranial base measurements in adult females

	CI/ II.1	CI/II.2	CI/III	CII.1/II.2	CII.1/III	CIII/II.2
SN	1.000	1.000	1.000	1.000	1.000	1.000
SN/H	1.000	1.000	1.000	1.000	1.000	1.000
SN-Ar	0.394	0.269	0.991	0.672	0.531	0.398
S-Ar	1.000	1.000	1.000	1.000	1.000	1.000

Table IV.25.a. Measurements of the relationship between jaws and cranial base in adult females

	Class I		Class II				Class III		Total	
			Division 1		Division 2					
Variables (°)	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Sagittal										
SNA	79.92	4.33	82.68	2.56	80.96	2.84	76.55	5.09	80.22	4.30
SNB	78.04	4.32	75.91	3.15	76.15	3.28	79.66	5.07	77.32	4.17
Vertical										
PP/H	-1.21	3.67	-4.64	4.34	-2.02	3.27	-1.63	3.58	-2.46	3.94
MP/H	30.30	7.44	31.25	7.76	25.51	4.35	29.99	6.57	29.28	6.95
MP/SN	37.30	7.44	38.25	7.76	32.51	4.35	36.99	6.57	36.28	6.95

Table IV.25.b. p-values of corresponding MANOVA or independent t tests between jaws and cranial base in adult females

	CI/ II.1	**CI/II.2**	**CI/III**	**CII.1/II.2**	**CII.1/III**	**CIII/II.2**
Sagittal						
SNA	0.078	0.420	0.192	0.156	<0.001	0.024
SNB	0.474	0.763	1.000	1.000	0.022	0.045
Vertical						
PP/H	0.020	1.000	1.000	0.142	0.078	1.000
MP/H	1.000	0.141	1.000	0.035	1.000	0.246
MP/SN	1.000	0.141	1.000	0.035	1.000	0.246

Table IV.26.a. Measurements of maxilla-mandibular relationships in adult females

	Class I		Class II				Class III		Total	
			Division 1		Division 2					
Variables	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
ANB (°)	1.88	1.08	6.75	1.79	4.79	2.63	-3.11	1.81	2.88	4.10
PP/MP (°)	25.70	6.52	29.04	8.40	21.21	4.16	26.82	5.29	25.73	6.92
LFH/TFH (%)	54.89	1.79	56.71	2.85	53.92	1.82	55.60	2.34	55.30	2.45

Table IV.26.b. p-values of corresponding MANOVA or independent t tests for maxilla-mandibular relationships in adult females

	CI/ II.1	**CI/II.2**	**CI/III**	**CII.1/II.2**	**CII.1/III**	**CIII/II.2**
ANB	<0.001	<0.001	<0.001	0.006	<0.001	<0.001
PP/MP	0.151	0.204	0.565	0.006	0.308	0.024
LFH/TFH	0.056	1.000	1.000	0.001	0.731	0.144

Table IV.27.a. Jaw-specific measurements in adult females

		Class I		Class II				Class III		Total	
				Division 1		Division 2					
Variables		**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Maxilla (mm)											
ANS-PNS		46.78	4.52	49.66	3.45	49.39	3.01	45.48	6.06	47.95	4.58
R-A		47.35	3.60	50.17	3.42	49.51	3.63	44.60	2.83	48.11	3.97
Mandible											
Distances (mm)	**Co-Go**	54.32	4.56	52.27	5.67	54.59	3.61	53.98	6.03	53.74	5.03
	Co-Gn	113.33	7.09	109.26	6.20	108.50	4.32	118.02	14.51	112.02	9.19
	Ar-Gn	107.03	6.23	104.65	6.23	103.89	4.65	112.90	14.12	106.85	8.84
	Go-Me	64.45	5.54	61.21	4.44	63.67	4.58	68.51	10.06	64.24	6.75
	Go-B	66.12	5.97	64.83	4.55	65.92	4.32	69.10	8.84	66.36	6.11
	Ar-Go	43.64	3.93	43.52	5.15	45.06	3.33	44.62	5.47	44.18	4.50
	R-B	52.08	3.79	48.33	3.09	47.82	3.05	53.08	3.97	50.13	4.09
	R-L1	49.25	4.78	49.49	3.36	47.05	3.44	50.10	3.91	48.92	3.98
	B-Pog	10.61	2.14	11.22	1.86	11.11	2.33	12.32	2.29	11.28	2.19
	Go-Pog	66.11	7.86	65.58	5.53	67.50	3.95	71.81	9.88	67.55	7.27
Angles (°)	**Ar-Go-Me**	128.17	5.90	128.11	6.58	121.40	4.84	129.66	7.72	126.76	6.95
	Co-Go-Me	122.72	5.62	121.75	6.45	115.69	4.50	123.82	7.12	120.91	6.65
	ASA	11.28	6.21	6.02	7.73	15.43	9.50	15.22	6.23	11.72	8.42

Table IV.27.b. p-values of corresponding MANOVA or independent t tests for jaw- specific measurements in adult females

		CI/ II.1	CI/II.2	CI/III	CII.1/II.2	CII.1/III	CIII/II.2
Maxilla(mm)							
ANS-PNS		0.181	0.322	1.000	0.037	0.018	0.037
R-A		0.050	0.263	0.091	1.000	<0.001	<0.001
Mandible							
Distances (mm)	**Co-Go**	1.000	1.000	1.000	0.787	1.000	1.000
	Co-Gn	0.294	0.118	0.224	0.792	0.078	0.156
	Ar-Gn	0.213	0.376	0.564	0.809	0.096	0.192
	Go-Me	0.572	1.000	0.304	1.000	0.003	0.121
	Go-B	1.000	1.000	0.771	1.000	0.165	0.628
	Ar-Go	1.000	1.000	1.000	1.000	1.000	1.000
	R-B	0.004	0.001	1.000	1.000	<0.001	<0.001
	R-L1	1.000	0.430	1.000	0.234	1.000	0.095
	B-Pog	1.000	1.000	0.093	1.000	0.649	0.501
	Go-Pog	0.797	0.309	0.318	0.636	0.084	0.169
Angles (°)	**Ar-Go-Me**	1.000	0.005	1.000	0.004	1.000	0.001
	Co-Go-Me	1.000	0.002	1.000	0.007	1.000	<0.001
	ASA	0.147	0.482	0.661	0.001	0.001	1.000

Table IV.28.a. Measurements of the relationship between teeth and jaws in adult females

	Class I		Class II				Class III		Total	
			Division 1		Division 2					
Variables	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Maxilla										
U1-NA (mm)	4.56	2.21	4.40	2.15	-0.11	2.94	6.77	1.58	3.81	3.34
U1/NA (˚)	23.70	5.69	24.13	6.08	10.99	5.50	31.26	5.44	22.24	9.12
U1/SN (˚)	103.65	8.02	106.73	7.46	88.64	9.90	107.82	6.48	101.61	11.10
U1/PP (˚)	114.83	6.97	115.08	7.76	99.31	9.62	117.62	6.12	111.58	10.54
Mandible										
L1-NB (mm)	4.51	2.12	7.41	2.26	3.30	2.24	3.22	1.62	4.73	2.70
L1/NB (˚)	24.82	6.28	32.21	5.43	21.74	7.32	21.05	4.24	25.27	7.41
L1/MP (˚)	89.49	8.89	98.06	8.13	93.08	7.66	84.39	6.43	91.67	9.20

Table IV.28.b. p-values of corresponding MANOVA or independent t tests for the relationship between teeth and jaws in adult females

	CI/ II.1	**CI/II.2**	**CI/III**	**CII.1/II.2**	**CII.1/III**	**CIII/II.2**
Maxilla						
U1-NA	1.000	<0.001	0.022	<0.001	0.009	<0.001
U1/NA	1.000	<0.001	0.001	<0.001	0.001	<0.001
U1/SN	1.000	<0.001	0.679	<0.001	1.000	<0.001
U1/PP	1.000	<0.001	1.000	<0.001	1.000	<0.001
Mandible						
L1-NB	<0.001	0.393	0.355	<0.001	<0.001	1.000
L1/NB	0.001	0.588	0.314	<0.001	<0.001	1.000
L1/MP	0.003	0.865	0.286	0.238	<0.001	0.006

Table IV.29.a. Measurements of interdental relationship in adult females

	Class I		Class II				Class III		Total	
			Division 1		Division 2					
Variables	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
OJ (mm)	2.71	1.15	6.19	1.56	3.00	0.60	-0.91	2.41	2.96	2.92
OB (mm)	0.96	1.50	1.92	2.00	5.22	1.50	0.12	0.92	2.12	2.46
U1/L1 (˚)	129.55	9.56	116.94	8.99	144.48	14.01	130.80	4.81	130.11	14.08

Table IV.29.b. p-values of corresponding MANOVA or independent t tests for interdental relationship in adult females

	CI/ II.1	**CI/II.2**	**CI/III**	**CII.1/II.2**	**CII.1/III**	**CIII/II.2**
OJ	<0.001	1.000	<0.001	<0.001	<0.001	<0.001
OB	0.273	<0.001	0.593	<0.001	0.003	<0.001
U1/L1	<0.001	<0.001	1.000	<0.001	<0.001	<0.001

Table IV.30. Age distribution in the malocclusion groups in adult males

	Class I		Class II				Class III		Total	
			Division 1		Division 2					
N	16		22		16		18		72	
Age	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
	25.79	7.22	22.92	4.65	31.84	27.73	25.73	10.06	26.24	14.65

Table IV.31.a. Cranial base measurements in adult males

	Class I		Class II				Class III		Total	
			Division 1		Division 2					
Variables	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
SN (mm)	70.59	3.32	68.92	2.74	70.23	2.79	68.26	4.60	69.42	3.48
SN/H (˚)	9.51	3.16	10.05	3.68	9.03	2.48	9.13	4.88	9.47	3.65
SN-Ar (˚)	121.56	5.38	125.05	3.61	127.73	4.36	123.01	6.92	124.36	5.51
S-Ar (mm)	35.00	3.48	33.66	2.64	33.60	3.56	33.52	4.47	33.91	3.52

Table IV.31.b. p-values of corresponding MANOVA or independent t tests for cranial base measurements in adult males

	CI/ II.1	**CI/II.2**	**CI/III**	**CII.1/II.2**	**CII.1/III**	**CIII/II.2**
SN	0.328	0.156	0.559	0.156	0.147	0.147
SN/H	0.645	0.147	0.156	0.788	0.645	0.636
SN-Ar	0.263	0.007	1.000	0.710	1.000	0.058
S-Ar	1.000	1.000	1.000	1.000	1.000	1.000

Table IV.32.a. Measurements of the relationship between jaws and cranial base in adult males

	Class I		Class II				Class III		Total	
			Division 1		Division 2					
Variables (°)	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Sagittal										
SNA	81.00	3.17	84.37	3.84	82.84	4.30	80.25	4.00	82.25	4.13
SNB	79.04	3.56	78.25	3.81	78.52	3.08	84.01	4.40	79.93	4.40
Vertical										
PP/H	-1.18	3.58	-2.36	4.00	-0.55	2.24	-1.52	3.82	-1.49	3.53
MP/H	28.42	5.22	26.63	6.66	20.20	5.97	28.48	7.60	26.06	7.13
MP/SN	35.42	5.22	33.63	6.66	27.20	5.97	35.48	7.60	33.06	7.13

Table IV.32.b. p-values of corresponding MANOVA or independent t tests between jaws and cranial base in adult males

	CI/ II.1	**CI/II.2**	**CI/III**	**CII.1/II.2**	**CII.1/III**	**CIII/II.2**
Sagittal						
SNA	0.058	1.000	1.000	1.000	0.008	0.330
SNB	1.000	1.000	0.002	1.000	<0.001	<0.001
Vertical						
PP/H	1.000	1.000	1.000	0.747	1.000	1.000
MP/H	1.000	0.004	1.000	0.021	1.000	0.002
MP/SN	1.000	0.004	1.000	0.021	1.000	0.002

Table IV.33.a. Measurements of maxilla-mandibular relationships in adult males

	Class I		Class II				Class III		Total	
			Division 1		Division 2					
Variables	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
ANB (°)	1.95	1.18	6.12	1.58	4.33	2.30	-3.77	3.11	2.32	4.39
PP/MP (°)	26.46	5.75	25.45	5.28	18.11	6.40	27.30	6.25	24.51	6.75
LFH/TFH (%)	57.05	2.85	55.45	2.22	54.03	3.01	57.73	2.01	56.06	2.83

Table IV.33.b. p-values of corresponding MANOVA or independent t tests for maxilla-mandibular relationships in adult males

	CI/ II.1	**CI/II.2**	**CI/III**	**CII.1/II.2**	**CII.1/III**	**CIII/II.2**
ANB	<0.001	0.016	<0.001	0.085	<0.001	<0.001
PP/MP	1.000	0.001	1.000	0.002	1.000	<0.001
LFH/TFH	0.353	0.007	1.000	0.543	0.035	<0.001

Table IV.34.a. Jaw-specific measurements in adult males

		Class I		Class II				Class III		Total	
				Division 1		Division 2					
Variables		**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Maxilla											
ANS-PNS		51.89	2.56	54.04	3.67	53.41	2.82	50.40	3.77	52.51	3.55
R-A		51.52	2.98	53.46	2.28	54.85	3.32	46.48	4.04	51.59	4.44
Mandible											
Distances (mm)	**Co-Go**	60.17	3.84	57.96	4.76	61.56	6.35	63.09	4.35	60.54	5.18
	Co-Gn	122.28	6.35	116.76	4.68	117.81	6.21	132.23	9.42	122.09	9.13
	Ar-Gn	116.03	6.85	107.24	20.34	113.70	5.70	127.65	8.46	115.73	14.68
	Go-Me	68.02	5.30	65.38	3.46	72.38	8.10	72.93	6.55	69.41	6.65
	Go-B	68.99	9.99	70.53	3.76	71.87	5.16	74.11	6.51	71.38	6.67
	Ar-Go	48.83	5.07	47.55	4.69	51.55	5.89	53.90	4.73	50.31	5.57
	R-B	54.28	5.07	53.26	3.02	52.12	3.51	58.54	3.78	54.56	4.48
	R-L1	52.61	3.92	54.26	3.16	51.92	4.43	51.32	12.44	52.64	6.99
	B-Pog	10.22	2.13	10.67	2.46	14.53	1.43	13.41	2.93	12.72	2.33
	Go-Pog	122.28	6.35	116.76	4.68	117.81	6.21	132.23	9.42	122.09	9.13
Angles (°)	**Ar-Go-Me**	128.31	4.96	125.01	6.03	119.19	6.04	131.13	7.87	125.98	7.56
	Co-Go-Me	122.00	5.28	119.14	5.94	112.92	5.59	125.05	8.33	119.87	7.64
	ASA	8.03	8.57	7.41	9.09	17.84	10.13	10.91	7.98	10.74	9.66

Table IV.34.b. p-values of corresponding MANOVA or independent t tests for jaw-specific measurements in adult males

		CI/ II.1	CI/II.2	CI/III	CII.1/II.2	CII.1/III	CIII/II.2
Maxilla(mm)							
ANS-PNS		0.314	1.000	1.000	1.000	0.006	0.061
R-A		0.174	0.036	<0.001	0.134	<0.001	<0.001
Mandible							
Distances (mm)	**Co-Go**	1.000	1.000	0.521	0.170	0.009	1.000
	Co-Gn	0.098	1.000	<0.001	<0.001	<0.001	<0.001
	Ar-Gn	0.240	1.000	0.061	0.773	<0.001	0.013
	Go-Me	0.564	0.492	0.138	0.024	<0.001	0.832
	Go-B	1.000	1.000	0.157	1.000	0.543	1.000
	Ar-Go	1.000	0.812	0.030	0.115	0.001	1.000
	R-B	0.481	0.173	0.066	0.290	<0.001	<0.001
	R-L1	1.000	1.000	1.000	1.000	1.000	1.000
	B-Pog	1.000	0.020	0.861	0.023	1.000	1.000
	Go-Pog	0.204	1.000	1.000	0.123	0.007	1.000
Angles (°)	**Ar-Go-Me**	0.712	0.001	1.000	0.041	0.021	<0.001
	Co-Go-Me	1.000	0.001	1.000	0.027	0.031	<0.001
	ASA	1.000	0.017	1.000	0.004	1.000	0.166

Table IV.35.a. Measurements of the relationship between teeth and jaws in adult males

	Class I		Class II				Class III		Total	
			Division 1		Division 2					
Variables	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Maxilla										
U1-NA (mm)	4.80	1.91	4.96	2.10	0.18	2.20	5.87	2.17	4.09	2.97
U1/NA (˚)	23.25	5.00	27.36	7.01	10.93	3.59	27.47	4.49	22.82	8.43
U1/SN (˚)	104.27	4.85	111.65	6.88	93.77	5.04	107.73	5.29	105.06	8.67
U1/PP (˚)	112.60	5.98	119.32	6.92	102.23	4.53	115.37	4.42	113.04	8.41
Mandible										
L1-NB (mm)	4.65	1.78	6.52	2.58	3.08	2.97	3.72	2.22	4.64	2.74
L1/NB (˚)	23.66	5.01	29.96	7.08	20.78	8.15	18.40	5.82	23.63	7.96
L1/MP (˚)	89.22	7.27	98.04	7.31	95.05	7.89	78.87	8.97	90.62	10.78

Table IV.35.b. p-values of corresponding MANOVA or independent t tests for the relationship between teeth and jaws in adult males

	CI/ II.1	CI/II.2	CI/III	CII.1/II.2	CII.1/III	CIII/II.2
Maxilla						
U1-NA	1.000	<0.001	0.871	<0.001	1.000	<0.001
U1/NA	0.318	<0.001	0.084	<0.001	0.955	<0.001
U1/SN	0.001	<0.001	0.487	<0.001	0.206	<0.001
U1/PP	0.003	<0.001	0.951	<0.001	0.192	<0.001
Mandible						
L1-NB	0.132	0.439	1.000	<0.001	0.003	1.000
L1/NB	0.032	1.000	0.146	<0.001	<0.001	1.000
L1/MP	0.007	0.240	0.002	1.000	<0.001	<0.001

Table IV.36.a. Measurements of interdental relationship in adult males

	Class I		Class II				Class III		Total	
			Division 1		Division 2					
Variables	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
OJ (mm)	2.59	1.11	6.63	1.61	2.88	0.78	-3.58	4.00	2.34	4.43
OB (mm)	1.72	1.35	3.71	2.24	5.76	1.18	-0.45	3.28	2.68	3.15
U1/L1 (˚)	130.44	7.82	116.67	10.19	143.95	10.36	137.87	9.18	131.09	14.14

Table IV.36.b. p-values of corresponding MANOVA or independent t tests for interdental relationship in adult males

	CI/ II.1	CI/II.2	CI/III	CII.1/II.2	CII.1/III	CIII/II.2
OJ	<0.001	0.407	<0.001	<0.001	<0.001	<0.001
OB	0.018	<0.001	0.102	0.012	<0.001	<0.001
U1/L1	<0.001	0.001	0.157	<0.001	<0.001	0.401

Table IV.37.a. Mean and standard deviation for all variables in all Class II division 2 subtypes

Class II division 2 subtypes										
Descriptive	**1A**		**1B**		**2A**		**2B**		**Total**	
Sample size	**9**		**28**		**9**		**23**		**69**	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Age	21.02	5.18	22.37	12.38	17.64	7.48	22.86	25.81	21.72	16.78
Cranial base										
SN	67.85	3.10	65.72	6.37	68.52	4.05	66.26	3.60	66.58	4.90
SN/H	11.38	3.39	13.06	4.57	9.26	3.23	10.07	2.74	11.35	3.94
SN-Ar	127.86	4.30	127.15	5.71	125.95	5.73	127.47	3.67	127.21	4.85
S-Ar	32.79	3.87	30.33	3.84	34.25	3.34	31.30	3.08	31.52	3.72
Intermaxillary relationship										
ANB	4.61	1.68	5.28	2.39	2.87	2.02	3.183	1.86	4.194	2.28
PP/MP	15.78	2.47	24.59	3.48	14.20	5.10	22.72	3.43	21.30	5.34
LFH/TFH	52.42	2.54	54.55	1.92	52.65	1.87	53.85	1.87	53.75	2.13
Relationship jaws/cranial base/Horizontal										
SNA	81.73	3.01	81.05	3.77	82.94	4.14	80.53	3.92	81.23	3.76
SNB	77.10	2.94	75.78	3.87	80.10	4.44	77.34	2.82	77.04	3.69
PP/H	-0.77	2.83	-3.25	2.73	0.84	3.65	-1.35	2.29	-1.73	3.03
MP/H	20.15	3.63	27.95	4.78	17.82	5.40	25.12	4.26	24.54	5.77
MP/SN	27.15	3.63	34.95	4.78	24.82	5.40	32.12	4.26	31.54	5.77
Jaw specific measurements										
Go-Pog	69.16	3.83	66.50	7.59	73.07	8.55	68.85	5.42	68.51	6.81
ANS-PNS	51.06	2.56	49.89	5.01	52.25	4.07	49.15	3.16	50.13	4.08
Ar-Go	47.30	5.95	43.91	6.04	46.22	8.56	44.43	5.34	44.90	6.17
Co-Gn	110.10	4.35	108.22	12.27	111.98	10.26	110.24	5.54	109.64	9.17
Ar-Gn	106.14	5.36	103.49	11.65	107.53	9.36	105.66	5.62	105.12	8.86
Go-Me	66.43	3.88	62.22	7.73	67.66	8.56	65.22	8.25	64.54	7.68
Go-B	67.81	3.13	65.33	7.05	71.08	6.43	66.81	5.16	66.93	6.09
Co-Go	57.09	5.73	53.27	6.94	56.70	9.32	54.07	5.10	54.56	6.61
B-Pog	11.47	1.98	10.89	2.15	10.53	2.46	10.74	2.49	10.89	2.25
Ar-Go-Me	119.27	3.31	123.99	5.31	119.91	6.80	118.95	23.92	121.11	14.25
Co-Go-Me	112.78	3.41	118.09	4.64	113.26	6.70	117.76	4.80	116.55	5.23
R-A	52.22	3.94	49.78	4.77	50.85	6.18	48.46	4.05	49.87	4.71
R-B	49.37	3.11	47.88	4.57	52.01	4.17	48.19	3.36	48.73	4.10
R-L1	48.03	3.49	47.12	4.71	51.13	5.79	47.35	3.99	47.84	4.56
ASA	20.18	5.75	11.64	7.80	31.60	41.88	14.15	8.52	16.31	17.15
Relationship jaws and teeth										
U1-NA	-1.27	2.15	-0.83	2.02	2.41	1.24	2.18	1.42	0.48	2.38
U1/NA	7.74	3.05	7.55	3.07	17.12	3.86	16.31	3.37	11.63	5.51
U1/SN	87.45	6.19	87.14	6.94	100.07	5.40	96.84	3.87	91.97	7.80
U1/PP	90.06	5.88	96.94	5.92	110.18	5.35	105.57	4.28	101.59	7.27
L1-NB	1.88	2.00	4.09	2.33	2.93	2.75	3.15	2.03	3.29	2.33
L1-NB	17.66	6.41	23.42	7.10	21.88	9.19	22.23	6.52	21.95	7.22
L1-MP	93.38	5.61	92.93	8.05	96.98	10.68	92.77	7.92	93.46	8.01
Relationship between teeth										
U1/L1	151.98	8.45	144.96	8.83	138.13	11.19	137.08	10.33	142.63	10.80
OJ	2.75	0.50	2.93	0.76	3.36	0.93	3.24	0.69	3.06	0.74
OB	5.82	1.73	5.04	1.02	5.40	0.75	5.30	1.00	5.29	1.13

Table IV.37.b. p-values for differences among Class II division 2 subtypes

	1A/1B	1A/2A	1A/2B	1B/2A	1B/2B	2A/2B
Age	1.000	1.000	1.000	1.000	1.000	1.000
Gender	0.853	1.000	1.000	1.000	1.000	1.000
Cranial base						
SN	1.000	1.000	1.000	0.845	1.000	1.000
SN/H	1.000	1.000	1.000	0.059	0.035	1.000
SN-Ar	1.000	1.000	1.000	1.000	1.000	1.000
S-Ar	0.341	1.000	1.000	0.033	1.000	0.229
Intermaxillary relationship						
ANB	1.000	0.409	0.391	0.022	0.004	1.000
PP/MP	<0.001	1.000	<0.001	<0.001	0.405	<0.001
LFH/TFH	0.024	1.000	0.338	0.096	1.000	0.796
Relationship jaws/cranial base/Horizontal						
SNA	1.000	1.000	1.000	1.000	1.000	0.656
ANS-PNS	1.000	1.000	1.000	0.797	1.000	0.334
PP/H	0.081	1.000	1.000	0.001	0.099	0.275
SNB	1.000	0.370	1.000	0.012	0.707	0.302
MP/H	<0.001	1.000	0.024	<0.001	0.182	0.001
MP/SN	<0.001	1.000	0.024	<0.001	0.182	<0.001
Jaw specific measurements						
Go-Pog	1.000	1.000	1.000	0.071	1.000	0.657
Ar-Go	0.76	1.000	1.000	1.000	1.000	1.000
Co-Gn	1.000	1.000	1.000	1.000	1.000	1.000
Ar-Gn	1.000	1.000	1.000	1.000	1.000	1.000
Go-Me	0.741	1.000	1.000	0.393	1.000	1.000
Go-B	1.000	1.000	1.000	0.083	1.000	0.430
Co-Go	0.650	1.000	1.000	1.000	1.000	1.000
B-Pog	1.000	1.000	1.000	1.000	1.000	1.000
Ar-Go-Me	1.000	1.000	1.000	1.000	1.000	1.000
Co-Go-Me	0.018	1.000	0.039	0.068	1.000	0.126
R-A	0.858	1.000	1.000	1.000	1.000	1.000
R-B	1.000	0.859	1.000	0.050	1.000	0.102
R-L1	1.000	0.770	1.000	0.134	1.000	0.211
Relationship jaws and teeth						
U1-NA	1.000	<0.001	<0.001	<0.001	<0.001	1.000
U1/NA	1.000	<0.001	<0.001	<0.001	<0.001	1.000
U1/SN	1.000	<0.001	<0.001	<0.001	<0.001	0.961
U1/PP	1.000	<0.001	0.002	<0.001	<0.001	0.194
L1-NB	0.045	1.000	0.762	1.000	0.866	1.000
L1-NB	0.156	1.000	1.000	1.000	1.000	1.000
L1-MP	1.000	1.000	1.000	1.000	1.000	1.000
Relationship between teeth						
U1/L1	0.264	0.012	<0.001	0.405	0.029	1.000
OJ	1.000	0.401	0.420	0.753	0.777	1.000
OB	0.333	1.000	1.000	1.000	1.000	1.000
ASA	0.120	0.380	0.252	0.192	0.278	0.249

Table IV.38. Teeth agenesis distribution in total sample

Malocclusion	Suspected %	Ascertained %	Ascertained excluding 3rd molars	Ascertained only missing 3rd molars
Class I	16.66 %	12.65 %	5.61%	5.61%
Class II.1	12.30 %	7.05 %	1.17%	5.88%
Class II.2	22.66 %	20.95%	17.38%	2.89%
Class III	20%	17.72 %	15.18%	2.53%

Table IV.39.a. Frequency distribution in different malocclusions of Co-Gn greater than the mean and beyond 1SD of the mean Co-Gn of Class I corresponding group

Mandibular length Co-Gn	Total Adult group		Adult male		Adult female	
Malocclusion	Greater than the Class I Mean>114.3	Beyond 1 SD > 133.59 (SD: 19.29)	Greater than the Class I Mean>122.28	Beyond 1 SD > 128.63 (SD: 6.35)	Greater than the Class I Mean>113.3	Beyond 1 SD > 120.39 (SD: 7.0)
Class I	69.44%	0%	50%	12.5%	65%	9.52%
Class II,1	24.4 %	0%	18.18%	0%	26.08%	4.34%
Class II,2	33.33 %	2.77%	18.75%	12.5%	15%	5%
Class III	80 %	13.88%	83.83%	72.22%	61.11%	38.88%
	Total Growing group		**Growing male**		**Growing female**	
Malocclusion	Greater than the Class I Mean>106.79	Beyond 1 SD > 116.37 (SD 9.58)	Greater than the Class I Mean>110.11	Beyond 1 SD > 120.48 (SD: 10.37)	Greater than the Class I Mean>104.0	Beyond 1 SD > 112.23 (SD: 8.23)
Class I	43.39%	16.98%	40.90%	22.72%	51.61%	16.12%
Class II,1	32.5%	10%	26.31%	5.26%	38.09%	4.76%
Class II,2	54.54%	6.06%	25%	6.25%	70.58%	11.76%
Class III	51.16%	25.58%	48%	36%	44.44%	11.11%

Table IV.39.b. Frequency distribution in different malocclusions of R-B greater than the mean and beyond 1SD of the mean R-B of Class I corresponding group

Alveolar length (RB)	Total Adult group		Adult male		Adult female	
Malocclusion	Greater than the Class I Mean>53.06	Beyond 1 SD > 57.54 (SD:4.48)	Greater than the Class I Mean>54.28	Beyond 1 SD > 59.35 (SD: 5.07)	Greater than the Class I Mean>52.08	Beyond 1 SD > 55.87 (SD:3.79)
Class I	47.22%	19.44%	43.75%	18.75%	60%	15%
Class II,1	28.88%	6.66%	27.27%	4.54%	13.04%	0%
Class II,2	22.22%	2.77%	12.5%	6.25%	10%	0%
Class III	66.66%	38.88%	83.33%	61.11%	61.11%	27.77%
	Total Growing group		**Growing male**		**Growing female**	
Malocclusion	Greater than the Class I Mean>49.10	Beyond 1 SD > 52.94 (SD:3.84)	Greater than the Class I Mean>50.08	Beyond 1 SD > 54.27 (SD: 4.19)	Greater than the Class I Mean>48.41	Beyond 1 SD > 51.88 (SD: 3.47)
Class I	49.05%	15.09%	31.81%	18.18%	51.61%	12.90%
Class II,1	20%	2.5%	26.31%	0%	9.52%	4.76%
Class II,2	45.45%	0%	33.33%	0%	70.58%	5.88%
Class III	55.81%	27.90%	68%	40%	44.44%	11.11%

Table IV.40.a. Distribution of mandibular length (Co-Gn) in Class II division 2 compared with other malocclusions in the total sample (Cut-off at 1SD of Class I mean)

	<1 SD of CI Co-Gn <100.76	**CI Co-Gn ±1SD** 111.07±10.31	**> 1 SD of CI Co-Gn** >121.38
N=69	5	58	6
%	7.24%	84.05%	8..69%
ANB	5.8˚± 2.3	3.9˚± 2.2	4.8˚± 2.03
SNA	78.7˚± 3.8	81.2˚± 3.6	84.7˚± 4.00
SNB	72.9˚± 3.8	77.3˚± 3.00	79.8˚± 5.44
B-Pog	8.6 mm ± 2.7	10.9 mm ± 2.1	13.4 mm ±1.93

Table IV.40.b. Distribution of mandibular length (Co-Gn) in Class II division 2 compared with other malocclusions in the total sample (cut-off at ½ SD of Class I mean)

	Comparable to CII.1 Co-Gn < 105.92	**Comparable to CI** Co-Gn ± ½ SD= 105.92±5.155	**Comparable to CIII** Co-Gn > 116.22
N=69	19	39	11
%	27.53%	56.52%	15.94%
ANB	4.6˚ ± 2.10	3.8˚ ± 2.40	4.6˚ ± 1.6
SNA	79.2˚ ± 3.60	81.8˚ ± 3.60	83.2˚ ± 3.43
SNB	74.6˚ ± 3.50	78.0˚ ± 2.90	78.6˚ ± 4.11
B-Pog	9.5 mm ± 1.70	10.9 mm ±2.10	13.4 mm ±1.64

Table IV.41.a. Distribution of mandibular length (Co-Gn) in Class II division 2 compared with other malocclusions in growing subjects (Cut-off at 1SD of growing Class I mean)

	<1 SD of I Co-Gn < 97.21	**CI Co-Gn ±1SD** 116.79±9.58	**> 1 SD of CI Co-Gn** >116.37
N=33	4	33	1
%	10.52%	86.84%	2.63%
ANB	5.8˚± 2.6	3.4˚± 1.69	2.8˚
SNA	78.6˚± 4.4	80.9˚± 3.85	84.4˚
SNB	72.9˚± 5.4	77.5˚± 3.43	81.6˚
B-Pog	9.1 mm ± 2.8	9.8 mm ± 1.70	11.6 mm

Table IV.41.b. Distribution of mandibular length (Co-Gn) in Class II division 2 compared with other malocclusions in growing subjects (Cut-off at ½SD of growing Class I mean)

	Comparable to CII.1 Co-Gn <102	**Comparable to CI** Co-Gn ± ½ SD= 116.79±4.79	**Comparable to CIII** Co-Gn >111.58
N=33	8	19	6
%	24.24%	57.57%	18.18%
ANB	4.8˚± 2.3	3.4˚± 1.6	2.9˚± 1.97
SNA	78.1˚± 3.7	81.6˚± 4	81.5˚± 2.36
SNB	73.3˚± 3.9	78.2˚± 3.5	78.6˚± 2.17
B-Pog	8.7 mm ± 2.00	9.7 mm ± 1.3	11.4 mm±2.12

Table IV.42.a. Distribution of mandibular length (Co-Gn) in Class II division 2 compared with other malocclusions in adults (Cut-off at 1SD of adults Class I mean)

	<1 SD of Class I Co-Gn <109.14	**Class I Co-Gn ±1SD** 117.20±8.06	**> 1 SD of Class I Co-Gn** >121.23
N=36	11	20	5
%	30.55%	55.55%	13.88%
ANB	4.8˚± 2.4	4.3˚± 2.5	5.2˚± 1.97
SNA	80.7˚± 3.0	81.7˚± 3.6	84.7˚± 4.47
SNB	75.9˚± 3.3	77.4˚± 2.3	79.5˚± 6.00
B-Pog	10.6 mm ± 1.3	12.2 mm ± 3.0	13.7 mm ± 1.92

Table IV.42.b. Distribution of mandibular length (Co-Gn) in Class II division 2 compared with other malocclusions in adults (Cut-off at ½SD of adults Class I mean)

	Comparable to Class II.1 Co-Gn < 113.17	**Comparable to Class I** Co-Gn ± ½ SD= 117.20±4.03	**Comparable to Class III** Co-Gn >121.23
N= 36	22	9	5
%	61.11%	25%	13.88%
ANB	4.8˚ ± 2.70	3.6˚± 1.50	5.2˚ ± 1.97
SNA	81.3˚ ± 3.90	81.4˚± 1.80	84.7˚± 4.47
SNB	76.5˚ ± 3.00	77.9˚± 1.50	79.5˚ ± 6.00
B-Pog	11 mm ± 2.10	13.2 mm ± 1.40	13.7 mm ± 1.92

Table IV.43. Correlations among mandibular variables in malocclusion groups

Between		Class I		Class II				Class III	
				Division 1		Division 2			
		Coefficient	p	Coef.	p	Coef.	p	Coef.	p
Co-Gn	B-Pog	0.555	<0.001	0.477	<0.001	0.594	<0.001	0.681	<0.001
	Ar-Gn	0.980	<0.001	0.644	<0.001	0.984	<0.001	0.797	<0.001
	Go-Me	0.847	<0.001	0.846	<0.001	0.801	<0.001	0.911	<0.001
	Go-B	0.672	<0.001	0.831	<0.001	0.853	<0.001	0.863	<0.001
	Go-Pog	0.720	<0.001	0.507	<0.001	0.837	<0.001	0.833	<0.001
	Ar-Go	0.819	<0.001	0.814	<0.001	0.715	<0.001	0.817	<0.001
	R-B	0.789	<0.001	0.727	<0.001	0.701	<0.001	0.837	<0.001
	R-L1	0.824	<0.001	0.718	<0.001	0.639	<0.001	0.537	<0.001
	Ar-Go-Me	-0.101	0.346	-0.155	0.156	-0.015	0.902	0.219	0.053
	U1/NA	-0.067	0.530	0.335	0.002	0.048	0.690	0.207	0.067
SNB	MP/SN	-0.684	<0.001	-0.658	<0.001	-0.652	<0.001	-0.496	<0.001
	PP/MP	-0.455	<0.001	-0.552	<0.001	-0.415	<0.001	-0.165	0.146
	Co-Go	0.472	<0.001	0.484	<0.001	0.278	0.019	0.535	<0.001
	Co-Gn	0.484	<0.001	0.516	<0.001	0.337	0.004	0.529	<0.001
	Ar-Gn	0.511	<0.001	0.346	0.001	0.310	0.009	0.386	<0.001
	Go-Me	0.435	<0.001	0.490	<0.001	0.370	0.001	0.481	<0.001
	Go-B	0.339	<0.001	0.566	<0.001	0.451	<0.001	0.502	<0.001
	Go-Pog	0.416	<0.001	0.332	0.002	0.436	<0.001	0.496	<0.001
	Ar-Go	0.495	<0.001	0.540	<0.001	0.184	0.125	0.501	<0.001
	R-B	0.361	<0.001	0.510	<0.001	0.426	<0.001	0.508	<0.001
	R-L1	0.364	<0.001	0.529	<0.001	0.327	0.005	0.270	<0.001
Co-Go	Co-Gn	0.873	<0.001	0.831	<0.001	0.813	<0.001	0.881	<0.001
	Ar-Gn	0.843	<0.001	0.459	<0.001	0.826	<0.001	0.726	<0.001
	Go-Me	0.649	<0.001	0.692	<0.001	0.626	<0.001	0.736	<0.001
	Go-B	0.482	<0.001	0.473	<0.001	**0.682**	<0.001	**0.714**	<0.001
	Go-Pog	0.569	<0.001	0.442	<0.001	0.789	<0.001	0.753	<0.001
	Ar-Go	0.936	<0.001	0.954	<0.001	0.956	<0.001	0.954	<0.001
	R-B	0.644	<0.001	0.616	<0.001	0.616	<0.001	0.722	<0.001
	R-L1	0.712	<0.001	0.682	<0.001	0.613	<0.001	0.462	<0.001
	B-Pog	0.480	<0.001	0.379	<0.001	**0.603**	<0.001	**0.650**	<0.001
Go-Pog	Ar-Go	0.492	<0.001	0.450	<0.001	0.723	<0.001	0.698	<0.001
	R-B	0.597	<0.001	0.405	<0.001	0.708	<0.001	0.683	<0.001
	R-L1	0.693	<0.001	0.479	<0.001	0.683	<0.001	0.629	<0.001
	B-Pog	0.470	<0.001	0.266	0.014	0.468	<0.001	0.602	<0.001
R-B	R-L1	0.887	<0.001	0.915	0.001	0.893	<0.001	0.592	<0.001

Table IV.44.a. Bivariate logistic regression for Class II division 2 with Class I malocclusion as a reference

Independent variables	Unadjusted Odds Ratio (OR)	Confidence interval (CI) for unadjusted OR	p-value
SN (mm)	1.06	(1.001 , 1.143)	0.046
SN/H (˚)	1.02	(0.943 , 1.111)	0.571
SN-Ar (˚)	1.10	(1.034 , 1.179)	0.003
S-Ar (mm)	1.03	(0.947 , 1.123)	0.470
ANB (˚)	2.43	(1.800 , 3.297)	<0.001
PP/MP (˚)	0.82	(0.759 , 0.886)	<0.001
LFH/TFH (%)	0.73	(0.628 , 0.857)	<0.001
SNA (˚)	1.09	(0.999 , 1.194)	0.050
ANS-PNS (mm)	1.15	(1.065 , 1.257)	0.001
PP/H (˚)	0.98	(0.897 , 1.077)	0.716
SNB (˚)	0.92	(0.844 , 1.007)	0.074
MP/H (˚)	0.83	(0.777 , 0.899)	<0.001
MP/SN (˚)	0.83	(0.777 , 0.899)	<0.001
Go-Pog (mm)	1.02	(0.980 , 1.075)	0.256
Ar-Go(mm)	1.06	(1.013 , 1.127)	0.014
Co-Gn (mm)	0.98	(0.954 , 1.018)	0.389
Ar-Gn (mm)	0.99	(0.963 , 1.029)	0.811
Go-Me (mm)	1.02	(0.982 , 1.078)	0.223
Go-B (mm)	1.04	(0.988 , 1.094)	0.131
Co-Go (mm)	1.05	(1.002 , 1.102)	1.102
B-Pog (mm)	1.12	(0.978 , 1.282)	0.101
Ar-Go-Me (˚)	0.77	(0.706 , 0.843)	<0.001
Co-Go-Me (˚)	0.75	(0.688 , 0.829)	<0.001
R-A (mm)	1.19	(1.101 , 1.291)	<0.001
R-B (mm)	0.89	(0.829 , 0.970)	0.007
R-L1 (mm)	0.98	(0.919 , 1.051)	0.627
U1-NA (mm)	0.38	(0.282 , 0.518)	<0.001
U1/NA (˚)	0.67	(0.602 , 0.764)	<0.001
U1/SN (˚)	0.76	(0.708 , 0.832)	<0.001
U1/PP (˚)	0.77	(0.716 , 0.835)	<0.001
L1-NB (mm)	0.71	(0.608 , 0.848)	<0.001
L1/NB (˚)	0.90	(0.858 , 0.954)	<0.001
L1/MP (˚)	1.04	(1.000 , 1.089)	0.048
U1/L1 (˚)	1.16	(1.106 , 1.216)	<0.001
OJ (mm)	1.54	(1.158 , 2.048)	0.003
OB (mm)	119.80	(9.546 , 1503.528)	<0.001
ASA (˚)	1.12	(1.072 , 1.176)	<0.001
Age	1.02	(0.995 , 1.055)	0.102
Gender	1.10	(0.587 , 2.064)	0.764
Missing teeth	1.53	(0.600 , 3.940)	0.369

Table IV.44.b. Model 1 of the multivariate logistic regression for Class II division 2 with Class I malocclusion as a reference

Independent variables	**OR**	**CI**	**p-value**
SN	1.19	(0.790 , 1.796)	0.401
SN-Ar	1.42	(1.092 , 1.865)	0.009
ANB	0.75	(0.166 , 3.444)	0.718
PP/MP	1.11	(0.811 , 1.518)	0.514
LFH/TFH	0.76	(0.394 , 1.493)	0.436
SNA	0.76	(0.490 , 1.184)	0.228
ANS-PNS	1.06	(0.665 , 1.697)	0.798
MP/H	0.51	(0.311 , 0.861)	0.011
Co-Go	0.91	(0.705 , 1.180)	0.487
B-Pog	1.96	(1.027 , 3.737)	0.041
Co-Go-Me	0.84	(0.656 , 1.092)	0.201
R-A	0.67	(0.423 , 1.083)	0.104
U1-NA	0.20	(0.047 , 0.911)	0.037
L1-NB	4.01	(1.065 , 15.155)	0.040
U1/L1	1.27	(1.083 , 1.504)	0.004
OJ	4.51	(1.225 , 16.647)	0.023

Table IV.44.c. Model 2 for multivariate logistic regression for Class II division 2 with Class I malocclusion as a reference

Independent variables (Model)	**OR**	**CI**	**p-value**
SN-Ar	1.40	(1.078 , 1.843)	0.012
ANB	0.98	(0.415 , 2.323)	0.962
SNB	1.21	(0.793 , 1.849)	0.375
PP/MP	0.70	(0.507 , 0.969)	0.032
ANS-PNS	1.71	(1.091 , 2.689)	0.019
R-B	0.43	(0.210 , 0.880)	0.021
B-Pog	1.39	(0.859 , 2.276)	0.176
ASA	1.14	(1.007 , 1.310)	0.038
U1/NA	0.59	(0.427 , 0.833)	0.002
L1/NB	0.89	(0.711 , 1.118)	0.324
OJ	1.50	(0.708 , 3.182)	0.288

Table IV.44.d. Model 3 for multivariate logistic regression for Class II division 2 with Class I malocclusion as a reference

Independent variables (model including Go-B)	**OR**	**CI**	**p-value**
SN-Ar	1.40	(1.064 , 1.864)	0.017
ANB	1.00	(0.416, 2.407)	0.997
SNB	1.17	(0.745 , 1.846)	0.491
PP/MP	0.71	(0.508 , 0.991)	0.044
ANS-PNS	1.52	(0.944 , 2.471)	0.084
R-B	0.41	(0.196 , 0.857)	0.018
B-Pog	1.34	(0.806 , 2.249)	0.255
ASA	1.15	(1.014 , 1.318)	0.030
U1/NA (˚)	0.58	(0.413 , 0.825)	0.002
L1-NB (˚)	0.88	(0.688 , 1.126)	0.311
OJ	1.61	(0.731 , 3.555)	0.236
Go-B	1.16	(0.919 , 1.476)	0.205

Table IV.45.a. Bivariate logistic regression for Class II division 2 with Class II division 1 malocclusion as a reference

Independent variables	Unadjusted OR	CI for unadjusted OR	p-value
SN (mm)	1.03	(0.966 , 1.110)	0.317
SN/H (˚)	0.94	(0.870 , 1.028)	0.193
SN-Ar (˚)	1.05	(0.982 , 1.123)	0.147
S-Ar (mm)	1.04	(0.959 , 1.138)	0.313
ANB (˚)	0.54	(0.433 , 0.687)	<0.001
PP/MP (˚)	0.81	(0.751 , 0.875)	<0.001
LFH/TFH (%)	0.70	(0.604 , 0.824)	<0.001
SNA (˚)	0.91	(0.833 , 1.000)	0.052
ANS-PNS (mm)	1.00	(0.937 , 1.086)	0.816
PP/H (˚)	1.14	(1.043 , 1.251)	0.004
SNB (˚)	1.08	(0.990 , 1.183)	0.082
MP/H (˚)	0.86	(0.807 , 0.918)	<0.001
MP/SN (˚)	0.86	(0.807 , 0.918)	<0.001
Go-Pog (mm)	1.06	(1.018 , 1.122)	0.007
Ar-Go(mm)	1.06	(1.006 , 1.122)	0.028
Co-Gn (mm)	1.01	(0.980 , 1.049)	0.411
Ar-Gn (mm)	1.02	(0.990 , 1.056)	0.169
Go-Me (mm)	1.08	(1.029 , 1.148)	0.00
Go-B (mm)	1.05	(0.995 , 1.113)	0.073
Co-Go (mm)	1.06	(1.009 , 1.115)	0.019
B-Pog (mm)	0.91	(0.786 , 1.055)	0.216
Ar-Go-Me (˚)	0.84	(0.792 , 0.908)	<0.001
Co-Go-Me (˚)	0.84	(0.782 , 0.903)	<0.001
R-A (mm)	1.03	(0.960 , 1.104)	0.406
R-B (mm)	1.01	(0.946 , 1.093)	0.640
R-L1 (mm)	0.95	(0.894 , 1.020)	0.178
U1-NA (mm)	0.29	(0.207 , 0.427)	<0.001
U1/NA (˚)	0.70	(0.630 , 0.783)	<0.001
U1/SN (˚)	0.71	(0.643 , 0.798)	<0.001
U1/PP (˚)	0.71	(0.645 , 0.797)	<0.001
L1-NB (mm)	0.55	(0.459 , 0.670)	<0.001
L1/NB (˚)	0.82	(0.771 , 0.879)	<0.001
L1/MP (˚)	0.93	(0.890 , 0.974)	0.002
U1/L1 (˚)	1.28	(1.184 , 1.400)	<0.001
OJ (mm)	0.01	(0.002 , 0.096)	<0.001
OB (mm)	2.70	(1.928 , 3.795)	<0.001
ASA (˚)	1.14	(1.090 , 1.207)	<0.001
Age	1.02	(0.993 , 1.062)	0.113
Gender	0.88	(0.467 , 1.656)	0.693
Missing teeth	3.01	(1.066 , 8.519)	0.037

Table IV.45.b. Model 1 for multivariate logistic regression for Class II division 2 with Class II division 1 malocclusion as a reference

Independent variables	OR	CI	p-value
SN/H	1.47	(0.565 , 3.869)	0.425
SN-Ar	1.08	(0.910 , 1.290)	0.364
ANB	0.22	(0.179 , 2.868)	0.252
PP/MP	1.36	(0.559 , 3.347)	0.492
LFH/TFH	1.15	(0.751 , 1.780)	0.508
SNA	2.45	(0.186 , 32.236)	0.494
PP/H	1.86	(0.748 , 4.656)	0.181
MP/H	1.75	(0.126 , 24.303)	0.676
Ar-Gn	1.25	(0.848 , 1.870)	0.253
Go-Me	0.98	(0.758 , 1.276)	0.902
Go-B	0.78	(0.533 , 1.149)	0.211
Co-Go	0.83	(0.577 , 1.220)	0.359
Ar-Go-Me	0.63	(0.407 , 0.991)	0.046
Co-Go-Me	1.07	(0.704 , 1.654)	0.725
R-L1	0.86	(0.673 , 1.110)	0.255
L1-NB	1.02	(0.491 , 2.124)	0.954
L1/NB	0.46	(0.033 , 6.487)	0.572
L1/MP	2.12	(0.157 , 28.855)	0.570
OB	2.65	(1.494 , 4.723)	0.001
ASA	1.01	(0.969 , 1.061)	0.532
Age	1.04	(0.953 , 1.145)	0.342
Missing teeth	1.74	(0.217 , 14.068)	0.600

Table IV.45.c. Model 2 for multivariate logistic regression for Class II division 2 with Class II division 1 malocclusion as a reference

Independent variables (model)	OR	CI	p-value
ANB	0.06	(0.003 , 1.453)	0.086
PP/MP	0.94	(0.524 , 1.689)	0.840
SNB	1.82	(0.591 , 5.657)	0.294
U1/NA	0.13	(0.006 , 2.786)	0.193
L1/NB	0.64	(0.162 , 2.520)	0.524
ASA	1.48	(0.764 , 2.903)	0.242

Table IV.46.a. Bivariate logistic regression for Class II division 2 with Class III malocclusion as a reference

Independent variables	Unadjusted OR	CI for unadjusted OR	p-value
SN	1.07	(1.005 , 1.142)	0.033
SN/H	1.06	(0.984 , 1.143)	0.119
SN-Ar	1.11	(1.048 , 1.186)	0.001
S-Ar	1.05	(0.974 , 1.144)	0.185
PP/MP	0.84	(0.789 , 0.908)	<0.001
LFH/TFH	0.72	(0.627 , 0.847)	<0.001
SNA	1.20	(1.094 , 1.322)	<0.001
ANS-PNS	1.22	(1.130 , 1.336)	<0.001
PP/H	0.94	(0.863 , 1.045)	0.293
SNB	0.76	(0.692 , 0.853)	<0.001
MP/H	0.89	(0.838 , 0.944)	<0.001
MP/SN	0.89	(0.838 , 0.944)	<0.001
Go-Pog	0.96	(0.930 , 1.008)	0.121
Ar-Go	0.99	(0.951 , 1.044)	0.903
Co-Gn	0.96	(0.936 , 0.987)	0.004
Ar-Gn	0.97	(0.949 , 0.997)	0.030
Go-Me	0.97	(0.939 , 1.013)	0.213
Go-B	0.98	(0.938 , 1.026)	0.411
Co-Go	1.02	(0.978 , 1.066)	0.337
B-Pog	0.95	(0.842 , 1.077)	0.442
Ar-Go-Me	0.76	(0.701 , 0.841)	<0.001
Co-Go-Me	0.74	(0.675 , 0.822)	<0.001
R-A	1.38	(1.244 , 1.533)	<0.001
R-B	0.83	(0.768 , 0.901)	<0.001
R-L1	0.97	(0.926 , 1.027)	0.351
U1-NA	0.38	(0.284 , 0.523)	<0.001
U1/NA	0.69	(0.615 , 0.778)	<0.001
U1/SN	0.75	(0.696 , 0.826)	<0.001
U1/PP	0.74	(0.687 , 0.817)	<0.001
L1-NB	1.00	(0.870 , 1.155)	0.967
L1-NB	1.04	(0.996 , 1.100)	0.066
L1-MP	1.19	(1.129 , 1.273)	<0.001
U1/L1	1.07	(1.039 , 1.115)	<0.001
OJ	21.76	(5.973 , 79.303)	<0.001
OB	10.77	(3.581 , 32.435)	<0.001
ASA	1.07	(1.026 , 1.120)	0.002
Age	1.03	(1.001 , 1.076)	0.043
Gender	0.68	(0.360 , 1.307)	0.253
Missing teeth	0.96	(0.411 , 2.281)	0.942

Table IV.46.b. Model 1 for multivariate logistic regression for Class II division 2 with Class III malocclusion as a reference

Dependent variables	OR	CI	p value
SN	0.92	(0.501 , 1.702)	0.799
SN/H	0.74	(0.393 , 1.427)	0.380
SN-Ar	1.15	(0.793 , 1.689)	0.446
PP/MP	0.74	(0.405 , 1.385)	0.358
LFH/TFH	0.48	(0.203 , 1.147)	0.099
SNA	1.13	(0.475 , 2.710)	0.774
ANS-PNS	4.09	(1.432 , 11.720)	0.009
Go-Pog	0.75	(0.496 , 1.162)	0.206
Co-Gn	0.85	(0.590 , 1.229)	0.392
Ar-Gn	0.91	(0.788 , 1.063)	0.248
U1-NA	0.30	(0.121 , 0.780)	0.013
L1/MP	1.18	(0.870 , 1.623)	0.277

Table IV.46.c. Model 2 for multivariate logistic regression for Class II division 2 with Class III malocclusion as a reference

Independent variables (model)	OR	CI	p-value
Co-Gn	0.84	(0.618 , 1.165)	0.310
SN-Ar	0.91	(0.657 , 1.286)	0.625
PP/MP	0.99	(0.708 , 1.391)	0.966
ANS-PNS	2.24	(1.154 , 4.377)	0.017
R-B	0.94	(0.514 , 1.737)	0.856
SNB	0.77	(0.463 , 1.310)	0.347
B-Pog	0.64	(0.310 , 1.343)	0.242
ASA	1.37	(0.921 , 2.046)	0.119
U1/NA	0.63	(0.415 , 0.965)	0.034
L1/NB	1.16	(0.903 , 1.504)	0.239

Table IV.47.a. Bivariate linear regression for the outcome mandibular length (Co-Gn)

Co-Gn	coefficient	CI	p-value
SN-Ar	-0.311	(-0.543, -0.079)	0.009
ANB	-1.038	(-1.355 , -0.722)	<0.001
PP/MP	0.017	(-0.189 , 0.225)	0.867
SNB	1.455	(1.198 , 1.712)	<0.001
R-B	1.807	(1.654 , 1.960)	<0.001
B-Pog	2.760	(2.325 , 3.196)	<0.001
ASA	0.133	(0.018 , 0.247)	0.023
U1/NA (˚)	0.206	(0.056 , 0.355)	0.007
L1/NB (˚)	-0.216	(-0.395 , -0.044)	0.014

Table IV.47.b. Multivariate linear regression for the outcome mandibular length (Co-Gn)

Co-Gn	coefficient	CI	p-value
SN-Ar	-0.055	(-0.173 , 0.063)	0.362
ANB	-0.852	(-1.121 , -0.583)	<0.001
ANS-PNS	1.068	(0.903 , 1.233)	<0.001
SNB	0.261	(0.063 , 0.458)	0.010
U1/NA (˚)	0.009	(-0.067 , 0.086)	0.803
L1/NB (˚)	0.034	(-0.066 , 0.135)	0.498
R-B	0.790	(0.632 , 0.949)	<0.001
ASA	-0.002	(-0.054 , 0.050)	0.931
B-Pog	1.176	(0.922 , 1.430)	<0.001
Constant	-5.350	(-29.749 , 19.048)	0.666

$p<0.001$, $R^2=0.830$

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APPENDIX 1

Intra-class examiner correlation of all the variables for repeated measurements in 10% of the total sample

Variables	p-value
SN (mm)	0.941
SN/H (˚)	0.903
SN-Ar (˚)	0.967
S-Ar (mm)	0.949
ANB (˚)	0.941
PP/MP (˚)	0.971
LFH/TFH (%)	0.967
SNA (˚)	0.946
ANS-PNS (mm)	0.902
PP/H (˚)	0.893
SNB (˚)	0.903
MP/H (˚)	0.929
MP/SN (˚)	0.890
Go-Pog (mm)	0.927
Ar-Go(mm)	0.967
Co-Gn (mm)	0.954
Ar-Gn (mm)	0.971
Go-Me (mm)	0.952
Go-B (mm)	0.945
Co-Go (mm)	0.916
B-Pog (mm)	0.953
Ar-Go-Me (˚)	0.942
Co-Go-Me (˚)	0.918
R-A (mm)	0.929
R-B (mm)	0.951
R-L1 (mm)	0.957
U1-NA (mm)	0.941
U1/NA (˚)	0.971
U1/SN (˚)	0.907
U1/PP (˚)	0.915
L1-NB (mm)	0.905
L1/NB (˚)	0.918
L1/MP (˚)	0.906
U1/L1 (˚)	0.944
OJ (mm)	0.954
OB (mm)	0.913
ASA (˚)	0.962

APPENDIX 2.a

Correlations between each 2 variables of the mandibular variables in Class I (upper right) and Class II.1 (lower left):

	SNB	MP/ SN	PP/ MP	Co- Go	Co- Gn	Ar- Gn	Go- Me	Go- B	Go- Pog	Ar- Go	R-B	R- L1	B-Pog	Ar- Go- Me	Co- Go- Me	ASA	L1/ NB	L1/ MP
SNB		-0.684	-0.455	0.472	0.484	0.511	0.435	0.339	0.416	0.495	0.361	0.364	NS	NS	NS	0.251	NS	NS
MP/SN	-0.658		0.812	-0.412	NS	-0.224	-0.286	-0.289	-0.350	-0.400	NS	-0.223	NS	0.616	0.645	-0.321	NS	-0.504
PP/MP	-0.552	0.840		-0.371	NS	NS	-0.253	-0.232	-0.262	-0.335	NS	NS	NS	0.619	0.608	-0.292	NS	-0.478
Co-Go	0.484	-0.506	-0.358		0.873	0.843	0.649	0.482	0.569	0.936	0.644	0.712	0.480	-0.366	-0.323	NS	NS	NS
Co-Gn	0.516	NS	NS	0.831		0.980	0.847	0.672	0.720	0.819	0.789	0.824	0.555	NS	NS	NS	NS	NS
Ar-Gn	0.346	NS	NS	0.459	0.644		0.831	0.654	0.708	0.855	0.796	0.810	0.555	NS	NS	NS	NS	NS
Go-Me	0.490	-0.449	-0.315	0.692	0.846	0.551		0.824	0.798	0.560	0.684	0.726	0.395	-0.285	-0.273	0.278	NS	NS
Go-B	0.566	-0.530	-0.393	0.473	0.831	0.484	0.909		0.679	0.384	0.465	0.602	NS	-0.317	-0.321	NS	NS	0.210
Go-Pog	0.332	-0.345	-0.317	0.442	0.507	0.311	0.539	0.593		0.492	0.597	0.693	0.470	-0.337	-0.322	NS	NS	NS
Ar-Go	0.540	-0.524	-0.367	0.954	0.814	0.461	0.662	0.708	0.450		0.646	0.675	0.486	-0.260	-0.232	NS	NS	NS
R-B	0.510	-0.317	-0.251	0.616	0.727	0.417	0.650	0.737	0.405	0.599		0.887	0.366	NS	NS	NS	NS	NS
R-L1	0.529	-0.386	-0.281	0.682	0.718	0.425	0.612	0.745	0.479	0.673	0.915		0.372	NS	NS	NS	0.251	NS
B-Pog	NS	NS	NS	0.379	0.477	NS	0.449	0.455	0.266	0.380	0.335	0.365		NS	NS	NS	NS	NS
Ar-Go-Me	NS	0.697	0.526	-0.485	NS	NS	-0.427	-0.531	-0.266	-0.446	-0.228	-0.323	NS		0.962	-0.302	NS	-0.441
Co-Go-Me	NS	0.726	0.573	-0.435	NS	NS	-0.400	0.499	-0.280	-0.390	NS	-0.284	NS	0.968		-0.325	NS	-0.473
ASA	NS	-0.400	-0.394	0.238	0.264	0.299	0.481	0.267	0.262	0.227	NS	NS	NS	-0.229	-0.281		-0.235	NS
L1/NB	NS	NS	NS	NS	NS	NS	-0.230	NS	NS	NS	NS	0.232	NS	NS	NS	-0.420		0.791
L1/MP	NS	-0.494	-0.423	0.236	NS	NS	NS	NS	0.250	0.262	NS	0.287	NS	-0.549	-0.555	NS	0.717	

APPENDIX 2.b

Correlations between each 2 variables of the mandibular variables in Class II.2 (upper right) and Class III (lower left):

	SNB	MP/ SN	PP/ MP	Co- Go	Co- Gn	Ar- Gn	Go- Me	Go- B	Go- Pog	Ar- Go	R-B	R- L1	B-Pog	Ar- Go- Me	Co- Go- Me	ASA	L1/ NB	L1/ MP
SNB		-0.6252	-0.415	0.278	0.337	0.310	0.370	0.451	0.436	NS	0.426	0.327	NS	NS	-0.308	NS	NS	NS
MP/SN	-0.496		0.829	-0.500	-0.253	-0.288	-0.386	-0.434	-0.484	-0.491	-0.455	-0.438	NS	0.215	0.718	-0.280	0.195	-0.290
PP/MP	NS	0.795		-0.360	NS	NS	NS	-0.256	-0.282	-0.373	-0.320	-0.270	NS	0.272	0.655	-0.280	0.247	NS
Co-Go	0.535	NS	NS		0.813	0.826	0.626	0.682	0.789	0.956	0.616	0.613	0.603	NS	-0.567	NS	NS	NS
Co-Gn	0.529	NS	0.240	0.881		0.984	0.801	0.853	0.837	0.715	0.701	0.639	0.594	NS	NS	NS	NS	NS
Ar-Gn	0.386	NS	NS	0.726	0.797		0.733	0.735	0.665	0.686	0.578	0.401	0.615	NS	NS	NS	NS	NS
Go-Me	0.481	NS	NS	0.736	0.911	0.805		0.844	0.748	0.553	0.662	0.610	0.415	NS	-0.373	NS	NS	NS
Go-B	0.502	NS	NS	0.714	0.863	0.854	0.951		0.892	0.630	0.706	0.621	0.543	NS	NS	NS	NS	NS
Go-Pog	0.496	NS	NS	0.753	0.833	0.849	0.877	0.878		0.723	0.708	0.683	0.468	NS	-0.499	NS	NS	NS
Ar-Go	0.501	NS	NS	0.954	0.817	0.771	0.644	0.582	0.698		0.552	0.575	0.586	NS	-0.563	NS	NS	NS
R-B	0.508	NS	0.245	0.722	0.837	0.720	0.750	0.770	0.683	0.691		0.893	0.383	NS	-0.369	NS	NS	NS
R-L1	0.270	NS	NS	0.462	0.537	0.665	0.585	0.748	0.629	0.420	0.592		0.321	NS	-0.431	NS	0.239	0.357
B-Pog	NS	NS	0.263	0.650	0.681	0.610	0.615	0.346	0.602	0.625	0.501	0.318		NS	NS	NS	NS	NS
Ar-Go-Me	NS	0.732	0.644	NS	NS	NS	NS	NS	NS	NS	0.254	NS	NS		NS	NS	NS	NS
Co-Go-Me	NS	0.734	0.622	NS	NS	-0.257	NS	-0.478	NS	NS	0.260	NS	NS	0.981		NS	NS	-0.416
ASA	NS	NS	NS	0.247	0.232	NS	0.284	NS	0.267	0.222	NS	NS	0.248	NS	NS		NS	NS
L1/NB	NS	0.228	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-0.345		0.848
L1/MP	-0.269	-0.387	-0.447	NS	-0.385	NS	-0.253	NS	NS	NS	-0.398	NS	NS	-0.576	-0.587	NS	0.663	