

On the Comparison of Temporomandibular Joint Angle Measures, Between Angle Class I and Angle Class II

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Advisor: Professor Rudolf Slavicek

Co-Advisor: Dr. Miguel de Carvalho

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Dedication

To my lovely wife, and to her unbounded patience and support.

To my daughter Carolina, for her strength.

"Knowledge is a process of piling up facts; wisdom lies in their simplification."

- Martin H. Fischer

"I am the proudest monkey..."

- Dave Mathews Band

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All errors are, of course, my entire responsibility.

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ABSTRACT OF THESIS

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Abstract

The maturation of the temporomandibular joint occurs predominantly in the functional phases of mixed dentition, and all angle classes generally differ from each other in the mature functional phase of dentition. One problem of considerable interest is to assess where such a difference begins. In this work we study whether there are significant differences over angle class I and class II for some relevant temporomandibular joint angle measures, namely the Sagittal Condylar Inclination (SCI), the transversal condylar inclination. In this context, it was collected a sample of said measures from individuals in the first and second functional phases of mixed dentition through a computerized axiography (CADIAX), the use of an articulator, and a cephalometric analysis. This work provides evidence supporting that there is no statistical evidence to reject the null hypothesis of mean value equality of such measures between angle classes I and II.

KEYWORDS: angle class I, angle class II, axiography, Bennett movement, sagittal condylar inclination, transversal condylar inclination.

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Glossary

AxOr-P	Axisorbital Plane
CMS	Cranial Mandibular System
CNS	Central Nervous System
ICP	Intercuspal Position
RCP	Retro Contact Position
s	the inclination of tooth 1.1 relatively to the Frankfurt plane
SCI	Sagittal Condylar Inclination
$SCI_{x,y}$	Sagittal Condylar Inclination at x -mm on the y -side
TCI	Transversal Condylar Inclination
$TCI_{x,y}$	Transversal Condylar Inclination at x -mm on the y -side
TMJ	Temporomandibular Joint

Chapter 1

Introduction

The stomatognathic organ has major changes during growth, specially the articular eminence. This eminence, which is located in the temporal bone, is rather flat in early years and becomes steeper when teeth erupts and occludes. Furthermore, it works as a cavity which during maturation is functionally dependent from the dynamic occlusion. Since deciduous till permanent dentition the eminence develops continuously. It is known (see [41]) that the way the teeth occludes in permanent dentition and the inclination of functional surface of the front teeth, are relevant to the change the slope of the articular eminence during maturation, and therefore significant to Sagittal Condylar Inclination (SCI, from hereafter), where SCI is the angle measured between the Axisorbital Plane (AxOr-P) and the tangent to articular eminence of temporomandibular joint. Another measure of special importance is the Transversal Condylar Inclination (TCI), which is defined as the angle between protrusion and the physical shift of the mandible to laterotrusion side during asymmetrical movement.

Teeth are the determinants of all function of the masticatory organ, they act as interference to a free movement of the mandible. In fact, quoting Slavicek [41], “the dynamic relationship of dental arches to each other is of utmost importance for

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the diagnosis of the masticatory organ.” Front teeth’s functional surfaces play an important role in the inclination of the eminence, being the chord of the front tooth guidance, in average, steeper around 9° than the associated route distance of the condyle course tendon (see [38]). The only structure which is mature before function is the coronal portion of the tooth. On the other hand, the relationship of crowns between each other, the development of roots, skeletal development and emergence of archs are genetic influenced, and they are subject to functional conditions. This functionally adaptive processes is coordinated in the temporal-mandibular joints region in reaction to the eruption of the hard tissues. The cranial determinant of mandibular growth is the spatial position of the maxillary teeth and functions accordingly to this position. Due to this, condylar growth occurs in response to mandibular translation.

The ontogenic maturation of the masticatory organ is slow and is divided in functional periods during growth (see [41]). Before the first functional period of changing teeth the movement pattern is rather free and flat. With the eruption of hard structures as the permanent teeth, there will be functional interferences. The lingual concavity of maxillary central incisor and the eruption of the mandibular incisor, bounds and defines the protusive pattern of mandibular movement. The first permanent molars eruption, behind the deciduous alters both the lateral and retral patterns of perception of the Central Nervous System (CNS). With the input of molars and incisors a completely new morphological principle enters the system. When the molars have a normal occlusal interdigitation, their morphology will fulfill their function. On the other hand, when they occlude in a different manner, the system as a functional adaptation mechanism, will try to achieve optimal function.

Given the evolution of the mandible, the ascending branch growths and the joint gets apart from the occlusal plane. With the presence of permanent molars and incisors the articular eminence is forced to become steeper. At the same time verti-

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calization is occurring, and the muscle pattern of the mandibular movement adapts to dental morphology, to its spatial pattern, and to its inter-relationships, even when the relation between dental archs is not ideal. An important spin-off from this maturation is the stronger development and steeper slope of the Sagittal condylar track.

Lateral movements forces the anterior arch development especially in the lateral incisor region, functionally inter-dependent on molar function, and vice versa, characterizing the transversal condylar track.

In the second functional period of changing dentition, given the eruption of premolars a more inclined lateral guidance is introduced in the system. Their morphology is important in the lateral, retrusive and protusive movements of the mandible, and also in the proprioceptive retral control through their position in the arch and root morphology. The first maxillary premolar assumes dominance over the character of transversal function. At this time, the articular eminence is almost mature. The temporomandibular joint adapts to the altered functions through additional inclination of the eminence, sagittal and transversely. The buccal cusps of the first maxillary premolar as lateral gliding and guiding elements are steeper than those of the first molar, assuming laterotrusive control. Lateral incisors adjust with the mandibular anterior arch in group function to the first maxillary premolar.

It is known in the state-of-art that 51.8% of the European population is angle class II (see [42]). It is therefore important to understand and learn more about this kind of patient. Two questions arise naturally: how does the SCI and the Transversal Condylar Inclination (TCI) relate in class I and class II subjects during mixed dentition? Is there a relation between vertical growth and SCI? If so, how do they relate?

In this work we study whether there are significant differences over angle class I and class II for some relevant temporomandibular joint angle measures, namely

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the SCI, the Transversal Condylar Inclination (TCI), and the inclination of tooth 1.1 relatively to the Frankfurt plane. In this context, it was collected a sample of said measures from individuals in the first and second functional phases of mixed dentition through a computerized axiography (CADIAX), the use of an articulator, and a cephalometric analysis.

The structure of this work is as follows: in the next section we revise literature issues which are considered important to understanding and analysis of the problem we propose to approach. In Section 3 we describe the methodology used to collect the data. Analysis of the collected data set is performed in section 4, where the relevant hypothesis are stated and tested. Concluding remarks are given in section 5.

Chapter 2

Literature Background

In this chapter we introduce literature review as well as some anatomic concepts of interest to a better understanding of the problems under analysis. The controversial issue of premolars extraction *vs* non-extraction is also referred.

2.1 Historical Notes

Understanding of joint function and its development has been studied since early years. Recording joint track relative to hinge axis is a principle which is known since the beginning of the century, and has been discussed by many authors. By that time, Campion [5, 6] said that it was a recording near the joint relative to the mandibular hinge axis, and described its significance for setting articulators. Posselt [32, 33] used a mandibular position indicator to study the movement bilaterally, being able to observe condylar path inclinations and Bennett movement. Stuart system, which was the state of the art in jaw recording system by the American school, making it a true pantomography. However his attachment system altered vertical dimension during recording. An improvement was introduced by Gysi expanding records near

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the joint into transversal movements both near the joint and in front of the mouth.

McCollum [17] described the lateral pterygoid muscles as the responsible for moving the condyle against the inner wall of the fossa creating the Bennett movement. He felt that the articulating system had to have an hinge axis similar to the jaw to assure a proper reproduction of jaw movements. Afterwards, Cohen [7] observed that the point in which the mandibular condyle underwent pure rotation is where centric rotation occurs. It was also perceived by Cohen that the shallowest fossa was the most tolerant to aberrant closure patterns, while the steepest eminence led to the most lateral strain on the teeth and pathology in the joint. He also stated that hinge axis location was necessary to determine if centric occlusion was in harmony with centric relation.

An important observation was achieved by Boucher [3], who noticed that the fossa is shallow at birth and gradually deepens thereafter. The eminence begins to form by the age of 7 till 9, and his development accelerates between 10 to 11. By the age of 13 the articular eminence has usually attained adult proportions.

A very complex axial pantomography. was developed by Robert Lee [13, 14] with which the joint courses are milled into solid blocks made of casting resin. One rigid, undivided face elbow made of aluminium is fastened to the upper and lower tooth row. At the upper elbow 3 plastic blocks are attached. The edges of cubes correspond to the coordination point of the articulator. The lower elbow carries 3 dental air turbines, which are provided with calibrated drills. The two posterior drills stand collinear to the hinge axis, the anterior drill perpendicularly to the axisorbital level. The rehearsing led into its terminal joint position and the drills to mill this position into plastic cubes, afterwards the rehearsing makes a free protrusion movement. The current turbine drill, will drill its course into the plastic blocks, and afterwards a mild mediotrusion movement is made. In the resin cube, three dimensional way, the joint course presents itself, being possible to compare free and led courses (Slavicek

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[38]). Despite the great friction being a valid factor during recording, it was possible to record translatory tracks without being affected by rotation, since the hinge axis is primarily located. Lee [13, 14] also proved that intercondylar distance can be fixed in adjustable articulators, as altered parameters permit complete programming of the mandibular border movements. When Lee [13, 14] introduced the Quick Analyzer he added a system that allow the registration of the Bennett movement, which permit a linear, total shift of the mandible. This side shift was recorded with a strong manually guided movement, that in some cases resulted in an artifact of a flat movement to the laterotrusive side.

By this time Slavicek and Lugner [39] were focusing in the determination and recording of the individual Bennett movement. The system of mechanical joint track recording included a registration set up for the side shift, which was attached to the corresponding mediotrusion side. Another alteration in the recording device was the use of a paraocclusal spoon, in order to be possible to have individual untouched joint courses without sliding occlusal on surfaces. It also became feasible posting the courses with the assistance of a central supporting pin and comparison to the freely written courses. Further, representing mastication as functional joint movement and its comparison with the courses determined before, and a representation of border movements forced manually also become possible. The Camper's scheme (a cephalometric datum plane Porion – Spina Nasalis anterior) which was the reference plane in the earlier literature differs from the axisorbital level in 20.7° , which was the datum plane used by Slavicek [38]. Their study average values give a steeply forward gliding path contradicting earlier literature. The values stored were obtained by digitalizing the protrusive and mediotrusive joint courses relatively to the axisorbital level.

Slavicek [38] also observed that adults without substantial malfunction show steep joint courses, which are concave after anterior. Fischer's angle is not suitable for the central approach range of the joint course, given that when the angle is large,

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functional disturbances are present. In these cases the average value of initial joint course is about 60° . Another result achieved was that in youth missing front teeth guidance it was observed a flatter uncharacteristic joint course, which was also found in wrong overbites. In the beginning of tooth change a flat joint is observed, with angle of inclination ranging 30° relatively to the axisorbital level. During that period if we have a good attitude from the front teeth the joint develops and by the age of ten, it has both inclination and characteristic of an adult individual. In heavy cover bite cases inclinations can be near 90° .

In trouble free cases no substantial difference was proven in the total characteristic between freely written courses and the posting with the help of a central supporting pin. Only during rapid and forced back getting movement the supporting pin course shows a clear tendency to the rear and down. The mastication movement does not run off at cranial border courses. In trouble free cases they are themselves parallel to it about 1 to 2 mm caudal and distributing on the entire route distance. In the disturbed case a far deviating course can be written.

To understand the dynamics of the chewing organ, Slavicek and Lugner [39], provided a mathematical-geometrical model of the jaw movement. The objective of such a mathematical computation and geometrical representation was to increase the understanding of the expirations. Additionally, it became possible the transference of dynamic combinations to the model in order to differentiate in diagnostics functional combinations. The principal interest was the range of function diagnostics, which is concerned with parafunctional and bruxismus movement. With the axiography it is possible to represent the mathematically the joint border course, to examine the boundary surfaces of the tooth rows, as we will describe later on. Given the compatibility of lateral radiograph and the articulator instrumentation, it becomes possible compile several values allowing an integration of the defined border courses of the joint and the guidance surfaces of the front tooth guidance into this relationship.

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This way the static relationship of the guidance surfaces is given. It is also feasible, to simulate over specific computational programs, movements of the parafunctional gliding type and study their effects on the individual elements of the chewing organ.

From the mechanical point of view, protrusion is the movement of choice for mathematical computation. Morneburg and Proschel [22], observed that in protrusion movement, traces of different condylar paths were equal and independent on sagittal position of the reference point and varied by 0.8° *per* 1 mm of change of location, while opening and closing differed considerably. Their lengths varied by, up to 9 mm and inclination angles varied by 40° .

With protrusion the condylar point of the axis moves along its guidance curve forward and down. Ideally this movement is symmetrical alike for both condyles. The lower incisors cut tip slides forward in the lingual concavity of the upper teeth. Adductors masseters are activated thereby. Apart from the course of motion of the lower jaw, forces are observed and become effective within the occlusion, in the case of a slide contact running off under energy expenditure. For the force analyses, 2 groups were considered, one for the adductor muscles more masseter and pterygoideus medialis muscle, and other moving group pterygoideus lateralis muscle and tense-read muscle in his posterior portion.

If we known front teeth guidance is known, position of the lower cut tip of the tooth as well the condyle movement, then for each period we can determine the geometrical situation of the lower part movement by equation 2.1,

$$Zs = \Phi(Xs) \tag{2.1}$$

For examination of the protrusion movement within the range of the front tooth

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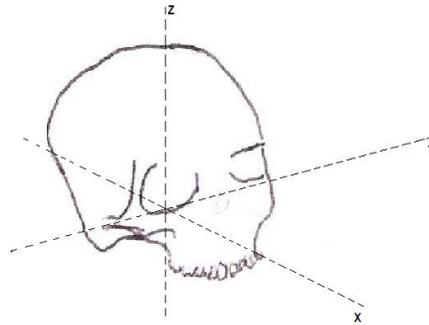


Figure 2.1: Three dimensional orientation of the skull

guidance, the situations of the points and the lines of application of the muscle force are minimum, so they are practically independent of the mandible position. The contacting force at front guidance and / or condyle movement can make friction in ways that they are practically the same as the work smoothing guidance surfaces. Their directions and sizes as a function of the momentary position of the mandible are thus determined by the form and the interaction of these two guidances.

So when it is necessary to observe the trajectories of the joint in a clear way bringing them to reference level into a measurable relationship representing the protrusive condyle course in degrees of angle we use axiography. The mechanical method allows the recording of sagittal condylar track in an easy way since it is determined by structure, however transversal condylar it is not possible because it is determined by function and ligaments. In the electronic method the collection of the translatory movement component of the Temporomandibular Joint (TMJ, from hereafter) are recorded and with the help of a measuring tool, the value of translation is transformed over a computational program into adjustable angles of the articulator. The great advantages is the recording of transversal condylar track, the recording is bound to time in steps of 0,009s, very accurate scale, real time calculation by moving the cursor on the screen along the pathway and reproducible tracings.

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Guidance				
Chord	Length	Dispersion	Angle	Dispersion
Above 1				
s	5.53mm	1.06	57.57°	10.92
S ₁	2.88		41.36°	
S ₂	3.02		73.41°	
Above 2	5.45	1.29	54.59°	10.44
Above 3	5.06	1.12	48.72°	9.87
Above 4	3.77	0.47	36.16°	9.36
Above 5	3.66	0.54	29.18°	8.38
Above 6				
mesial	3.52	0.67	23.05°	6.82
distal	3.69	0.72	21.05°	7.29

Table 2.1: Source: The Functional Determinants of the Chewing Organ, Slavicek.

With the evolution of the axiography and the knowledge build from it, we transfer this information to the lateral head introducing function information in cephalometry. This information is transferred by obtaining a common reference, which is valid both for the articulator and for the lateral radiograph from the head. We obtain this reference level by after perform the axiography, gluing radiopaque marks on the skin of the patient that correspond to hinge axis and orbitarium cutaneum, having the axisorbital plan. The points of reference also serve to set the articulator. With the analysis of mandibular positions it is possible to confront retral joint position and maximum intercuspation. After this we can analyze the lateral radiography.

As it is clear from the observation of Table 2.1, the guidance surfaces of a natural occlusion evidences a clear dominance of the group of the front hitting corner tooth opposite to the premolar and molar ones. The chords of the middle and lateral incisor tooth are clearly the steepest guidance of the occlusion. When we consider the lingual concavity and S1 and S2 guidance chords of the front teeth, we see that if there is a breakdown in that guidance canine will dominate. He almost does not show any

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concavity and the s1 chord of the front teeth is flatter, however is 5° steeper than the first premolar. Despite this when we consider the spatial position in the system it shows that “ a movement would change harmoniously from the front guidance s1 into the premolar direction s2'' , without conflict between front teeth guidance concept and group function concept in the laterotrusion side, adding a reduction in Wilson curve this concept will develop automatically . If the cusp of the premolar is raised it leads to a less functional transition to group function.

Ogawa et al. [23] in their study about the influence of anterior guidance and condylar guidance on mandibular protrusive movement they calculated the inclinations of the sagittal paths on the incisor, canine ,1st molar , 2nd molar and condylar points. A regression analysis was performed in order to assess in a quantitative manner the contribution of the incisal and condylar paths on the path of each tooth. The influence of the incisal path on any tooth path was consistently greater than that of the condylar path. It was verified that the condylar path had a greater influence on the paths of posterior teeth than on the paths of anterior teeth.

2.2 Recent Developments

In a study by Piehslinger et al. [30], it was determined that the average range for Bennett angles at maximum excursion free mediotrusive movement was between 0.41° and 5.89° (mean 4.43°) on the right side and between 2.45° and 10.07° (mean 6.87°) at the left side in trouble free patients. The values for TMJ problem patients were higher. In the same study, but observing transversal condylar shift in protrusive and retrusive movements, the results were that the mean mandibular shift was 0.15 mm to the left.

Travers et al. [43] concluded that maximum incisor opening does not provide reliable information about condylar translation and its use as diagnostic indicator of

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condylar movement should be limited, healthy individuals may perform normal opening with highly variable amounts of condylar translation, the straight-line distances of the incisor and condyles provide adequate information about the length of the curvilinear pathway and variation in maximum incisor opening is largely explained by variation in the amount of mandibular rotation.

Johnson and Winstanley [12] concluded that in fixed sagittal condylar angle articulators 30 degrees appear to be an appropriate setting.

Fukui et al. [8], investigate the relationship between parameters of facial morphology, maximal voluntary mouth opening ability and condylar movements. The results suggest that facial morphology size has a limited effect on maximal voluntary mandibular opening and condylar movements in normal adult female subjects.

Buschang et al. [4], studied the correlations between condylar translation and incisor movements during maximum protrusion and laterotrusion. They concluded that incisor protrusion and laterotrusion provide moderately reliable measures of condylar translation. The linear that the incisors move during laterotrusion provide the best measure of contralateral condylar translation and condylar movements are not affected by repeated protrusion or laterotrusion.

Katsavrias [15], based in the principle that the articular eminence of the temporomandibular joint dictates the path and type of condylar- disk complex movement, he concluded by taking impressions and measuring articular fossas of skulls presenting deciduous , mixed and permanent dentition, that the inclination changes rapidly until the completion of deciduous dentition, attaining more or less 45% of its adult value. By the age of ten years, it was 70% – 72% completed, and by the age of 20 years, it was 90 – 94% completed.

Matsumura et al. [16] studied the sagittal condylar path during protrusive and lateral excursions by analyzing the actually measured jaw movement data and re

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– evaluated the setting of the sagittal condylar path inclination in consideration of Fischer’s angle. Condylar path inclinations at the hinge axis point and the corresponding external point laterally extending from the condyle were evaluated in the sagittal plane. Analyses was performed at three different magnitudes of excursions, where the incisal point was located at 1.3 and 5 mm away from the Intercuspal Position (ICP). They concluded that there was no significant difference in the sagittal condylar inclination or the Fischer’s angle between two condylar reference points. However, they were significantly different across the three different magnitudes of excursions for both condylar reference points, they became smaller the more distant they are from ICP.

More recently, Baqaien et al. [1] quantified the changes in sagittal condylar path inclination during mandibular protrusion between the ages of 6 and 12 years. The control group consisted of 41 adults with a mean age of 28 years. All subjects had a normal temporomandibular joint function and neutral occlusion. Each subject, performed five maximum protrusion – retrusion movements which were recorded with six degrees of freedom using an ultrasound jaw-tracking system. Condylar path inclination angle was calculated stepwise for each millimeter distance, for the first 10mm of protrusive tracing path on both sides. Afterwards, a mean value was determined for the entire protrusive path. They observed that the mean condylar path inclination angle is 43° to 44° at the age of seven, increases annually by 1.2° to 1.3° and reaches an average of 49° to 50° by the age of 12 at which time it attains around 83 – 85% of its adult level. In the group with a mean age of 11.4 years old the female population had steeper condylar path on the left hand side than the male population. Condylar path inclinations indicated a symmetrical growth pattern of the articular eminence.

2.3 Extraction vs non extraction

Through the years extractions of premolars versus expansion is a very controversial subject. In 1907 angle said that every individual has the potential to have the 32 teeth in an ideal occlusion. He was impressed by Wolff bone law which explained that bone trabeculae is organized in response to effort lines. Angle reached the concept that an adequate function would to a right teeth position.

During the thirties some relapse was observed in cases treated by angle without extractions and Charles Tweed, which was a student of him, decided to re treat some of his cases by performing extractions. After the extractions Tweed concluded that occlusion was more stable (see [35]). He published the work and in the final of years 40° extractions were reintroduced. At the same time in Australia, Begg [2] defended that with diet alterations there is no proper wearing in the occlusal and proximal facets of teeth, and with the extraction of the premolar will solve this problem in normal development of dentition.

In the beginning of the sixties in the United States (U.S.) most of orthodontic treatments were extractive ones, since it was thought that extractions didn't affect facial development and it was necessary extractions to accommodate teeth to maxillary discrepancies.

In late years the percentage of patients with extractions diminished since it does not assure a stable treatment. However when there is a discussion between extraction and expansion stability is measured in terms of position of teeth, arch length and width. The defenders of extractive therapy argue that nor arch length neither arch width is changed. They defend also that intercanine width is maintained and can even be widen to avoid relapse. The intermolar region where premolar and molar mesialization in the narrower part of the arch is compensated by the second molar position assement.

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Jason et al. [11] observed better occlusal and less relapse in cases treated with premolar extractions.

However, in cases with extractions of the first upper premolars we can observe overretraction of front teeth, loss of posterior support which can cause TMJ arthrosis, prevalence of posterior discrepancy, narrowing of tongue space, and molar mesial and tipping rotation . Even during treatment, we can find some difficulties in controlling vertical relationship during distal movement of front teeth for space closure in deep overbite cases. On the other hand, when we consider negative discrepancy in its broad sense (considering not only the difference in the length of the alveolar base and the size of the tooth crown width, but taking also in consideration dynamic mechanism of the maxillofacial skeleton and the functional movement of the mandible) molar extraction presents some advantages, such as eliminating supraeruption (one of the causes of the abnormal growth of the jaw) and mesial tipping of molars, cuspal interferences. However, we must know the proper molar to extract. The first molar has a big occlusal force loading, and it is of utmost importance in the bite relationship of the upper and lower jaw in order to obtain a centric stop and a retral protection of TMJ. So the choice must be between second and third molar, being age a matter that we must take in consideration, in order to avoid third molar tipping and rotation, when we extract second molars.

2.4 Anatomy Review

The Cranial Mandibular System (CMS, from hereafter) is anatomically divided according to Slavicek [41] into seven categories:

- Bony Structures
- Ligamentary Structures (including the temporomandibular ligament)

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- Articular disk
- Retro-articular structures
- The muscle system for the TMJ
- The sinovial-capsule apparatus
- Extended ligamentary attachments

2.4.1 Bony structures

The bony structures correspond to the condylar process of the mandible and the temporal bone. Both of the TMJ surfaces (in the temporal bone and condyle) are covered with fibrous cartilage.

The condylar process of the mandible extends from the posterior portion of the ramus posterosuperiorly and articulates with the temporal bone in the glenoid fossa. The condyle is an oblong eminence whose longitudinal axis runs from lateral to medial and slightly anteroposteriorly, leading towards the foramen magnum (depends on the individual). Anterior to the condyle there is a small depression, the pterygoid fovea for attachment of the inferior head of the lateral pterygoid muscle. Roughening of the condyle is noted laterally for attachment of the subchondral tubercle and medially where the disc and medial collateral ligaments attach.

The temporal bone is located in the inferior and lateral part of the skull, being constituted by three distinct parts: squama, tympanic bone and petromastoid part. The glenoid fossa, which articulates with the condyle, located in the inferior face of the temporal squama, is an elliptic depression, presenting a long axis from lateral to medial and anteroposteriorly, located immediately anterior to the auditory meatus which is already located in the tympanic bone. The zygomatic process extends

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anterolaterally from the fossa. The fossa is bordered anteriorly by a smooth, convex eminence, the articular eminence. Its shape is developed during growth, according to the functional influence of the dynamic occlusion, responding to these influences throughout life. Posteriorly there is no defined post-glenoidal region.

These two bony elements are loosely together by the joint capsule, corresponding to functional demands.

2.4.2 Ligamentary Structures of the TMJ

Like it was already referred, the joint capsule is very loose, allowing a very wide range of physiological movements of the TMJ. The temporomandibular ligament reinforces the capsule, protecting it against traumas in posterior direction, by a special construction of its fibers (extended from anterior-superior to the temporal bone and postero-inferiorly to the mandible). To a closer inspection, one can observe that the principle vector of these fibers repeats itself in the pterygoid-masseter loop.

The temporomandibular ligament also aids to center the mandible against the forces of the gravity.

2.4.3 Articular disk

The articular disk is composed of dense fibrocartilage (densely organized collagen, elastic fibers and cartilage like proteoglycans) and exists in a biconcave shape except for the lateral portion which is more rectangular in nature. Its thickness decreases towards the center with the thinnest portion interposed between the head of the condyle and the articular eminence in maximum intercuspation. It is also increased in the posterior part (3 – 4 mm versus 2 mm in the anterior part).

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The disk is attached to the condyle by a lateral collateral ligament and a thinner medial collateral ligament. Another two ligaments secure the articular disk:

- disco-condylar ligament – this is the largest of both, lying tautly against the condyle in a retrusive position and loosening in protrusion;

- disco-temporal ligament – extends from the petro-tympanic groove, behind the glenoid fossa, to the posterior edge of the disk, forming the upper plate of the bilaminar zone. Oppositely to the previous ligament, it's strained in a protrusive position and relaxed in a retrusive position.

On an opening movement, the disk is pulled backwards by the temporo-condilar ligament. It's important to emphasize that, depending on the subject, variations are possible.

2.4.4 Retro-articular structures

The retro-articular area is a highly vascularized pad whose function is to maintain hydrodynamic pressure adjustment as the condyle translates, assisting in the determination of functional condylar position. In addition, the presence of this hydraulic pressure protects the TMJ against forces or traumas with a posterior direction.

It is composed by collagen fibers with a loose arrangement, elastic fibers, blood vessels, nerves, adipose and lymphoid tissues.

2.4.5 The muscle system for the TMJ

Several parameters are controlled and under direct dependence of the immanent muscle system like the position of the mandible regarding its relation with the articular eminence, the distance between mandible and maxilla and the direction of dental

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arches to each other.

These muscles act in a coordinated effort, a well orchestrated combinations, allowing the mandible to move in all six degrees of freedom. So, the muscles involved in the TMJ region are the upper head of the lateral pterygoid, the deep head of the masseter and the fourth frontal head of the temporal muscle, present in 30% to 40% of the cases. All of these muscles have an anteriorly oriented vector and appear to be responsible for mandible centering. It is also recognized that the TMJ muscles have fibers that insert in the capsule and disk, acting like capsule tensors.

■ Lateral pterygoid – upper head – this muscle extends from the sphenoid bone, both wings and pterygoid apophysis, converging almost horizontally to the median half of the condyle, with some fibers inserting, directly or not, to the capsule and articular disk (specially seen in young TMJs), functioning as a stabilizer during sudden movements. It's a protractor of the mandible, working, despite other assumptions, not synchronized with the inferior head. It is also active during closing and slightly active in floating rest-position, centering the condyle against the eminence. So it is fair to assume that the upper head of the pterygoid muscle acts like an anti-gravitational system.

■ Deep head of masseter – This muscle is divided into two units or layers, attached in the anterior margin and open backwards, with somewhat different functions.

The deep layer extends from the outer side of the mandible to the zygomatic arch and, by some fibers, to the temporal fascia and lateral third of the joint trochlea. The upper layer also extends from the outer side of the mandible but towards the zygomatic bone and temporo-zygomatic suture.

These layers differ regarding to their innervation, physiology and vectors. They provide stability for the mouth and the lateral open space.

■ Frontal head of temporal muscle – In 30% to 40% of the cases, the frontal head

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of this muscle inserts in the capsule, articular disk and condylar process (between masseter and pterygoid). It is involved in the closing movement and centers the mandible.

It's important to recognize that exist different fibers with different characteristics. The muscle fibers are divided into type I (slow twitch), type IIa (fast twitch), type IIb (fast twitch) and type IIc. The type I have a high resistance to fatigue and are activated at very low thresholds, acting to produce lower forces. The type IIa are also resistant to fatigue but react more rapidly. They are found in muscles that exhibit frequent and intense activity. Type IIb fibers generate large forces with higher thresholds. They are best used in short bursts of activity and are sensitive to fatigue. Finishing, the type IIc fibers are composed by both fast and slow myosins.

The opening muscle groups include the infrahyoids, suprahyoids and the anterior and posterior digastric muscles. The digastric muscles are primarily responsible for opening the mandible in combination with the inferior portion of the lateral pterygoid muscle. The infrahyoid muscles stabilize the hyoid bone thereby allowing the suprahyoid muscle groups to contract and depress the mandible.

The elevator muscle groups are responsible for the complex actions of closure of the mandible. The masseter muscle, divided in two portions, superficial and deep (already described), is a very strong muscle. The superficial portion acts primarily as an agonist and exerts its primary force perpendicular to the ipsilateral curve of Spee in the molar region. Type IIb fibers are present, which contribute to possible myospasticity and fatigue.

The inferior portion of the lateral pterygoid is responsible for protrusion of the mandible and, contracted unilaterally, mediotrusion occurs. This muscle is also active during depression of the mandible. The superior head of this same muscle is active

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during closure, stabilizing the condyle.

Also the medial pterygoid muscle acts as an elevator of the mandible, assisting in ipsilateral mediotrusion. This is a very active muscle with many IIB fibers.

The anterior temporalis muscle is active in mediotrusion and medioretrusion as well as clenching in maximum intercuspation. The middle temporalis is active in closing and retrusion, especially mediotrusion and medioretrusion. The posterior part is active as a retruder of the mandible, mediotrusion and medioretrusion.

2.4.6 The sinovial-capsule apparatus

In order to allow the translatory function, the dominant one regarding mandible movements, it is necessary to have no friction whatsoever between the condyle-disk assembly on the eminence. During the protrusive movement, an anterior directed inter-capsular pressure results, due to the vector of the inferior head of the lateral pterygoid, causing synovial fluid to be expelled. In a low pressure situation, an incisive movement, the opposite occurs, causing the synovial fluid to return to the complex. This is the physiological basis for the joint metabolism. This metabolism is jeopardized when functional perturbations of the condyle-disk assembly occur. The reason is an innate absence of vascular supply system.

2.4.7 Extended ligamentary attachments

Ligaments fix the mandible to the hyoid bone in a ligamentously self-centering position. Due to their detailed fiber distribution and course, these ligaments are suited to center the mandible on a non-muscular centering. Hence, minimal activity of the postural muscles is required.

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■ **Ligamentum sphenomandibulare** – this ligament extends from the angular process of the sphenoid to the lingual, located on the inner face of the mandible, lying between the medial pterygoid and the inferior head of the lateral pterygoid. The vector is similar to these muscles.

It's role, as a ligament, is to hold the ascending branch between these muscles, centering the mandible simultaneously to the middle and anteriorly against the eminence. This way, these masticatory muscles don't have to be used for this function.

■ **Ligamentum stylomandibulare** – It extends from the lateral edge of the styloid process, next to its vertice, to the inner side of the mandible angle, where it mixes with the fascia of the medial pterygoid. This ligament has the capacity of active recovery from the medio-eccentric position, due to its histomorphologic structure.

Studies performed by E. Olivier (see [37], for a reference) suggest that this ligament is a consequence of the regression from fibers of the mandibular part of the styloglossus muscle.

■ **Ligamentum stylohyoideum** – This ligament extends from the inner, anterior and inferior part of the styloid process to the hyoid bone. Like the antecedent ligament, there are meshes with intermediate fibers, resulting in tension within the intermediate fibers during eccentric movement to the mediotrusive side. To a median muscular movement, ligaments respond to replace the mandible to the middle.

■ **Ligamentum pterygospinale** – This is a very short and powerful ligament with a very important insertion on the posterior margin of the pterygoid process. Important because it's suitable to assume that it has effect of indirectly transfer tension onto the vomer bone during rotation and expansion in the ontogenetic process towards bipedal locomotion, and a simultaneous expansion in breadth of the neurocranium.

■ **“Alpha ligament”** – According to Rocabado [36], there is a ligamentary loop connecting the hyoid bone and the cervical spine. Hence, changes in flexion of the

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cervical spine have a direct effect on the position of the hyoid bone and thereby also on the position of the mandible.

Chapter 3

Design of the Study

In this chapter we describe details concerning the data set collected, and the way that data was collected. The complete data set can be found in appendix.

3.1 Methodology

The sample was collected from schools in Lisbon, Palmela and Pinhal Novo, and from private practice. The first approach was a visit to the schools, where we checked decays, restorative work in the permanent teeth, angle's sagittal dental classification and the prior use of orthodontic appliances from the students. In the first visit to schools 548 children were observed. The students which were selected, it was given an authorization for the parents to fill in order to go to the clinic. In the clinic, dental arch impressions were taken, and afterwards dental casts were mounted in a Girrback articulator. Their age range from 8 years till 13 years. Four groups with ten students were then defined:

Group 1

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Biotype	Race	
	Caucasian	Afro-European
Dolic	65.51%	65.64%
Mesio	34.49%	36.37%

Table 3.1: Biotype/Race Relationship

Students with Angle sagittal class I, with upper and inferior permanent incisors, and upper and lower first permanent molars.

Group 2

Students with Angle sagittal class II, with upper and inferior permanent incisors, and upper and lower first permanent molars.

Group 3

Students with Angle sagittal class I, with upper and inferior permanent incisors, upper and lower first permanent molars, and first upper premolars in occlusion.

Group 4

Students with Angle sagittal class II, with upper and inferior permanent incisors, upper and lower first permanent molars, and first upper premolars in occlusion.

In the collected data set there were individuals from Caucasian and Afro-European race. The following Biotype / Race relationship, was verified in the data,

In the clinic, dental arch impressions were taken with closed trays. Afterwards relation of the upper jaw with cranium was taken with reference SI facebow, and the most retral position was determine between upper and lower dental arches. Dental casts were then mounted in a Girrback reference SI articulator. This adjustable articulator allows us to take a silicone impression of upper front teeth related to axle orbital plan, when upper dental arch relation with cranium is performed with an



Figure 3.1: Silicon clay.

exact facebow, since hinge axis was located. A straight bar is attached to the upper branch of the articulator which have a relocatable bar parallel to axle orbital level fastened, and to the end of the parallel bar is attached a metal angle. The horizontal level corresponds to the x and y coordinates of the articulators and the x and z to the vertical level. We fed the modeling clay (metal angle) with silicone and move up the parallel bar, to take impression of the front teeth of the upper jaw. The lingual surface has to be precisely cast into the still soft modeling clay. When silicone is hard the metal angle is moved down and the silicone casting is removed from the model. In this study we checked tooth 1.1, so we made a incision in sagittal direction in the silicone casting. This corresponds to the protrusive guide way. These cuts were applied in such a way on a millimeter raster that the angle edges were appropriate accordingly to the raster. So the axisorbital level is fixed as datum plane.

We did not use an exact facebow so upper dental arch was related to Frankfurt

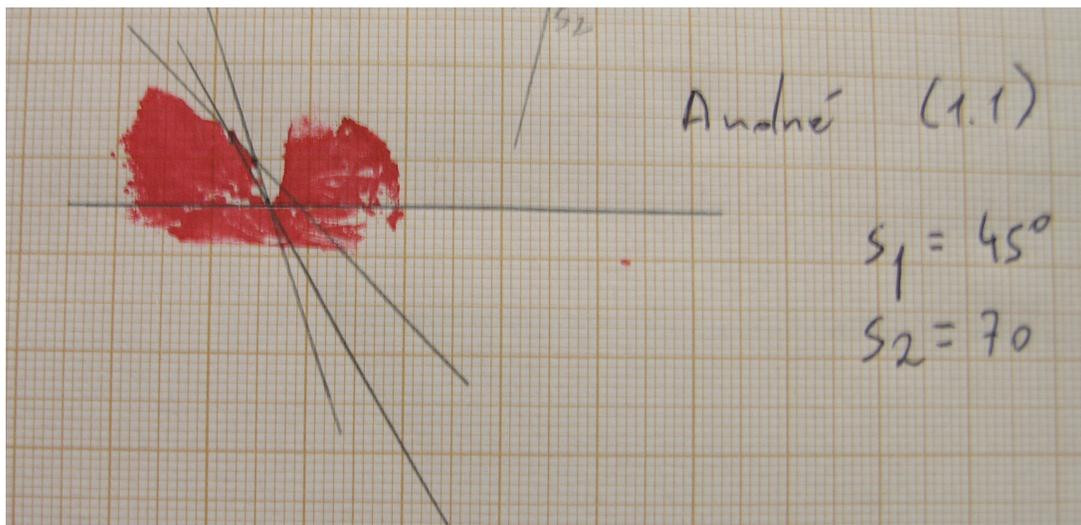


Figure 3.2: Determination of s .

plan. There is an approximate difference 6.5° between both plans.

Panoramic rx were taken.

3.2 Equipment Used for Collecting the Data

The axiography (CADIAX) was the principal equipment used in this study. It permits to observe undistorted condyle trajectories, representing the protrusive course in degrees of angle. In fact, quoting Slavicek [38], "the collection of the translatory movement component of the jaw junction as a sign of the so called moistening movement takes place with the help of a measuring tool, which permits to transform the value of the translation ($\Delta \mu$) over a computational program into adjustable angles of the articulator." Since a paraocclusal clutch is used it is possible to have untouched joint courses individuals without sliding occlusal on surfaces, representing a self-written central individuals, representing behandler led central. Posting the

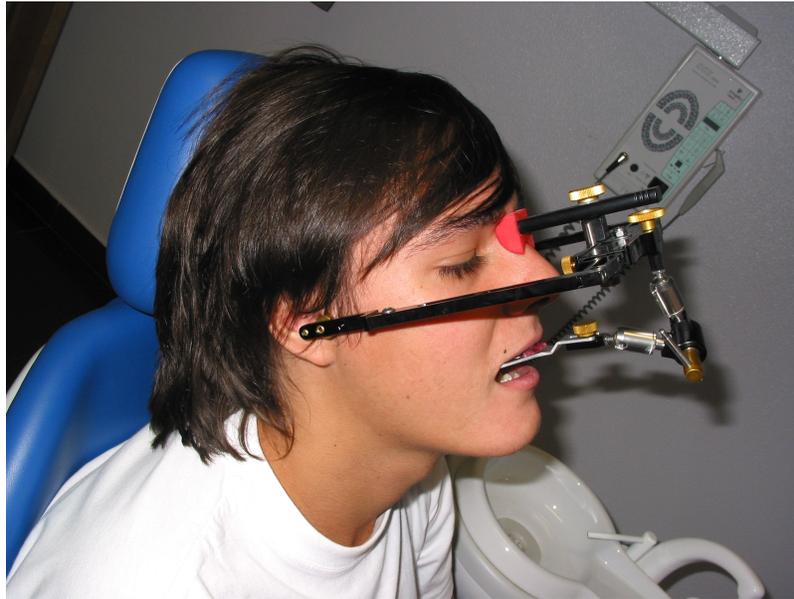


Figure 3.3: Articulator face bow, side view.

courses with the help of a central supporting pin and comparison to the freely written courses. It also permits to represent mastication as functional joint movement and its comparison with the courses determined before. It is also possible a representation of border movements forced by manually led joint movements in the sense.

Another equipment used was the articulator (Girrbach reference sl). The assembly into an articulator is independent of the age of the patient. The casts are mounted by the retral reference position and the joint position. This reference is usually established in retral contact position to the occlusion (Slavicek [38]). The possibility of the accurate positioning in the articulator permits the conclusion that in the articulator there is also a cephalometric principle. With the help of this setting articulator jaw model a head datum plane is assigned. The most important is the axle orbital level. It is similarly appropriate as the Frankfurt horizontals, together for orbital, but the posterior points of the reference differ against it. Both points

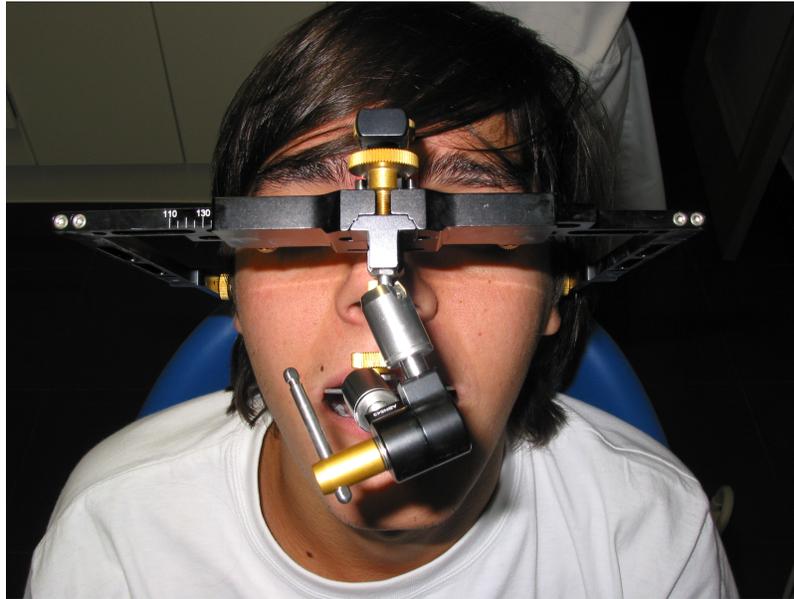


Figure 3.4: Articulator face bow, front view.

that are the hinge axis points lie anterior and caudal opposite the Porion point. The angle between the two levels amounts to 6.5° , after the proper cephalogram.

It functions as coordinate system that allows an exact tooth position measurement.

3.2.1 CADIAX

The patient was primarily informed about the steps of the procedure, and all the movements were practiced before the exam. The functional clutch was fitted to the lower dentition of the patient. It must be observed if the clutch is traumatizing the soft tissues. Afterwards acrylic material which is used to make provisionals Rebuilda (Voco) is used in the clutch to make a key of the lower dentition. When the acrylic is polymerized we checked occlusion, observing first if the patient can

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achieve full intercuspation and if there was an interference free dynamics in the mandibular movements without any disturbance, having no alteration in vertical dimension. Then, we glued the functional clutch with cyanoacrylate gel to the lower teeth

Afterwards we position the upper facebow in the patients head and adjust him. The nasion portion of the upper bow was relined with Express STD putty (3M ESPE) to cushion the bridge of the nose. Then we attach it with a neck band to the patients head, checking if right and left sides are positioned symmetrically. The flags are then attached in the joint area, positioned over the left and right ears with the most posterior portion at the tragus. The lower bow is attached to the clutch and his parallelism, from a superior and frontal view, to the upper facebow is checked. The electronic recording block is attached to the upper facebow and styli with approximately 1 cm of activation applied in the right and left and the posterior arms of the lower bow were tightened. After the assembly procedure the parallelism between the bows is checked again. The nine pin connector from the electronic recording block and styli were connected to Cadiax Diagnostic (Gamma Dental , Klosterneuburg, Austria), which was connected to a computer with Cadiax software version 3.24.8.0 Gamma Dental, Klosterneuburg, Austria) and the axiography was initiated by a dynamic determination of the reference position and the hinge axis. No refix was done during recording.

During the exam we ask the patient to perform the following movements:

- Open close
- Protrusion and retrusion
- Mediotrusion right free
- Mediotrusion left free

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- Counting backwards from 90 to 80
- Cpm
- Mpi

3.2.2 Cephalometry

After the Cadiax was performed, the led marks as described previously were glue to the face of the patient. In the lateral film a 1 mm section wire with 1 cm was glued to the tape, to measure the magnification factor. A 10% magnification was determined. Afterwards the lateral rx was scanned and converted to JPEG file, in order to be used in Cephalometric part of the CADIAX software. Slavicek and Sato analysis were applied using the following points represented in Figure 3.5:

1. Reference line point1
2. Reference line point2
3. Spina mentalis
4. D point
5. Menton
6. gnathium
7. pogonium osseum
8. suprapogonium
9. B point
10. Lower incisor root
11. infradentale

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12. tip of lower incisor
13. tip of upper incisor
14. supradentale
15. upper incisor root
16. A point
17. Spina nasalis anterior
18. Spina nasalis posterior
19. Hyoid
20. Incisura premasseterica
21. Lower ramus tangent point 1
22. Inferior ramus tangent point
23. Dorsal ramus tangent point
24. Basion
25. Articulare
26. Axis point1
27. Axis point 2
28. Condylum
29. Porion
30. Sella centrum
31. Pterygoidal

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32. Ptm
33. Processus muscularis
34. Orbitale osseum
35. Orbitale cutaneum
36. Temporale
37. Orbit roof
38. Supraorbitale
39. Nasion
40. Tip of nose
41. Subnasale cutaneum
42. Labrale superius
43. Stomium superior
44. Stomium inferior
45. Labrale inferius
46. Pogonium cutaneum
47. Caninale superius
48. Apex caninus superior
49. Caninale inferius
50. Apex caninus inferior
51. Tip lower 4

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52. Tip lower 5
53. Mesial cusp lower 6
54. Distal cusp lower 6
55. Central crown lower 6
56. Central root lower 6
57. Mesial Cusp lower 7
58. Distal cusp lower 7
59. Mesial cusp lower8
60. Distal cusp lower 8
61. Distal root lower 6
62. Lower molar contact point
63. U6 mesial contact point
64. U6 central crown point
65. U6 central root point
66. Distal cusp upper 6
67. Upper molar contact point
68. Distal root upper 6
69. Anterior ramus contour
70. Superior ramus contour
71. Posterior ramus contour

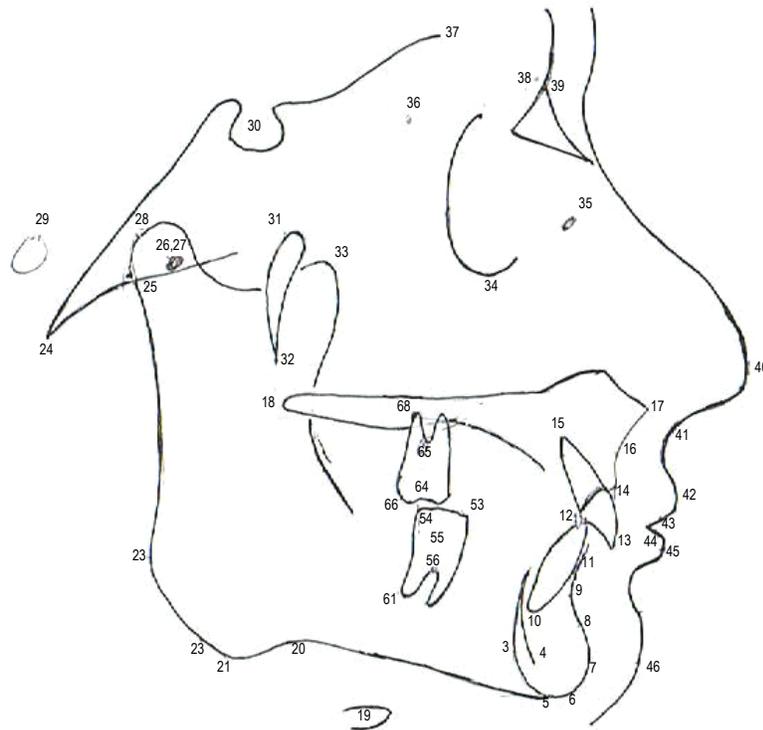


Figure 3.5: Lateral rx cephalometric points

- 72. Inferior ramus contour
- 73. Soft tissue profile
- 74. Symphysis
- 75. maxilla

From the analysis of Table 3.2 values we can classify the Biotype of an individual in one the three types of facial skeletal patterns under which malocclusions are classified. The ideal face is mesiofacial which usually presents with a class one occlusion, acceptable maxillo-mandibular bony relationships, harmonious musculature and a pleasing soft tissue profile. The dolichofacial pattern is usually a long narrow face,

Determinants	Norm
Facial Axis	90.0°
Facial Depth	88.7°
Facial Taper	68.0°
Mandibular Plane	24.2°
Related Values	Norm
Bjoerk Sum	396°
Facial Length Ratio	63.5°
Y Axis to SN	67.0°
Y Axis (Downs)	61.2°
SN to Gonion Gnathion Angle	32.6°

Table 3.2: Determination of Skull Type (Slavicek) from CADIAS

retrognathic vertical mandible, narrow dental arches and class II malocclusion with crowding. This is typical pattern of oral breathing individuals. The brachyfacial pattern usually exhibits an horizontal facial growing pattern, represented by a short wide face, usually with broad dental arches, deep overbites, and with well developed masticatory muscles.

Legend to Table 3.2

Facial Axis: This is the angle between the Nasion Basion Plane and the connection between Pterygoid and Gnathion measured between Basion and Gnathion. This value indicated direction of growth of the molars and chin.

Norm 90 +/- 3 degrees

Facial Depth: is the angle between Frankfurt Horizontal Plane (FH) and Facial Plane (from Nasion to Pogonion) measured between Porion and Pogonion. This value is a measure of the horizontal position of the chin.

Norm 88.7 +/- 3 degrees

Facial Taper: is the angle between Facial Plane (Nasion to Pogonion) and

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mandibular plane (Menton to Gonion). This is a growth pattern indicator.

Norm 68 +/- 3.5 degrees

Mandibular Plane: This is the angle between Frankfurt Horizontal Plane and Mandibular Plane measured between Orbitale and Menton. This value indicates a skeletal deep or open bite caused by the mandible.

Norm 24.2 +/- 3.00 degrees

Bjoerk Sum: is the sum of the following angles: Saddle, Articular and Gonial. High values indicate a Dolichofacial (clockwise) pattern and low values indicate a Brachyfacial pattern (counterclockwise pattern).

Norm 396 +/- 2.50 degrees

Facial Length Ratio: is the ratio of the distance between the Sella and Gonion and the distance between nasion and Gnathion. High values indicate a counterclockwise growth pattern (Brachyfacial) and low values indicate a clockwise growth pattern (Dolichofacial).

Norm 63.5% +/- 2.00%

Y Axis to SN: This is the angle between Nasion-Sella (SN) and Sella-Gnathion and is a growth direction indicator.

Norm 67.0 +/- 3.00 degrees

Y Axis (Downs): This is the angle between Frankfurt Plane and the line Sella to Gnathion measured at Orbitale.

Norm 61.2 +/- 3.00 degrees

SN To Gonion Gnathion: This angle is between Sella, Gonion and Gnathion.

Norm 32.6 +/- 3.5 degrees

Chapter 4

Data Analysis

In this chapter it is analyzed whether there are significant differences on the SCI's, the TCI's and the s (as defined above) over angle class I and angle class II. Some auxiliary notation can be found in the Glossary. The referred hypothesis can be formally stated as being of the following type,

$$\begin{aligned} H_0 & : \mu_I(\alpha) = \mu_{II}(\alpha) \\ H_1 & : \mu_I(\alpha) \neq \mu_{II}(\alpha) \end{aligned} \tag{4.1}$$

where $\mu(\cdot)$ denotes the mean value of interest, and α stands for the type of angle, namely the SCI, or the TCI, or the s .

In order to test those hypothesis we will use standard two-sample t -tests (for a reference, see Montgomery [21]).

All tables built in this chapter are queries made to the master tables found in appendix, which contain the entire data set collected. The TCI and SCI values used in this section are all 5 mm values, given that this is the value at which the occlusion occurs. The entries are, of course, in degrees.

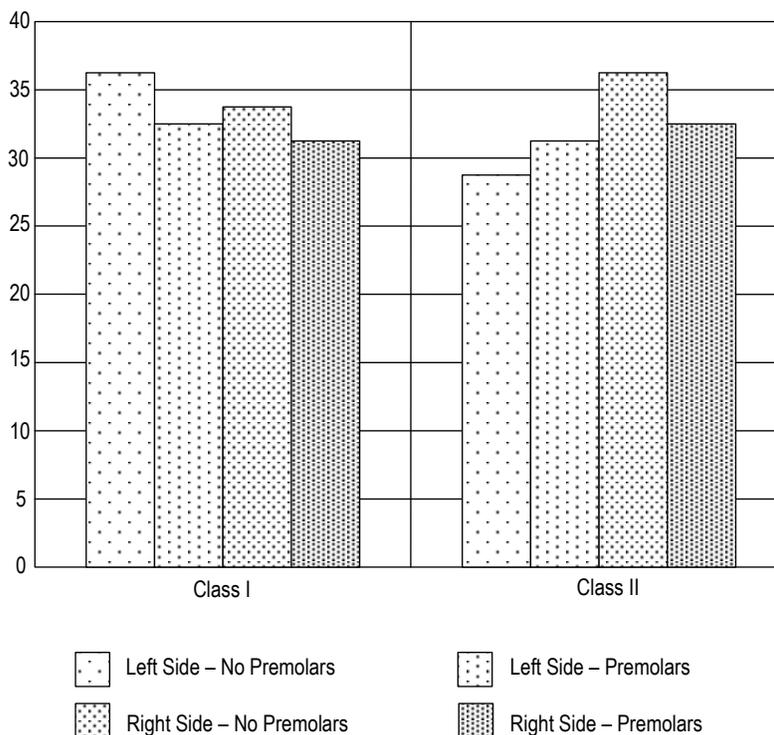


Figure 4.1: Sagittal Condylar Inclination with/without premolars: Class I *vs* Class II

4.1 Comparison of SCI over Angle Class I and Angle Class II

The SCI values will be clustered by side and by functional phase. One of the hypothesis relevant in this section will be:

Chapter 4. Data Analysis

Observations on $SCI_{5mm,r}$, no premolars											
	1	2	3	4	5	6	7	8	9	10	Average SCI
Class I	37	24	38	44	44	41	25	21	30	39	34.3
Class II	26	33	27	32	34	40	27	37	58	43	35.7

Table 4.1: Observations on SCI, for right side, without premolars

Observations on $SCI_{5mm,r}$, with premolars											
	1	2	3	4	5	6	7	8	9	10	Average SCI
Class I	38	26	24	27	36	22	22	46	39	23	30.3
Class II	48	41	20	31	32	42	33	38	37	0	32.2

Table 4.2: Observations on SCI, for right side with premolars

$$\begin{aligned}
 H_0 & : \mu_I(SCI_{5mm,r}) = \mu_{II}(SCI_{5mm,r}), \quad \text{with no premolars} \\
 H_1 & : \mu_I(SCI_{5mm,r}) \neq \mu_{II}(SCI_{5mm,r}), \quad \text{with no premolars}
 \end{aligned} \tag{4.2}$$

Given the absence of premolars and considering the right side we have the following:

This yields a t of -0.3424 and a p -value of 0.7360 . The obtained p -value supports no evidence to reject the null hypothesis of mean equality of the $SCI_{5mm,r}$ across angle class I and angle class II. Another hypothesis of interest is the following,

$$\begin{aligned}
 H_0 & : \mu_I(SCI_{5mm,r}) = \mu_{II}(SCI_{5mm,r}), \quad \text{with premolars} \\
 H_1 & : \mu_I(SCI_{5mm,r}) \neq \mu_{II}(SCI_{5mm,r}), \quad \text{with premolars}
 \end{aligned} \tag{4.3}$$

The data necessary to test this hypothesis is, given in Table 4.2

We now obtain a t of -0.3725 and a p -value of 0.7147 suggesting the same type of conclusion as above.

	Observations on $SCI_{5mm,l}$, with premolars										Average SCI
	1	2	3	4	5	6	7	8	9	10	
Class I	31	32	35	30	35	32	23	42	31	20	31.1
Class II	42	42	0	30	34	44	32	39	35	21	31.9

Table 4.3: Observations on SCI, for left side, with premolars

If we now turn to the left side, then we have the following hypothesis,

$$\begin{aligned}
 H_0 & : \mu_I(SCI_{5mm,l}) = \mu_{II}(SCI_{5mm,l}), \text{ with premolars} \\
 H_1 & : \mu_I(SCI_{5mm,l}) \neq \mu_{II}(SCI_{5mm,l}), \text{ with premolars}
 \end{aligned} \tag{4.4}$$

This hypothesis can be tested using the data contained in Table 4.3.

We now obtain a t of -0.1743 and a p -value = 0.8644. Again this suggests no evidence to reject the null hypothesis of equality of means over angle class I and angle class II.

Finally, we have the following hypothesis:

$$\begin{aligned}
 H_0 & : \mu_I(SCI_{5mm,l}) = \mu_{II}(SCI_{5mm,l}), \text{ with no premolars} \\
 H_1 & : \mu_I(SCI_{5mm,l}) \neq \mu_{II}(SCI_{5mm,l}), \text{ with no premolars}
 \end{aligned} \tag{4.5}$$

Using Table 4.4, we achieve a t of 2.2582 and a p -value of 0.04098. Given that the p -value is below the 5% level we reject the null hypothesis of mean equality of the $SCI_{5mm,l}$ across angle class I and angle class II.

However, as we will see below, if we define \overline{SCI}_{5mm} as the SCI mean value considering the right and left sides, i.e.:

Chapter 4. Data Analysis

Observations on $SCI_{5mm,l}$, no premolars											
	1	2	3	4	5	6	7	8	9	10	Average SCI
Class I	40	23	23	43	40	37	50	36	25	44	36.1
Class II	26	24	23	27	34	29	23	30	31	38	28.5

Table 4.4: Observations on SCI, for left side, with no premolars

Observations on \overline{SCI}_{5mm} , without premolars											Average
	1	2	3	4	5	6	7	8	9	10	SCI
Class I	38.5	23.5	30.5	43.5	42	39	37.5	28.5	27.5	41.5	35.2
Class II	26	28.5	25	29.5	34	34.5	25	33.5	44.5	40.5	32.1

Table 4.5: Observations on SCI, for average value, without premolars

$$\overline{SCI}_{5mm} \equiv \frac{SCI_{5mm,r} + SCI_{5mm,l}}{2}$$

we will not be able to reject the null hypothesis of mean equality across angle class I and angle class II. In fact, consider now the hypothesis,

$$\begin{aligned} H_0 &: \mu_I(\overline{SCI}_{5mm}) = \mu_{II}(\overline{SCI}_{5mm}), \text{ with no premolars} \\ H_1 &: \mu_I(\overline{SCI}_{5mm}) \neq \mu_{II}(\overline{SCI}_{5mm}), \text{ with no premolars} \end{aligned} \quad (4.6)$$

Then, using Table 4.5 produces a value of t of 1.0135 and a p -value of 0.3243. So we have no statistical evidence to reject the null hypothesis.

Similarly, if we consider the hypothesis:

$$\begin{aligned} H_0 &: \mu_I(\overline{SCI}) = \mu_{II}(\overline{SCI}_{5mm}), \text{ with premolars} \\ H_1 &: \mu_I(\overline{SCI}_{5mm}) \neq \mu_{II}(\overline{SCI}_{5mm}), \text{ with premolars} \end{aligned} \quad (4.7)$$

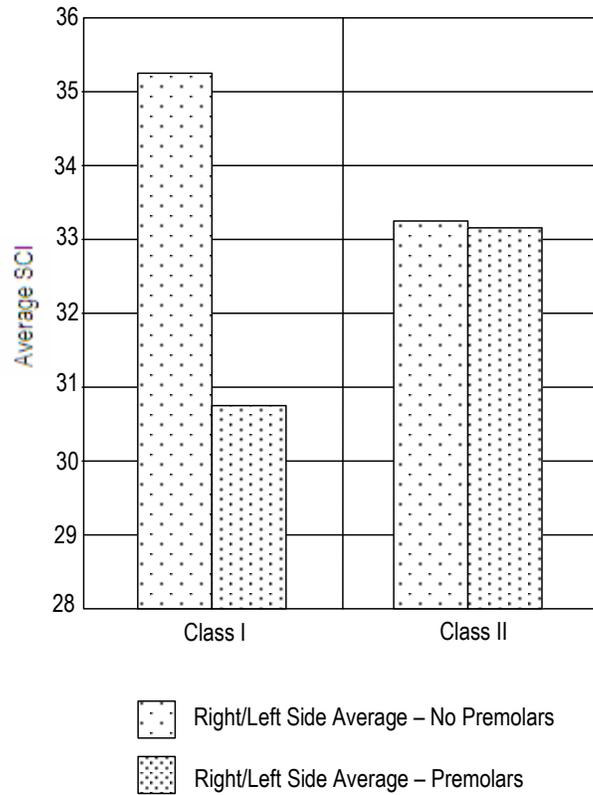


Figure 4.2: Right/Left Side Average Sagittal Condylar Inclination with/without premolars: Class I *vs* Class II

and consider Table 4.6 we get a t of -0.5773 and a p -value of 0.5709. Again, we have no statistical evidence to reject the null hypothesis of mean equality across angle class I and angle class II.

	Observations on \overline{SCI}_{5mm} , with premars										Average
	1	2	3	4	5	6	7	8	9	10	SCI
Class I	34.5	29	29.5	28.5	35.5	27	22.5	44	35	21.5	30.7
Class II	45	41.5	10	30.5	33	43	32.5	38.5	36	10.5	32.1

Table 4.6: Observations on SCI, for average value, with premolars

	$TCI_{5mm,r}$, no premolars										Average TCI
	1	2	3	4	5	6	7	8	9	10	
Class I	1	1	9	10	1	8	0	0	3	0	3.30
Class II	5	7	2	1	0	12	14	0	0	13	5.40

Table 4.7: Observations on TCI, for right side, without premolars

4.2 Comparison of TCI over Angle Class I and Angle Class II

Similarly to what was done in the latter section, we will cluster the TCI values by side an by functional phase. The first relevant hypothesis is given by:

$$\begin{aligned}
 H_0 & : \mu_I(TCI_{5mm,r}) = \mu_{II}(TCI_{5mm,r}), \quad \text{with no premolars} \\
 H_1 & : \mu_I(TCI_{5mm,r}) \neq \mu_{II}(TCI_{5mm,r}), \quad \text{with no premolars}
 \end{aligned} \tag{4.8}$$

The values necessary to test this hypothesis can be found in Table 4.7. The obtained t and p values were of -0.9449 and 0.3586, respectively.

Another relevant hypothesis is the following:

$$\begin{aligned}
 H_0 & : \mu_I(TCI_{5mm,r}) = \mu_{II}(TCI_{5mm,r}), \quad \text{with premolars} \\
 H_1 & : \mu_I(TCI_{5mm,r}) \neq \mu_{II}(TCI_{5mm,r}), \quad \text{with premolars}
 \end{aligned} \tag{4.9}$$

Using Table 4.9 we get a t of 0.2315 and a p -value 0.82, suggesting again no

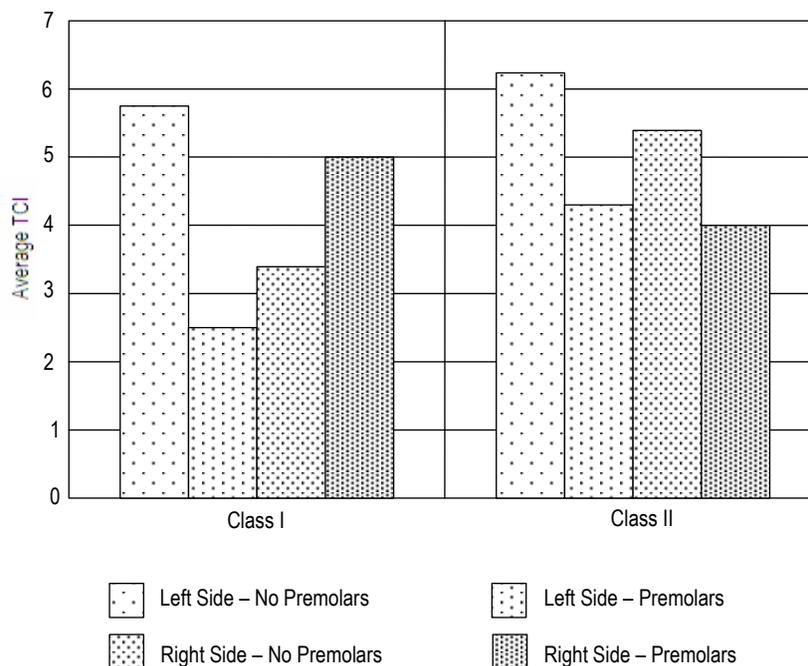


Figure 4.3: Transversal Condylar Inclinations with/without premolars: Class I *vs* Class II

evidence to reject the null hypothesis.

	TCI _{5mm,r} , with premolars										Average TCI
	1	2	3	4	5	6	7	8	9	10	
Class I	3	0	0	2	0	22	1	0	9	7	5.00
Class II	5	4	4	0	6	1	7	14	9	0	4.00

Table 4.8: Observations on TCI, for right side, without premolars

Chapter 4. Data Analysis

	TCI _{5mm,l} , no premolars										Average TCI
	1	2	3	4	5	6	7	8	9	10	
Class I	3	14	7	5	8	3	0	14	3	1	5.80
Class II	12	6	0	0	2	0	7	22	7	6	6.20

Table 4.9: Observations on TCI, for left side, without premolars

	TCI _{5mm,l} , premolars										Average TCI
	1	2	3	4	5	6	7	8	9	10	
Class I	0	0	1	0	3	4	13	0	4	0	2.50
Class II	0	1	n.a.	3	9	17	6	0	0	2	4.22

Table 4.10: Observations on TCI, for left side, with premolars

Similarly, for the left side we have the following hypothesis of interest:

$$\begin{aligned}
 H_0 & : \mu_I(TCI_{5mm,l}) = \mu_{II}(TCI_{5mm,l}), \quad \text{with no premolars} \\
 H_1 & : \mu_I(TCI_{5mm,l}) \neq \mu_{II}(TCI_{5mm,l}), \quad \text{with no premolars}
 \end{aligned} \tag{4.10}$$

and

$$\begin{aligned}
 H_0 & : \mu_I(TCI_{5mm,l}) = \mu_{II}(TCI_{5mm,l}), \quad \text{with premolars} \\
 H_1 & : \mu_I(TCI_{5mm,l}) \neq \mu_{II}(TCI_{5mm,l}), \quad \text{with premolars}
 \end{aligned} \tag{4.11}$$

Making use of Table 4.9 and Table 4.10 we obtain a t of -0.1501 and of -0.7513, and p -values of 0.8825 and 0.4646, respectively. Again, we have no evidence to reject the null of equality of TCI mean values across angle class I and angle class II. In Table 4.10, "n.a." means "not available", meaning that the axiography was not able to extract this value.

	Observations on s ,										Average s
	1	2	3	4	5	6	7	8	9	10	
Class I	45	35	51	60	56	50	50	65	31	41	48.40
Class II	50	57	39	52	69	61	53	70	55	61	56.70

Table 4.11: Observations on s , with premolars

	Observations on s										Average s
	1	2	3	4	5	6	7	8	9	10	
Class I	58	62	39	65	32	60	35	61	50	42	50.40
Class II	52	64	51	67	62	58	47	52	44	55	55.20

Table 4.12: Observations on s , with premolars

4.3 Comparison of s over Angle Class I and Angle Class II

Proceeding in an analogous manner to what has been done in latter sections, consider the following statistical hypothesis,

$$\begin{aligned}
 H_0 & : \mu_I(s) = \mu_{II}(s), \quad \text{with premolars} \\
 H_1 & : \mu_I(s) \neq \mu_{II}(s), \quad \text{with premolars}
 \end{aligned}
 \tag{4.12}$$

If we query Tables 4.11 and 4.12 we achieve values of t of -1.8609 and -1.048, and p -values of 0.07955 and 0.3115, respectively. Again, we have no evidence to reject the null at the 5% level.

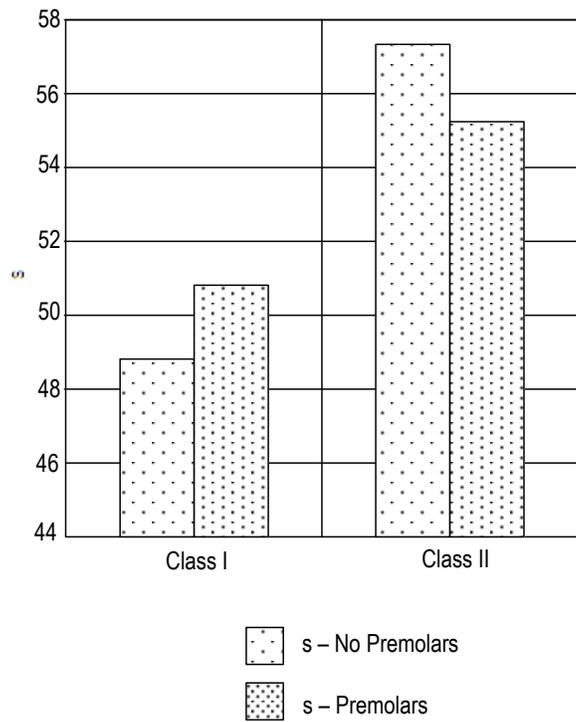


Figure 4.4: s values with/without premolars: Class I vs Class II

Chapter 5

Concluding Remarks

In this work we study whether there are significant differences over angle class I and class II for some relevant temporomandibular joint angle measures, namely the SCI, the TCI, and the s . In order to analyze such hypothesis it was extracted a sample of the aforementioned angles from individuals in the first and second functional phases of mixed dentition. The data was collected through computerized axiography (CADIAX), the use of an articulator, and a cephalometric analysis.

This work provides evidence supporting that there is no statistical evidence to reject the null hypothesis of mean value equality of such measures between angle classes I and II.

Future research should be towards the analysis of the third functional period of mixed dentition, in order to assess further where the angle classes differences begins in fact. It should also be pointed out that given the canine morphology, its eruption will bring a new steepest guidance dominance which implies slope variations in the TMJ, which could affect our results. Further, the eruption of the second molar will give an individual spherical form to occlusion changing relations in the stomatognathic organ, which could also have consequence on the results achieved.

Appendix A

Appendix

In this appendix, we state the collected data set. The following legend will prove to be useful:

n.a.

not available

Type

$C_I NP$ - Angle class I, no premolars.

$C_{II} NP$ - Angle class II, no premolars.

$C_I P$ - Angle class I, with premolars

$C_{II} P$ - Angle class II, no premolars

Biotype

D - Dolic

M - Mesio

Appendix A. Appendix

Race

C - Caucasian

A - Afro-European

Appendix A. Appendix

Patient Code	Type	Biotype	Race	Age	s
CD	$C_I NP$	D	C	9	45
GC	$C_I NP$	D	C	9	35
AV	$C_I NP$	D	C	9	51
AL	$C_I NP$	D	C	12	60
DA	$C_I NP$	M	C	9	56
FO	$C_I NP$	D	A	9	50
NC	$C_I NP$	M	A	9	50
AF	$C_I NP$	D	A	9	65
RN	$C_I NP$	D	A	9	31
TM	$C_I NP$	M	A	8	41
BL	$C_{II} NP$	M	C	8	50
TC	$C_{II} NP$	M	C	8	57
AC	$C_{II} NP$	D	C	10	39
JM	$C_{II} NP$	M	C	9	52
JEM	$C_{II} NP$	D	C	9	69
IS	$C_{II} NP$	D	C	8	61
RR	$C_{II} NP$	D	C	9	53
IF	$C_{II} NP$	D	C	8	70
J	$C_{II} NP$	D	C	10	55
D	$C_{II} NP$	M	C	10	61
SS	$C_I P$	D	C	10	58
CN	$C_I P$	D	C	10	62
SF	$C_I P$	D	C	11	39
DA	$C_I P$	M	C	11	65
LF	$C_I P$	M	A	11	32
MC	$C_I P$	D	C	10	60
LN	$C_I P$	M	A	13	35
PT	$C_I P$	D	C	9	61
VT	$C_I P$	D	A	9	50
WF	$C_I P$	D	A	9	42
IA	$C_{II} P$	D	C	11	52
BM	$C_{II} P$	M	C	10	64
RV	$C_{II} P$	D	A	10	51
JS	$C_{II} P$	M	C	9	67
LS	$C_{II} P$	D	A	9	62
NP	$C_{II} P$	D	C	10	58
AT	$C_{II} P$	M	C	11	47
JG	$C_{II} P$	M	C	10	52
JC	$C_{II} P$	D	C	10	44
CR	$C_{II} P$	D	C	10	55

Table A.1: Patient Angle Class, Biotype, Race, Age and s Values

Appendix A. Appendix

Patient Code	SCI _{3mm,r}	SCI _{3mm,l}	SCI _{5mm,r}	SCI _{5mm,r}
CD	41	42	37	40
GC	19	16	24	23
AV	37	13	38	23
A	50	48	44	43
DA	44	41	44	40
FO	41	34	37	41
NC	18	70	25	50
AF	20	34	21	36
RN	25	23	30	25
TM	40	44	39	44
BL	21	19	26	26
TC	32	20	33	24
AC	27	21	27	23
JM	31	24	32	27
JEM	35	30	34	34
IS	34	20	40	29
RR	27	30	27	23
IF	27	34	37	30
J	69	28	58	31
D	34	36	43	38
SS	38	29	38	31
CN	28	32	26	32
SF	21	27	24	35
DA	24	26	27	30
LF	31	32	36	35
MC	8	28	22	32
LN	17	21	22	23
PT	44	48	46	42
VT	39	31	39	31
WF	19	16	23	20
IA	45	37	48	42
BM	41	43	41	42
RV	4	0	20	0
JS	29	26	31	30
LS	32	34	32	34
NP	44	50	42	44
AT	31	30	33	32
JG	32	40	38	39
JC	35	27	37	35
CR	0	17	0	21

Table A.2: SCI values for 3mm and 5mm

Appendix A. Appendix

Patient Code	TCI _{3mm,r}	TCI _{3mm,l}	TCI _{5mm,r}	TCI _{5mm,l}
CD	0	2	1	3
GC	0	4	1	14
AV	18	2	9	7
A	7	4	10	5
DA	0	11	1	8
FO	6	2	8	3
NC	0	22	0	0
AF	20	34	0	14
RN	2	4	3	3
TM	0	1	0	1
BL	6	12	5	12
TC	11	4	7	6
AC	3	0	2	0
JM	0	n.a.	1	0
JEM	0	1	0	2
IS	16	4	12	0
RR	16	4	14	7
IF	0	11	0	22
J	21	3	0	7
D	18	4	13	6
SS	3	1	5	0
CN	3	0	4	0
SF	6	0	4	1
DA	0	0	0	0
LF	9	5	6	3
MC	1	5	1	4
LN	14	15	7	13
PT	9	0	14	0
VT	15	6	9	4
WF	0	0	0	0
IA	3	0	3	0
BM	0	2	0	1
RV	0	n.a.	0	n.a.
JS	4	2	2	3
LS	0	3	0	9
NP	22	20	22	17
AT	2	5	1	6
JG	0	0	0	0
JC	7	0	9	0
CR	6	n.a.	7	2

Table A.3: TCI values for 3mm and 5mm

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