CAN AN ORTHOPANTOMOGRAPH BE USED AS AN INDICATOR OF VERTICAL JAW RELATIONS?

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DECLARATION

I, Mohamed Faried Suliman, declare that this research report is my own work. It is being submitted for the degree of Master of Science in Dentistry in the branch of Orthodontics at the University of the Pretoria. It has not been submitted before for any degree or examination at this or any other university.

Signature of Candidate

Date: 2014

DEDICATION

This research is dedicated to my son Muhammad Saeed, my family, students and colleagues

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Sincere gratitude is due to:

God, for His Infinite Mercy, Kindness and Blessings

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KEYWORDS

Orthopantomograph

Lateral cephalogram

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Vertical Growth

Horizontal Growth

Vertical Dysplasia

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SUMMARY

Introduction: Clinicians have long been interested in the multitude of differences in the diagnosis, treatment, and the treatment response between the hyperdivergent or dolicofacial types and hypodivergent or brachyfacial types.

Since its introduction by Broadbent in 1931, the cephalometric radiograph is used as the golden standard in orthodontic diagnosis and treatment planning. Many analyses have been created by which to compare skeletal and dental relationships.

Lateral cephalometry is an important tool in orthodontic diagnosis of the vertical jaw relationships, treatment planning, prediction of growth and the evaluation of these different facial forms. Little research has been undertaken to evaluate how valuable an orthopantomograph radiograph is in diagnosing and treatment planning orthodontic patients with regard to facial types.

Purpose: The aim of this study was to evaluate the use of the measurements taken from the orthopantomograph as compared to that of the lateral cephalogram for investigating the vertical jaw relationship patterns of individuals.

Materials and Methods: The sample size consisted of ninety patients, equally divided into the three different growth patterns namely dolicofacial, mesofacial and brachyfacial. Lateral cephalograms and orthopantomographs of these patients were compared

The patients were categorized as vertical, normal and horizontal. The cephalogram was used as the gold standard for the three different categories

The gonial angle which is the angle between the tangents of the inferior border and posterior border of the mandible was measured on the lateral cephalogram and the orthopantomograph. The upper and lower facial heights was measured on the lateral cephalogram, as well as the Y axis. The condyle angle which is an angle formed at the intersection of the ramus height and a line parallel to the posterior tangent line was measured on both the orthopantomograph and the lateral cephalogram. The ramus height was also measured on both the lateral cephalogram and orthopantomograph.

Results: Comparisons were made of the mean and standard deviation and the median values from the gonial angle, the ramus height and the condyle angle, measured for the three different growth types. With respect to the normal growth pattern and the horizontal growth pattern the mean and median for the gonial and the condyle angles, there was no significant difference. However there was a significant difference in the mean and median values for the ramus height.

The results were different for the vertical patient. The mean and median values for both the gonial angle and the ramus height differed significantly for the two

radiographs. While the mean and median values for the condyle angle did not differ significantly.

The results with respect to the correlations showed significant correlations between the gonial angle and the condyle angle for all three growth patterns. However this was not the case for the ramus height.

Conclusion: Based on these findings it can be concluded that angular measurements could be correlated between the two radiographs. There is however, little consistency between the linear measurements taken from an orthopantomograph and that of a lateral cephalogram.

CHAPTER 1

1.1 Introduction

The vertical dimension of the face has been a subject of study and debate since orthodontics became a specialty. The diagnosis of the vertical facial dimension is a complex problem. It may be simplified by studying a face and applying common sense diagnostic tools to ascertain that the lower face is too long or too short.

Vertical Dysplasia’s are to some extent the result of growth that was programmed in that direction, but their expression is influenced by the interactions of both form and function. The clinician must make a careful differential diagnosis for each patient who seeks his or her care. The diagnosis must analyze all three components of malocclusion namely, facial, dental and skeletal.

Orthodontics is more than merely the correction of dental malocclusion. It also includes diagnosis and treatment of facial and skeletal problems, upper airway obstruction, temperomandibular dysfunction, and abnormal myofunctional habits. Each component must be carefully studied and understood so that the proper questions are asked and the correct diagnostic decisions are made to lead to an effective treatment plan.

Every person's face is different. We have the ability to perceive exceedingly subtle differences in the relative shape, size, and proportions of both the hard and soft tissue parts and also the minute variations in the topographic contours amongst them.

Two extreme forms exist for the shape of the face:

- the long and narrow, dolicofacial form and
- the wide and short, brachyfacial form
- the intermediate one is the mesofacial form

All three of the above have different vertical facial relationships.

Clinicians have long been interested in the multitude of differences in the diagnosis, treatment, and the treatment response between these hyperdivergent or dolicofacial types and hypodivergent or brachyfacial types. Radiographs are an important diagnostic tool in assessing these different facial types, thereby enabling and determining a suitable treatment plan.

Lateral cephalometry is an important tool in orthodontic diagnosis of the vertical jaw relationships, treatment planning, prediction of growth and the evaluation of these different facial forms. However the major source of error in cephalometric analysis includes radiographic film magnification, superimposition, tracing, measuring, recording and landmark identification.

To overcome all these limitations of lateral cephalograms, the orthopantomograph plays a significant role in almost every field of clinical dentistry. The popularity of the orthopantomograph stems from the simplicity of the operation, its low radiation dosage when compared to a conventional lateral cephalogram and full mouth periapical radiographs, and the wide field of visible projected structures with reduced superimposition of the investing tissue. In this manner, some limitations of lateral cephalograms can be overcome by using the orthopantomograph (Shahabi *et al*., 2009).

This study is therefore undertaken to evaluate the accuracy of the measurements taken from the orthopantomograph as compared to that of the lateral cephalogram for investigating the vertical jaw relationship patterns of individuals.

CHAPTER 2

2.1 Literature review

The two most common radiographs used in orthodontics are the orthopantomograph and the lateral cephalogram view.

The orthopantomograph was first introduced by the University of Helsinki in 1961 (White and Pharoah, 2000). The radiograph provides information about the presence and position of unerupted teeth, the health of the supporting bone around the teeth, the joints of the lower jaw, sinuses, and both the jaw bones (maxilla and mandible).

Figure 1: Orthopantomograph

Orthopantomography is a very popular and widely accepted radiographic technique of the oral region. The radiograph allows the visualization of the left and right sides of craniofacial structures by producing an accurate, predictable image of all the teeth and related structures on the radiograph. This radiograph is an easy and quick process, with minimal amount of radiation to the patient and the operator.

Since the introduction of cephalometrics by Broadbent in 1931, orthodontists have used the measurements on the lateral cephalogram to analyze the relationship between teeth, bone, and the facial soft tissues. Cephalometric analysis has thus contributed to the analysis of a malocclusion and has become a standardized diagnostic method in orthodontic treatment planning. It is also used extensively in research.

The lateral cephalogram is a profile radiograph of the skull and soft tissues and is used to assess the relationships of the teeth in the jaws, the jaws to the skull and that of soft tissues to the teeth and jaws. In children, growth predictions can be made and we can also determine the changes that have occurred with treatment. Similarly in adults, the treatment plan can be predicted with varying degrees of accuracy and the results can also be quantified.

Lateral cephalometric radiographs are an important diagnostic aid in determining the extent of any maxillomandibular discrepancy in two planes of space - namely the sagittal and the vertical. They help determine the size and the relationship of various anatomical structures to one another, including the soft-tissue covering relative to the supporting skeletal structures.

These radiographs also provide comparative data for evaluating any growth or changes that can occur in the patient following orthodontic treatment.

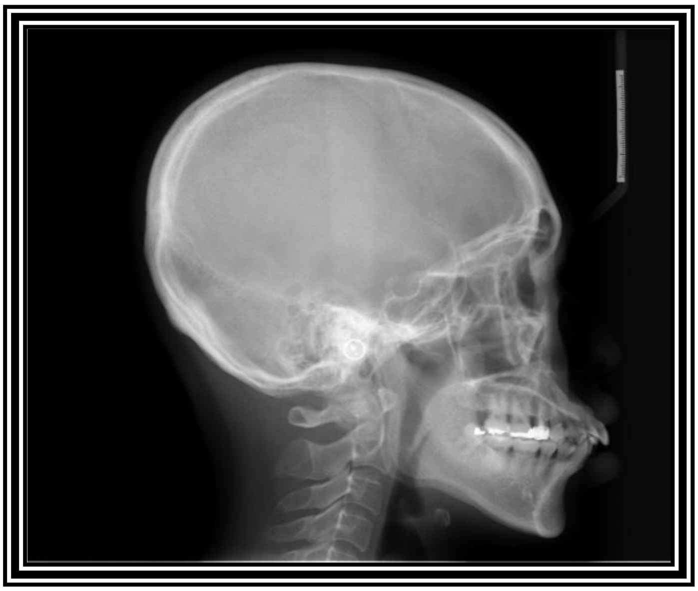


Figure 2: Lateral cephalogram

Cephalometric analysis is often used as an adjunct to clinical assessment of the skeletal pattern and maxillomandibular discrepancy. The cephalometric radiograph and the analysis are considered to be part of the 'gold' standard for diagnosis at the start of orthodontic treatment.

Although the lateral cephalogram provides much information regarding the craniofacial structure, it is impossible to accurately visualize the right and left sides of these structures in a single radiograph due to the superimposition of the two sides.

Ideally, panoramic and cephalometric radiographs should be taken when information from the clinical examination is considered insufficient. Guidelines for orthodontic radiographs permit panoramic radiographs as part of an orthodontic assessment to determine the condition of the dentition and presence or absence of unerupted teeth (Isaacson *et al.*, 2008).

Cephalometric radiography is only justified if it directly influences the information of other non-radiographic records used in orthodontic treatment planning. Besides its role in orthodontic treatment planning, anatomical structures on cephalometric radiographs need to be interpreted for evidence of disease or injury (National Council on Radiation Protection and Measurements, 2003). Further utilization of cephalometric radiography has also been claimed as a screening tool to determine the need for a more rigorous ear, nose and throat follow-up concerning deviant measurements of adenoid size (Major *et al*., 2006).

Cephalometric radiographs may also be used for assessment of the possible difficulty of attaining an ideal occlusion after specific orthodontic treatment, to assist in the location and assessment of unerupted, malformed, or misplaced teeth and to identify optimal treatment timing in dentofacial orthopaedics (Pae *et al*., 2001). Limited serial cephalometric radiographs may help in the assessment of a trend in the growth, or to monitor treatment changes (Isaacson *et al.*, 2008).

Superimposition of different bilateral anatomic landmarks, such as the condyle and gonion, present great challenges during their tracing and radiographic analysis.

An average of these landmarks is calculated to overcome these problems. However, by doing so, not only is the bilateral information of the patient lost, but it is also impossible to evaluate any asymmetry that may exist in the mandible.

The orthopantomograph present all anatomic landmarks in a panoramic view, thus demonstrating the right and left landmarks for the bilateral structures. In addition, it displays many anatomic landmarks with great detail and enables the diagnosis of mandibular asymmetries. Therefore, the panoramic radiograph is a valuable orthodontic screening tool.

For many years, the limitations of orthopantomographs have been contemplated. The orthopantomograph does display limitations that can limit its accuracy. These limitations include:

- image magnification
- geometric distortion and
- superimposed images

Consequently, there are very few studies that involve the use of orthopantomographs in evaluating dentoskeletal measurements (Akcam *et al*., 2003; Piedra, 1995).

Some studies have also shown that vertical and horizontal linear measurements in orthopantomographs are unreliable.

Tronje *et al*. (1981) stated that horizontal assessments of linear dimensions on panoramic radiographs are unreliable, but the vertical dimensions are reliable if patients are properly positioned. Likewise, Turp *et al.* (1996) advocated that vertical linear measurements of the condyle and the ramus, obtained by direct measurements of skulls, were poorly correlated with their value obtained from the panoramic radiographs. Van Elslande *et al.* (2008) claimed that although vertical measurements were more accurate than horizontal or angular measurements, they were not true representations of the real objects to which they corresponded. He therefore advised to be cautious when using conventional or digital panoramic images to assess mandibular asymmetry. For this reason, many studies have focused only on angular measurements (Akcam *et al.,* 2003; and Frykholm *et al*., 1977).

Levandoski was one of the first to introduce a method of orthopantomographic analysis for evaluating facial asymmetry (Levandoski, 1993). According to him, in these cases of asymmetry, it is especially challenging to achieve reliable skeletal measurements owing to the interference presented by superimposed images of the lateral cephalograms.

Further studies have since been conducted to investigate the possibility of enhancing the clinical versatility of orthopantomographs to evaluate changes in craniofacial morphology in comparison with lateral cephalograms (Ongkosuwito *et al*., 2009; and Shahabi *et al*., 2009).

An online search of the literature has also revealed that there are no published articles specifically studying the interrelationship between facial type and condylar position.

The orthodontic diagnosis of the vertical dimension is complex and multifactorial and there is generally more than one single causative factor. The clinician should have amongst others, an understanding of mandibular and condylar growth, sutural lowering of the maxillary complex, dentoalveolar development, dental eruption, and the patient‘s oral habits and respiration.

2.2 Orthodontic Diagnosis

Orthodontic diagnosis and treatment planning has three components: to consider: facial, dental and skeletal. The facial diagnosis is performed immediately upon meeting the patient and has become increasingly important as the orthodontic fraternity is undergoing a paradigm shift of only the hard tissue analysis as the primary concern to include soft tissue analysis as well.

Angle's model of ideal occlusion and harmony of the dental and skeletal components is being replaced by the soft tissue aesthetics and the functional goals of the soft tissue paradigm (Table 1).

Table 1: Comparison between Angle's paradigm and soft tissue paradigm: A new way of looking at treatment goals (Proffit, 2007)

	Angle Paradigm	Soft Tissue Paradigm
Primary goal of treatment	Ideal dental occlusion	Ideal soft tissue proportions and adaptations
Secondary goal of treatment	Jaw relationships	Functional occlusion
Hard versus soft issue relationships	Ideal skeletal and dental relationships produces ideal soft tissue	Ideal soft tissue defines ideal skeletal and dental relationships
Diagnostic emphasis	Dental cast and radiographs	Clinical examination of soft tissues
Treatment approach	Obtain ideal dental and skeletal relationships and the soft tissue will follow	Determine ideal soft tissue relationships and then place the jaws and teeth as needed to obtain them

According to Angle, the diagnosis and treatment planning should focus on the skeletal and dental components and that the soft tissue relationships were merely a by-product of the latter relationship.

This is at variance with the soft tissue paradigm, which states that the proportions of the soft tissue of the face and the relationship of the dentition to the lips and face are the major determinants of facial appearance. Therefore, ideal soft tissue relationships and aesthetics are considered first and the skeletal and dental relationships are secondary goals (Proffit, 2007; Graber *et al*., 2005).

2.2.1 Facial Evaluation and Diagnosis

During the initial clinical examination, facial photographs are taken and these would most commonly include facial frontal, facial profile, facial smile, oblique smile and the intra-oral photographs (Graber *et al.,* 2005).

Lay people are increasingly aware of facial aesthetics, dental irregularities and malocclusions. Otuyemi and Kolawole (2005) demonstrated a strong relationship in the perceptions of dental appearance by patients and parents. Patients also have perceived opinions on their treatment outcomes. Ethically, orthodontists have a responsibility to consider the patients' goals during the planning of the treatment options. Facial photographs enable two-dimensional soft tissue analysis in horizontal and vertical planes for the purposes of evaluating facial asymmetries and soft tissue characteristics. In addition, lip fullness, lip incompetence, chin protrusion, facial convexity, gingival display, smile arc and overall facial balance should be considered in the overall treatment plan. Facial photographs should be examined in consultation with the patient and the soft tissue goals should be agreed upon.

Analysis of the frontal facial photographs focuses on proportions and asymmetries. A small degree of bilateral facial asymmetry exists in essentially all normal individuals, and this is considered as normal asymmetry. An ideally proportioned face can be divided into central, medial, and lateral equal fifths, and superior, middle, and inferior facial thirds (Proffit, 2007).

The study of facial balance using photographs is not unique to orthodontics.

The works of the anthropologist, Farkas (1994) provided norms for twelve facial dimensions routinely used in orthodontic diagnosis.

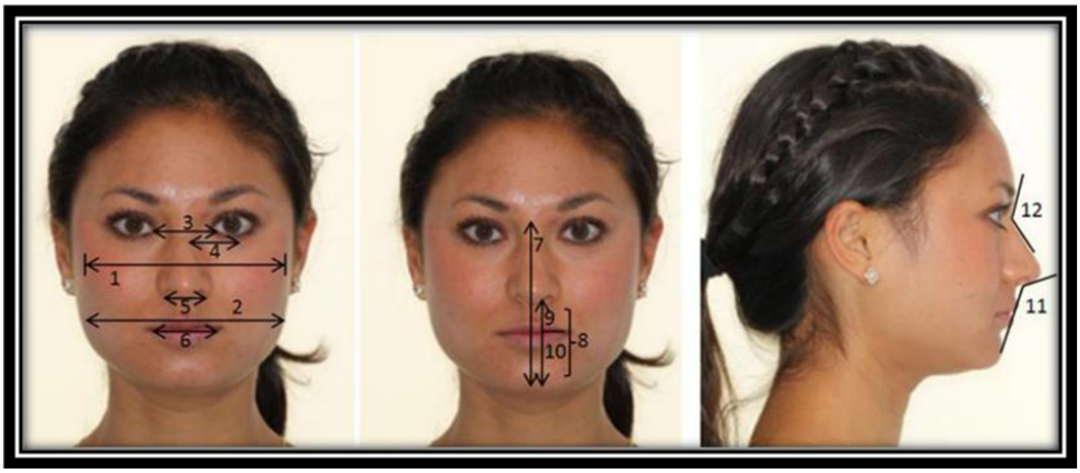


Figure 3: Anthropometric facial analysis (Farkas, 1994)

The above Figure describes the dimensions that Farkas showed on a study done in 1994. The study was done on Canadians and modern Europeans. The results of the study provided the data shown in Table 2.

Table 2: Facial soft tissue averages determined by Farkas, 1994

	Parameter	Grading students	Change
1.	Zygomatic width (Zy-Zy) (mm)	137(4.3)	130(5.3)
2.	Gonial Width (Go-G0) (mm)	97(5.8)	91(5.9)
3.	Intercanthal distance (mm)	33(2.7)	32(2.4)
4.	Pupil-midfacial distance (mm)	33 (2.0)	31(1.8)
5.	Nasal base width (mm)	35(2.6)	31(1.9)
6.	Mouth width (mm)	53(3.3)	50(3.2)
7.	Face height (N-Gn)(mm)	121(0.8)	112(5.2)
8.	Lower face height 9subnasale-Gn)(mm)	72(6.0)	66(4.5)
9.	Upper Lip vermilion (mm)	8.9(1.5)	8.4(1.3)
10.	Lower lip vermilion (mm)	10.4(1.9)	9.7(1.6)
11.	Nasolabial angle (degrees)	99(8.0)	99(8.7)
12.	Nasofrontal angle (degrees)	131(8.1)	134(1.8)

Modern day orthodontists routinely analyse facial photographs for symmetry in facial fifths and facial thirds to determine soft tissue balance. Analysing the frontal view in terms of fifths and thirds, points to potential asymmetries and helps the clinician determine if the treatment should address the discrepancy.

Another study done by Meyer-Marcotty *et al.* (2011), noted that compared to orthodontists and oral surgeons, laymen were also able to detect asymmetries when located near the midline, and they believed asymmetries of the nose to be more negative than those of the same degree of the chin. The increasingly educated and perceptive public has helped develop the current soft tissue paradigm shift and an increased focus on facial symmetries as determined by photography.

The facial frontal smile photograph is used to assess what could be called mini-aesthetics. These include an assessment of gingival display, tooth display, gingival heights, and buccal corridors. Along with the attention to the soft tissue treatment objectives, mini-aesthetics is routinely a part of the patient's chief complaint. Smile arc and buccal corridors have become part of the layperson's orthodontic focus and research has been dedicated to layperson's perspective of these dental characteristics.

As described by Sarver (2001) and depicted in Figure 4, the smile arc is defined by the curvature of the maxillary incisal edges being consonant to the curvature of the lower lip. Buccal corridors exist when the transverse dimension of the maxillary dentition is deficient in relation to the adjacent soft tissue. Black shadows appear in the lateral segments of the smile giving an unaesthetic appearance.

Figure 4: The smile arc (Sarver, 2001)

Sarver's research focused on the smile arc from the frontal point of view. In addition to the frontal smile, the oblique/45 degree smile photograph studies the relationship between the occlusal plane and curvature of the lower lip (i.e. the smile arc). However, Springer *et al.* (2011) defined the ideal smile arc as one where the occlusal plane is consonant with the curvature of the lower lip in the antero - posterior direction. Therefore, according to Springer the oblique smile photograph is necessary to able to critique the smile arc.

The profile photograph is used to assess facial convexity, nose and chin protrusion and the anterior-posterior relationship between the maxilla and mandible (Figure 5).

Figure 5: Facial outlines depicting Class I, Class II and Class III profiles (Jacobson, 1995)

Orthodontic skeletal diagnosis has long been, and continues to be, based on cephalometric radiographs. A facial profile photograph allows the analysis of the face from the same perspective as the lateral cephalometric radiograph, however in this case its purpose is soft tissue evaluation.

The maxillo-mandibular relationship, chin projection and/or retrusion, lip competence and any other lateral soft tissue views may be studied from the profile photograph. Although skeletal dimensions may not be determined from a facial photograph, in many cases skeletal discrepancies are evident on the photographs.

The above Figure depicts Class I, Class II, and Class III facial profiles. Although maxillary and mandibular dimensions are not known, the type of skeletal disharmony is evident.

2.2.2 Dental Evaluation and Diagnosis

In 1899, Edward Angle defined ideal dental occlusion based on the maxillary and mandibular first molars. The mandibular arch is, as we know somewhat smaller than the upper arch, the labial and buccal surfaces of the teeth of the upper jaw slightly overhang those of the lower jaw. In normal occlusion the mesio-buccal cusp of the upper first molar lies in the sulcus between the mesial and distal buccal cusps of the lower first molars. The slight overhanging of the upper teeth brings the buccal cusps of the bicuspids and molars of the lower jaw into the mesio-distal sulci of the opposing teeth, while the upper centrals, laterals, and cuspids overlap the lower anterior teeth about one-third the length of their crowns.

Figure 6 is a lateral view of Angle's ideal Class I dental occlusion. Vertical lines on the maxillary first molar clearly demonstrate its relationship of the mesial buccal cusp resting in the embrasure of the buccal groove of the mandibular first molar.

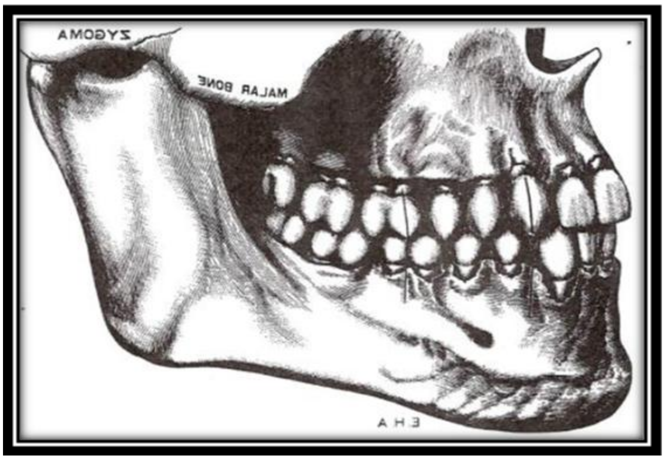


Figure 6: Class I dental occlusion (Angle, 1899)

The maxillary central and lateral incisors are larger in height and width than the mandibular central and lateral incisors. The upper central incisors overlap the lower incisors about one-third the length of their crowns and extend beyond them distally overlapping about one-half of the opposing mandibular lateral incisors.

The first molars are also the reference point for defining Class II and Class III malocclusion. A Class II malocclusion exists when the lower first molar is positioned distally relative to the upper first molar. In most cases a Class II dentition will exhibit maxillary incisors in a forward position relative to the lower incisors with the presence of an increased overjet.

Class II malocclusions are further defined by the relationship of the anterior segments. In the Class II division 1 malocclusion, the upper incisors are more proclined in relation to the remainder of the maxillary dentition establishing an enlarged overjet (Figure 7), while a Class II division 2 malocclusion presents with retroclined central incisors, and a decreased overjet.

Figure 7: Dental appearance of Class II division 1

Class III malocclusion (Figure 8) exhibits a mandibular first molar that is mesially positioned relative to the maxillary first molar. Most often the maxillary incisors in a Class III malocclusion are behind the mandibular incisors and it is noted as a negative overjet.

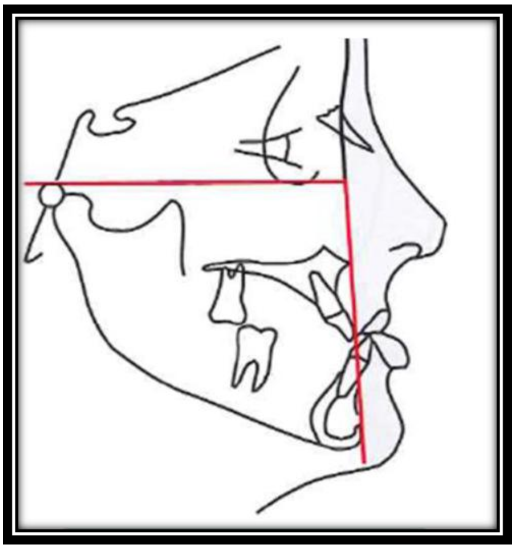


Figure 8: Class III dental and facial appearance (Jacobson, 1995)

Both Class II and Class III malocclusion are defined when at least one side of the dentition exhibits the molar relationship of the particular type of classification.

Earlier studies have demonstrated the influence that the treatment philosophy and diagnostic records have on orthodontic diagnosis and treatment planning.

Brown *et al.* (1977) evaluated the responses of four orthodontists to the treatment needs of fifty orthodontic patients by only using study models. All fifty cases were studied three times at weekly intervals answering the following questions:

- was treatment necessary
- why was treatment necessary, and
- when should treatment begin

In forty one of the fifty cases (82%) it was thought by at least one examiner that treatment was indicated, but disagreement existed among them as to why and when treatment should begin.

Following Brown's study, Silling *et al*. (1979) focused on the value orthodontists placed on cephalometric radiographs in treatment planning of orthodontic cases. Twenty-four orthodontists independently evaluated six cases, three with the radiograph and three without, and questionnaires were provided for each case focusing on treatment decisions and growth patterns. The author's demonstrated high or total agreement on treatment decisions with or without cephalometric radiographs; therefore, it may be necessary for orthodontists to reassess their routine use of cephalometric radiographs.

Brown and Silling were both able to demonstrate orthodontists' confidence in treatment planning with limited diagnostic information. However, neither study distinguished between what was the most important aspect of the records.

Han *et al.* (1991), sought to evaluate how each record, when provided incrementally, contributes to treatment decisions. Pretreatment records of fifty seven orthodontic cases were evaluated on five different occasions by five separate orthodontists. The records were provided in the following stages:

1) Study models (S)
2) S + facial photographs (F)
3) S + F + panoramic radiograph (P)
4) S + F + P + lateral cephalogram (C)
5) S + F + P + C + tracing

A diagnostic standard (DS) was created for each case by each orthodontist based on their evaluation at stage five and used to compare to treatment decisions rendered at the other four stages. Overall the DS was achieved with study models alone in 54.9% of the cases, study models and photographs - 54.2%, study models, photographs and orthopantomographs - 60.9% and study models photographs, orthopantomographs and cephalometric radiograph 59.9%. Similar to Brown *et al.'s* results fourteen years prior, Han *et al.*, showed study models alone were sufficient in treatment planning cases almost 55% of the time and the addition of a cephalometric radiograph decreased the DS by 1% compared to the same records without a cephalometric radiograph.

During the time Han *et al.,* (1991) were evaluating treatment decisions relative to increases in available diagnostic records, Atchinson *et al.,* (1991) were focusing on the contribution of radiographs to treatment plans. Thirty-nine orthodontists diagnosed and created treatment plans for six cases using orthodontic records which included the study models, facial and intra oral photographs, and medical and dental histories. Following the initial evaluation the clinician requested any radiograph he desired and reported his gain in confidence of the treatment plan. There were seven hundred and forty one radiographs ordered, of which one hundred and ninety two produced changes in the diagnoses, and the lateral cephalometric radiograph was the most productive. The results showed that orthodontists were approximately 75% confident of their diagnosis before reviewing any radiograph.

A diagnosis of the vertical dimension is more complicated because vertical discrepancy malocclusions are multidimensional. For example, dentoalveolar abnormalities can impact the skeletal pattern, and poor skeletal patterns can cause dentoalveolar compensations that are difficult for the clinician to correct. The following variations can be present, either alone or in combination:

1) maxilla: maxillary posterior alveolar excess and inferiorly positioned maxilla and

2) mandible: mandibular posterior alveolar excess and short mandibular rami. Other abnormalities may include superiorly positioned condylar fossa, obtuse cranial base angle, and condylar resorption

Any of these conditions, with or without aberrant mandibular growth rotation, can be a causative factor in the vertical discrepancy malocclusion.

2.3 Mandibular and Condylar Growth

A common scenario affecting the skeletal problem is mandibular growth and growth rotation, which unfavourably impacts dentoalveolar development in both the maxilla and mandible. From as early as the 1960's, Björk, Björk and Skieller in 1972 and 1983 respectively, have performed numerous studies that have shown that the most common direction of condylar growth is vertical, with some anterior component. Patients with a pronounced short lower anterior facial height (Figure 9 A and B) generally exhibit upward and forward condylar growth (Figure 10).

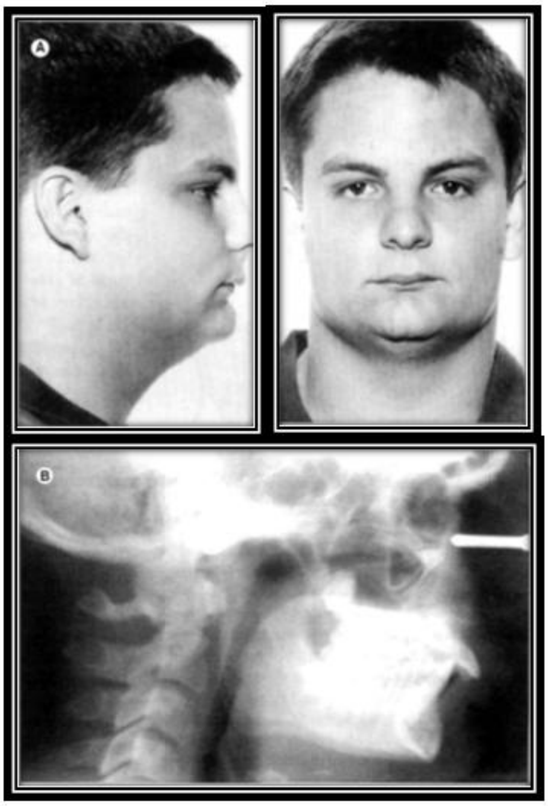


Figure 9: A patient with a pronounced short lower anterior facial height. (A) The cephalometric radiograph is also shown. (B) (Björk and Skieller, 1983)

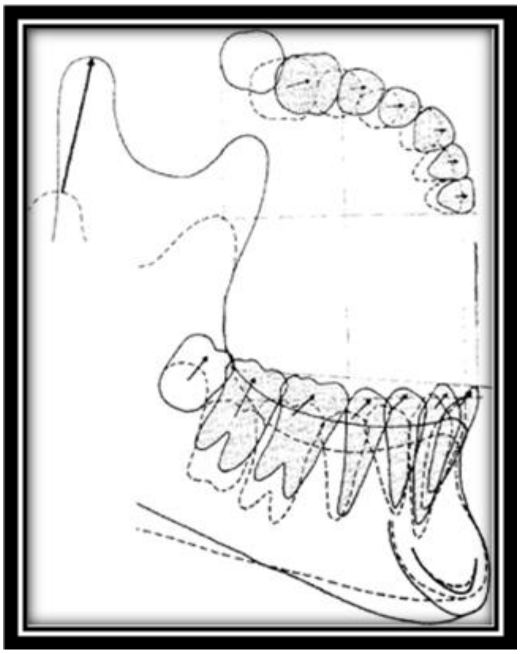


Figure 10: An example showing upward and forward condylar growth. (Björk, 1972)

These individuals generally have a deep vertical overbite with a deep mentolabial sulcus and a strong over closed appearance.

In contrast, patients with a long-face syndrome (Figure 11 A and B) have a more posteriorly directed growth pattern of the mandibular condyle (Figure 12). (Schudy, 1964)

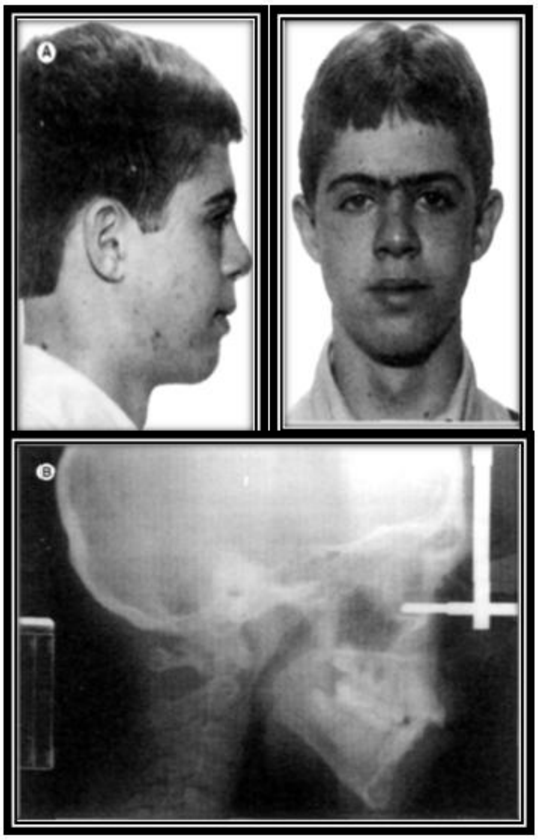


Figure 11: An example of a patient with long-face syndrome. (A) The cephalometric radiograph is also shown. (B) (Björk and Skieller, 1983)

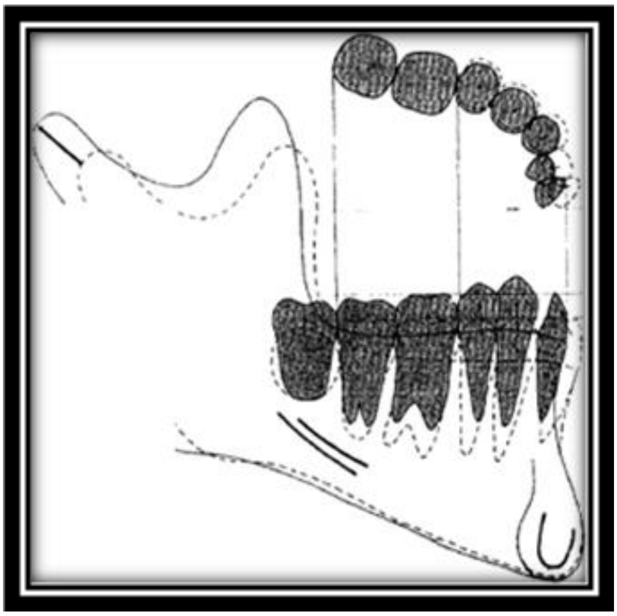


Figure 12: An example showing a posterior-directed growth pattern of the mandibular condyle. (Isaacson, 1977)

These backward growth rotators have increased anterior facial height, a more posterior position of the chin, and in extreme cases, an anterior open bite may develop.

An understanding of the maxillomandibular growth rotation of the patient would be most helpful in the diagnosis of vertical variations. Björk (1969) has contributed information that offers some guidelines for the clinician to assist in the determination of the growth rotation of the mandible so that the concomitant vertical changes are more easily understood. His method of prediction of condylar growth rotation from a cephalogram offers the clinician some guidelines. Seven specific structural features that might develop as a result of remodelling during a particular type of growth rotation were identified.

However his suggestions for predicting condylar rotation have not been widely used by the clinicians because:

1) some of the indicators cannot be easily seen on the average cephalogram
2) the use of the indicators is very time-consuming for the clinician, and
3) there has been no scientific validation of the suggested indicators because of difficulties encountered in the study design

Some in the field also question whether several of the suggestions are valid indicators of a particular type of growth rotation. However, when used for their intended purpose, as guidelines only, the indicators have some useful clinical applications in the diagnosis of the patient with vertical dysplasia.

Using Björk's guidelines, it is interesting to study Figures 8B and 10B.

Figure 8 B, the forward rotator,

Exhibits several of Björk's indicators including observations that:

1) the condylar head curves forward
2) the mandibular canal is curved
3) the symphysis has a backward cant
4) the interincisal angle is obtuse and
5) lower anterior facial height is short

Figure 10 B, the backward rotator

Also exhibits several of Björk's indicators including observations that:

1) a straight inclination of the condyle
2) a relatively straight mandibular canal
3) the symphysis slopes forward and
4) lower anterior facial height is long

Isaacson *et al*, (1977) following on Björk's reports, studied jaw rotation caused by vertical condylar growth. A summary of the findings is that a forward mandibular rotation occurs when vertical condylar growth exceeds the sum of the vertical growth of the maxillary sutures and the maxillary and mandibular alveolar processes. If growth of the maxillary sutures and the maxillary/mandibular alveolar processes exceeds vertical condylar growth, a backward rotation occurs, and the face becomes longer.

An understanding of the effect of condylar growth on mandibular position is fundamental if the clinician is to adequately and appropriately diagnose a vertical dimension abnormality.

The underlying theme that arises is the concept that there cannot be good balance and harmony in the lower face unless the vertical dimension is within normal limits.

The most important prerequisite for facial balance is a normal vertical dimension of the lower face.

Serial images of the patient taken to monitor the direction of condylar growth would be very useful for the diagnosis of vertical growth. At the present time, serial imaging poses certain concerns, most significantly radiation exposure. Advances in imaging technology may, in the future, permit the clinician to use these methods for diagnostic purposes with greater safety.

Vertical dimension skeletal abnormalities are not solely caused by condylar growth direction. They are also caused by differences in anterior facial height and posterior facial height development. These differences in height development can lead to rotational growth or to changes in mandibular position that greatly influence the position of the chin. The etiologies influencing unfavourable differences in development of anterior and posterior facial height are multifactorial.

2.4 Vertical dysplasia

In the field of Prosthetics, the occlusal vertical dimension is defined as the distance between any point on the maxilla and any point on the mandible where the teeth are in maximum intercuspation. Commonly, nasion and menton are used for these points.

The human face has been the subject of study since man could first express himself. As civilizations have risen and subsequently fallen away, one thing that has remained is art and in most cases, drawings, paintings, and sculptures of the face. During the Renaissance, da Vinci, Michelangelo, and Duhrer led other artists to study faces. Facial proportions were thus categorised by art and there were standards set for the balance and harmony of the lower face.

In the speciality of orthodontics, Angle was vitally concerned about the face. Many authors have cited from his sixth edition wherein Edward Angle, also known as the father of Orthodontics states, "One of the evil effects of malocclusion is the marring or distorting of the normal facial lines. It follows that, in the application of the principles of orthodontia, our efforts should be so directed as to mould and modify these lines of disharmony to those of harmony and facial beauty so far as lies within the range of the possibilities of art, and of the type and temperament of the individual. Our opportunities for benefiting humanity are very great in this field, far exceeding those offered by any other branch of dental science, for patients with facial lines so distorted as sometimes to be a marked deformity and a source of constant humiliation to themselves and their friends may now be so treated as to bring about a complete transformation of the facial expression, even to the establishment of lines of beauty" (Angle *et al.,* 1899).

Many researchers followed on Tweed (1944), who revolutionized orthodontic diagnosis because of his concern for the balance and harmony of the lower face. They have studied the face (Peck *et al.,* 1995) and developed diagnostic guidelines for quantifying facial balance. Czarnecki (1993), Ricketts (1982), and Holdaway (1983), and have proposed treatment protocols that give the orthodontic clinician a greater certainty that facial balance and harmony is an attainable goal for their patients.

The underlying theme that surfaces from all artists and orthodontic investigators is the concept that there cannot be good balance and harmony in the lower face unless the vertical dimension is within normal limits. The most important prerequisite for facial balance is a normal vertical dimension of the lower face.

In the article on soft-tissue profile preference, DeSmit and Dermaut in 1984, created three different series of nine profile photographs so that a total of more than two hundred profiles could be ranked by graduate dental students.

It was found that differences in gender and orthodontic knowledge of the students seemed to have no significant influence on their aesthetic preference. The results of their study confirmed the importance of anteroposterior deviations. The study also suggested that unaesthetic facial profiles that were a result of anteroposterior deviations were completely overshadowed by long-face features, with the long-face feature being more unaesthetic.

Because of the challenge of the vertical dimension, not only must the specialist recognize the problem, but he/she must understand the effect of the problem so that all facets and components of the vertical dimension are understood. The clinician must be able to recognize the various components of a vertical dimension abnormality and understand the interrelationship of all the elements of the problem.

As mentioned earlier, diagnosis of the vertical dimension is a complex problem. Researchers in the field of vertical dimension diagnosis, as seen above, including Björk and Isaacson and others have provided the speciality with many useful guidelines and concepts that can be used by clinicians as they diagnose a malocclusion that is complicated by a vertical dimension discrepancy. The practitioner should continue to use the work of these researchers as a foundation in their treatment planning. Further studies are being undertaken that should yield more knowledge so that diagnosis of the vertical dimension becomes less of an art and more of a science.

Before discussing the abnormal, it is prudent to understand the normal. Two of the most accepted descriptions or publications of vertical facial proportions have been published by Farkas (1994).

In these studies, the ideal face is described vertically as being divided into equal thirds by horizontal lines that approximate the hairline, the bridge of the nose, the ala of the nose, and menton (Figure 13).

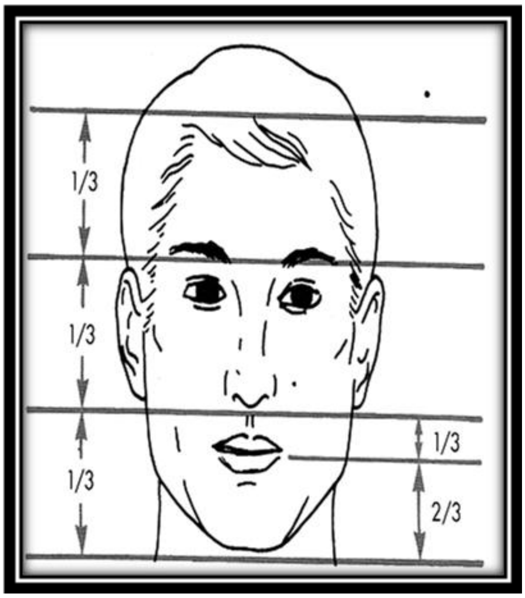


Figure 13: The ideal facial proportions as described by Farkas and Farkas and Munro. (Proffit, 2007)

The above picture also shows that in the ideal vertically proportioned face there is a further division of the lower one third of the face into an upper one third and a lower two third. These divisions of the face can be used by the clinician to help diagnose vertical dimension problems. For example, does the subject have a disproportionately long lower facial height because of vertical maxillary excess or is it due to excessive chin height? Conversely, is a short facial height caused by vertical maxillary deficiency or a short chin height (Sarver *et al*., 2001)?

By using these accepted proportions as a guide, the subject shown in Figure 14 has an excessive lower anterior facial height, whereas the subject shown in

Figure 15 has diminished lower anterior facial height. Although it is evident that both have vertical dimension abnormalities by looking at the face, measuring the facial proportions confirms this intuitive conclusion. A careful observation of the vertical proportions of the face is therefore the first step in the diagnosis of a vertical dimension imbalance.

Figure 14: Increased Vertical Dimension

Figure 15: Decreased Vertical Dimension

Vertical dysplasia's are among the most difficult dentofacial problems to treat. It seems obvious that inherited facial proportions and habits, functional adaptations and other environment factors may all contribute to the etiology.

2.4.1 Characteristics of vertical dysplasia

The most common types of vertical dysplasia are generally referred to as hyperdivergent (Dolichofacial) and hypodivergent (Brachyfacial). The former type of dysplasia is described as the long face syndrome while the latter is referred to as the short face syndrome.

2.4.1.1 Dimensional Deviations

The total anterior facial height is relatively large in persons with open bite faces when compared to the patient with normal overbite and overjet. The morphological basis of an open bite is associated with a large gonial angle, lack of compensating curve of Spee, large vertical posterior maxillary dimension, anteroposterior rotation of maxilla and midcranial fossa and long mandibular corpus (Trouton *et al.*, 1983).In the deepbite subjects (Figure16) the deviations essentially are opposite to the openbite subjects (Figure17).

Figure 16: Deep Bite

Figure 17: Open Bite

It can therefore be seen that there is a strong influence of lower anterior facial height on the formation of vertical facial proportions. Openbite subjects are characterized by larger lower vertical facial heights in comparison with the deep bite subjects.

2.4.1.2 Positional deviations

The four basic horizontal planes (palatal plane, mandibular plane, occlusal plane, anterior cranial base) tend to be steeper and more divergent in persons with large lower face height than in deep bite subjects whose facial planes are more parallel.

Several investigators have noted that the posterior half of the palate tends to be tipped downward in persons with open bite (Trouton *et al.*, 1983). Carrying the molars downwards with posterior teeth acting as a fulcrum, there is a concomitant backward rotation of the mandible and this consequently results in an increase in the anterior face height and also an increase in the palatomandibular angle. Isaacson *et al.,* (1971) confirmed that the increased angle of the mandibular plane commonly found in persons with long faces is associated with a backward rotational growth pattern that can affect the vertical proportions of the anterior component of the face.

2.4.1.3 Soft tissue characteristics

A large interlabial gap is usually evident on clinical examination of a skeletal open bite patient. The lips are incompetent at rest and when the lips are closed, the mentalis muscle is strained and displaced to the level of the alveolar bone, giving the patient a chinless appearance. The distance between the posterior border of the palate and gonion is extremely small and the tongue and soft palate are crowded within a narrow pharyngeal space.

The tongue position and incompetent lips would lead to a mandibular rotation and a high and narrow palatal vault resulting in a maxillary lingual crossbite.

2.4.1.4 Breathing behaviour and posture

The term “respiratory obstruction syndrome” is used to describe the constellation of features seen in mouth breathers. Qiunn has assigned nasal airway obstruction as a possible cause of facial asymmetries and vertical dysplasia’s (Qiunn, 1978).

Mouth breathing may cause habitual mouth open posture; this is the end result of the condition known as long face syndrome. Posterior crossbite occurs because the tongue is lowered, leaving the contracting effect of the buccinators muscles unopposed. Vertical posterior alveolar growth and dental eruption are enhanced because the forces restraining these changes are diminished as the jaw is apart. Reduced facial height has been reported in patients who wore Milwaukee braces with chin rests for spinal scoliosis (Alexander, 1966). The weight of the head was expressed between the dental arches, simulating overactive elevators of the mandible.

The aetiology influencing unfavourable differences in development of anterior and posterior facial height are multifactorial. These factors can, for simplicity, be subdivided into those caused by:

a) facial and dentoalveolar development during growth (Genetic factors)

b) environmental factors (Extrinsic Factors)

2.4.2 Genetic factors

Vertical problems arise in the end from a discrepancy between mandibular ramus growth and tooth eruption. The amount of tooth eruption that must be coordinated with ramus growth is determined by the orientation of the jaws. During the examination of a vertical dysplasia case three major questions must be considered:

1) what determines the orientation of the jaws
2) what controls the amount of tooth eruption and
3) how do these factors interact

2.4.2.1 Vertical facial height during growth and development

Many factors affect the occlusal vertical dimension during growth and development:

- the growth of the ramus
- the gonial angle of the mandible
- the eruption of the teeth and
- the cranial base angle

As the ramus grows, the teeth continue to erupt, maintaining the occlusion. There can, however, be significant differences in the length of the ramus, which has a significant impact on anterior facial height or "vertical dimension." In what would be considered normal or ideal ramus development, the midface, measured from glabella to the base of the nose, is roughly equal in measurement to the lower face measured from the base of the nose to the bottom of the chin at the completion of growth.

This gives the one third equal ratio of the face, as mentioned earlier. As ramus length varies, both anterior facial height and tooth display vary. Differences in ramus length are primarily influenced by genetic variations (Björk and Skieller, 1983; Beckmann *et al.*, 1998; Nanda, 1998; Janson *et al.*, 1994).

A patient who has a short ramus with normal posterior tooth eruption will have an increased anterior facial height and an anterior open bite. Often, however, the anterior teeth in such a patient over erupt to maintain the occlusion, creating both excessive tooth and gingival display. Commonly, the patient with a short ramus shows a long lower facial height when compared with their midfacial height. This patient has excessive gingival display and is often treated with a maxillary impaction to decrease their vertical dimension (Figures 18 and 19), (Fish *et al.*, 1978; Cangialosi, 1984; Van Spronsen *et al.*, 1996).

Figure 18: A short ramus exhibiting a long anterior facial height. (Fish, 1978)

Figure 19: Before and after photographs of the picture seen in Figure 17 after a maxillary impaction.
(Fish, 1978)

A patient who has a long ramus with normal posterior tooth eruption will have the opposite facial appearance to that of the person with a short ramus.

Commonly, this patient will have a very short lower face in comparison to

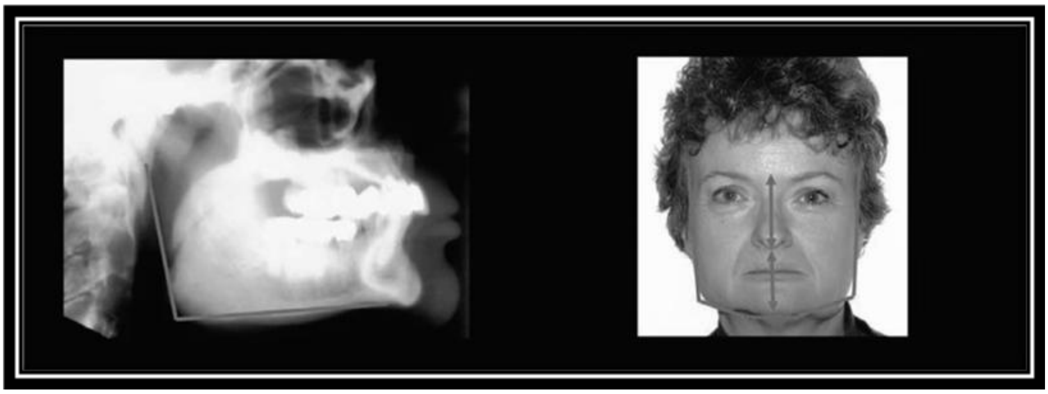


Figure 20: A long ramus. (Ingervall, 1974)

their midface and may have inadequate maxillary tooth display. Unlike the long, slender face of the short ramus patient, the long ramus patient may have a very square face (Figures 20 and 21).

Figure 21: Before and after photographs of the picture seen in Figure 19 after double-jaw surgery.
(Ingervall, 1974)

The gonial angle also has an impact on the patient's anterior vertical dimension. A patient with an acute gonial angle has a tendency to mimic the facial features of a patient with a long ramus, with a square face and short lower face compared to their midface. These patients are commonly referred to as having a flat mandibular plane angle. Patients who have more obtuse gonial angles mimic the appearance of patients with short ramus heights, with a long narrow face, excessive tooth and gingival display, and a long lower face when compared to their midface. Patients with more obtuse gonial angles are often referred to as having steep mandibular plane angles. There appears to be some evidence that the formation of the gonial angle may be influenced by the strength of the masseter muscle. The stronger and more developed the masseter muscle is, the more pronounced or acute the gonial angle is (Figure 22) (Ingervall and Thilander, 1974).

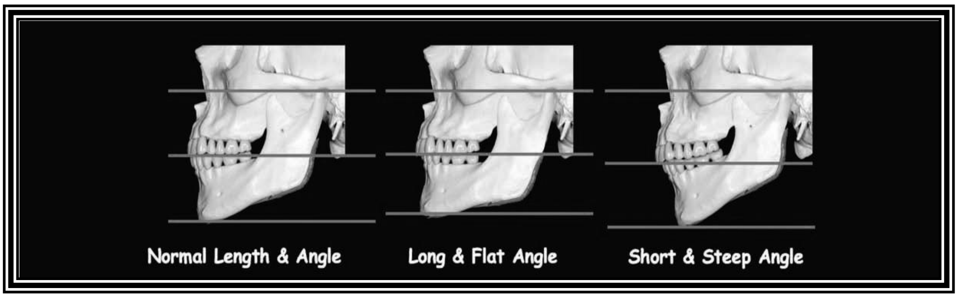


Figure 22: The impact of ramus length and gonial angle on lower facial height and mandibular plane angle.
(Ingervall, 1974)

In addition to ramus length and gonial angles, tooth eruption plays a critical role in the development of a patient's vertical dimension. In normal growth and development, the maxillary and mandibular teeth erupt to maintain occlusal contact as the face grows. There can be variations, however, in tooth eruption that can result in alterations in facial vertical dimension. After growth is completed, tooth eruption is necessary to maintain the vertical dimension if any wear occurs. If eruption occurs at the same rate as tooth wear, the vertical dimension of the patient will be unchanged.

If, however, the eruption does not keep up with tooth wear, the vertical dimension may decrease with time. The question of whether eruption keeps up with tooth wear to maintain vertical dimension is one of the most heated debates in dentistry (Proffit and Vig, 1981).

Vertical dimension skeletal abnormalities are not solely caused by condylar growth direction. They are also caused by differences in anterior facial height and posterior facial height development.

These differences in height development can lead to rotational growth or to changes in mandibular position that greatly influence the position of the chin.

Isaacson *et al.,* (1971) studied dentoalveolar development in three groups of subjects - those with short anterior facial height, those with average anterior facial height, and those with excessive anterior facial height. The amount of maxillary posterior alveolar development was found to decrease as the mandibular plane (MP)-sella nasion (SN) angle decreased. In patients with long anterior facial height (high MP-SN angles), the mean distance from the occlusal plane to the inferior edge of the palate was 22.5 mm. This distance decreased to 19.6 mm for the average group and 17.1 mm for the group with short anterior facial height (low MP-SN angles).

Mandibular posterior alveolar development similarly decreased with decreases in the MP-SN angle but much less dramatically than those found in the maxilla. Mandibular height showed a mean of 31.2 mm for the long anterior face height group, 28.2 mm for the average group, and 28.3 mm for the short anterior face height group.

The findings of the above study by Isaacson *et al.* were confirmed in a study performed by Janson *et al*., (1994).

These investigators found that all dentoalveolar heights were significantly greater in long anterior facial height patients than in patients with normal facial height. In the short lower anterior facial height, all dentoalveolar heights were significantly shorter than in the normal lower anterior facial height group.

The differences in dentoalveolar development, most particularly in the maxilla, have a significant impact on the anterior facial height of the orthodontic patient.

Ingervall and Thilander (1974) have postulated that excessive maxillary posterior dentoalveolar development is associated with weaker masticatory musculature, in high-angle patients compared with the strong musculature commonly associated with short anterior facial height patients.

2.4.2.2 Influences of jaw orientation

Bjork's implant studies show that rotation of the maxilla occurs during growth and although the internal rotation of the maxillary core usually is concealed by surface remodelling that maintains the orientation of the palatal plane, this rotation does not always occur in patients with vertical dysplasias (Björk and Skieller, 1972). If the maxilla is rotated down posteriorly, or up anteriorly, the amount of space for eruption of posterior teeth is reduced, space for eruption of anterior teeth increases and there is a tendency toward an anterior open bite.

Another influence on jaw orientation is the length of the ramus (Figure 23).

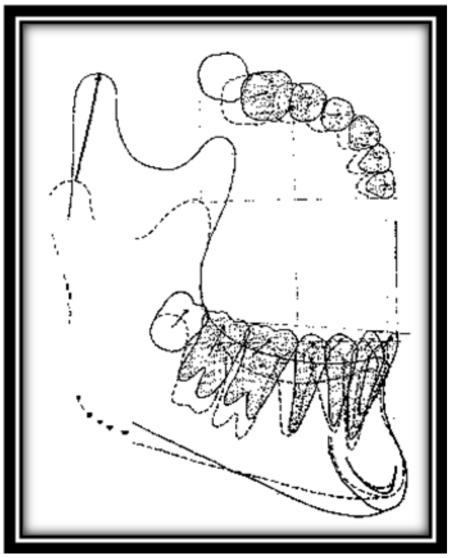


Figure 23: Posterior-directed growth pattern of the mandibular condyle. (Björk, 1972)

The shorter the ramus, the smaller is the space available for the eruption of the posterior teeth and the greater the probability that the mandible will rotate downward and backward. The longer the ramus, the greater will be the chance of mandibular rotation in the upward and forward direction.

2.4.2.3 Influences of tooth eruption

Based on the observations at frequent intervals, it was found through initial video microscope studies that active eruption occurred during the early evening but not during the day and was facilitated by having the child resting and quiet during the evening (Proffit *et al.*, 1991; Lee and Proffit, 1995).

A flexible fibre optic cable to bring the image of the rulings to the video microscope allowed continuous observation of an erupting premolar for twelve hour periods.

The above studies confirm that essentially all net eruptions occur during a few critical hours in the evening, usually from about eight in the evening until midnight (Risinger and Proffit, 1996).

This period of active eruption is remarkably similar to the time of major release of human growth hormone which suggests that adequate human growth hormone (HGH) levels may be necessary for eruption.

The path of eruption of the maxillary teeth is downward and somewhat forward. In normal growth the maxilla usually rotates a few degrees forward but frequently rotates slightly backward. The eruption path of the mandibular teeth is upward and somewhat forward. When excessive rotation occurs in the short face type of development, the incisors tend to be carried into an overlapping position even if they erupt very little, hence the tendencies for deep bite malocclusion in short face individuals. In the long face growth pattern, an anterior open bite will develop as anterior face height increases unless the incisors erupt for an extreme distance.

2.4.3 Extrinsic factors

The role of tongue posture, swallowing, and breathing are still subjects of debate, argument, and study in orthodontics.

Their respective impacts on the vertical dimension are in need of continued study and research.

2.4.3.1 Mouth breathing

The relationship between mouth breathing, altered posture, and the development of malocclusion is not as clear cut as the theoretical outcome of shifting to oral respiration might appear at first glance (Vig, 1998). Therefore experimental studies have only partially clarified the situation.

Current experimental data for the relationship between malocclusion and mouth breathing are derived from studies of the nasal/oral ratio in normal versus long-face children (Fields *et al.*, 1991).The data from the study shows that both normal and long-face children are likely to be predominantly nasal breathers under laboratory conditions. A minority of the long-face children had less than 40% nasal breathing, whereas none of the normal children had such low nasal percentages.

When adult long-face patients are examined, the findings are similar. The number of subjects with evidence of nasal obstruction is increased in comparison to a normal population, but the majority are not mouth breathers in the sense of predominantly oral respiration.

Airway problems, such as large adenoids, tonsils, or blocked airways caused by septum deviations, large conchae, or allergies are frequently observed in high-angle patients and may affect mandibular posture, allowing more freedom for posterior eruption.

This hypothesis is supported by Woodside *et al.* (1991) who showed closing of the mandibular plane angle and reduction in the anterior face height after removal of adenoids and tonsillectomy.

It appears that research on respiration, up to the present time, has resulted in two opposing views:

a) total nasal obstruction is highly likely to alter the pattern of growth and lead to malocclusion in experimental animals and humans, and individuals with a high percentage of oral respiration are overrepresented in the long-face population, but
b) the majority of individuals with the long-face pattern of deformity have no evidence of nasal obstruction and must therefore have some other etiologic factor as the principal cause

Mouth breathing may be a contributor to the development of orthodontic problems but it is difficult to confirm it as a frequent etiologic agent.

Clinically, most orthodontists refer mouth breathers to an otolaryngologist for an evaluation. This problem should be carefully evaluated during the diagnosis of a patient with excess vertical dimension.

2.4.3.2 Swallowing and tongue posture

One viewpoint holds that tongue thrust swallowing is seen in:

a) younger children with reasonably normal occlusion in whom it represents only a transitional stage in normal physiologic maturation and

b) in individuals who have displaced incisors

In the latter viewpoint, it is an adaptation to the space between the teeth. Others argue that tongue thrust swallowing simply has too short a duration to have an impact on tooth position. Pressure by the tongue against the teeth during a typical swallow lasts for approximately one second. A typical individual swallows about eight hundred times per day while awake but has only a few swallows per hour while asleep.

The total per day, therefore, is usually under one thousand times. One thousand seconds of pressure, of course, totals only a few minutes, not nearly enough time, it is argued, to affect the equilibrium (Proffit *et al*., 1991).

Most clinicians believe that if a patient has a forward resting posture of the tongue, the duration of this pressure, even if very light, could affect tooth position, vertically or horizontally.

Tongue-tip protrusion during swallowing is sometimes associated with a forward tongue posture. During the diagnosis of the patient with a vertical dimension problem, the clinician must understand that condylar growth, sutural lowering of the maxillary complex, dentoalveolar development, dental eruption, the patient's oral environment and the patient's habits are all interrelated. Generally there is not a single causative factor that predisposes the patient to too much or too little vertical development of lower facial height. To simplify, one might conclude that as an overall rule, when vertical condylar growth exceeds tooth eruption (alveolar development), forward mandibular rotation occurs. The result is increased posterior facial height and an increase in the ratio of posterior facial height to anterior facial height. Conversely, if dentoalveolar growth and tooth eruption are greater than vertical condylar growth, the resultant mandibular change is backward rotation. The anterior facial height with the posterior facial height ratio decreases.

Environmental factors can play a role, but the role is, at times, difficult to assess and varies from patient to patient.

2.5 Radiographs used in orthodontic diagnosis

Orthodontic treatment is generally performed to improve a person's appearance by increasing harmony between dental and jaw relationships. Orthodontic evaluation and treatment planning comprises of three components: facial, dental and skeletal diagnosis. These dimensions can further be divided into three planes of space:

Anteroposterior

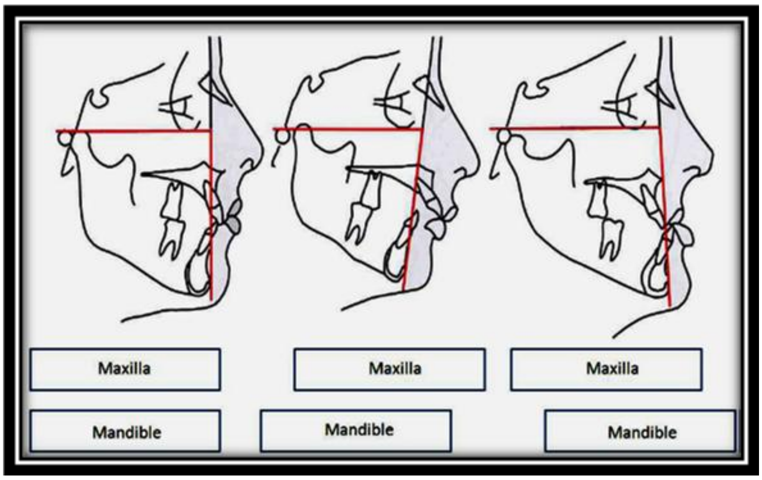


Figure 24: Class I, Class II, and Class III soft tissue and skeletal discrepancy (Jacobson, 1995)

Transverse

Figure 25: Upper and Lower Midline not coinciding

Vertical

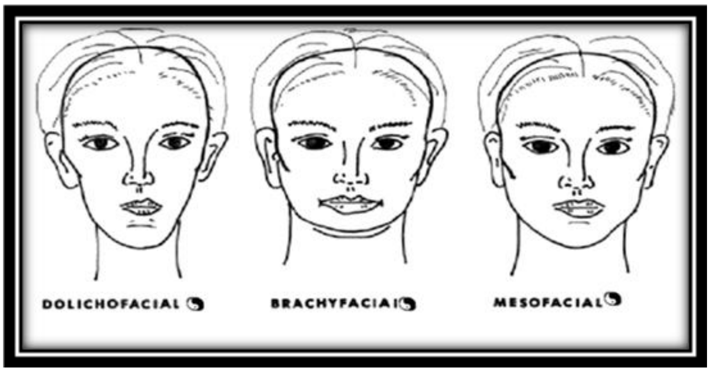


Figure 26: Different Facial Types (Ingervall, 1974)

Prior to treatment, records are taken in order to diagnose and create a treatment plan for the case. The purpose of diagnosis is twofold:

a) document the patient's initial condition and

b) supplement the diagnostic information with a clinical examination

Standard records consist of:

- dental casts
- intra and extra-oral photographs
- orthopantomographs
- cephalometric radiographs
- often cone beam computer tomography (CBCT) scans and
- direct clinical measurements

The records provide the clinicians with the necessary facial, dental and skeletal information needed to thoroughly diagnose and decide on the orthodontic treatment plan. While photographs and study models generally offer no harm to the patient, standard orthodontic radiographs expose patients to various levels of radiation. Although radiation levels experienced by dental radiographs are low, (Gibbs *et al.,* 1988) when compared to medical radiation scans and everyday background exposures, there must be clinical justification for exposing patients to x-rays.

The American Dental Association believes "dentists should weigh the benefits of dental radiographs against the consequences of increasing a patient's exposure to radiation" and practice the "as low as reasonably achievable" (ALARA) principle to minimize exposure to radiation (American Dental Association Council on Scientific Affairs, 2006). The primary purpose of the radiographic examination is to provide additional information that may not be clinically evident. However, many orthodontic textbooks do not describe a radiograph protocol.

Rather, they explain the diagnosis and treatment benefits for periapical, bitewing, panoramic, cephalometric radiographs and CBCT scans (Proffit, 2007).

There is no aspect of the health sciences that is not influenced by the discovery of radiographs. Orthodontics is no exception. Radiographs are a valuable tool in orthodontic diagnosis.

CHAPTER 3

3.1 Aims and Objectives

Aim: The aim of this study is to investigate the accuracy of the orthopantomograph compared to that of a lateral cephalogram for assessing vertical jaw relationships.

Objective: To investigate whether orthopantomographs can be used as an alternative to lateral cephalograms, for predicting the three different facial forms. The vertical jaw relationship will be assessed on both the radiographs using linear and angular measurements.

3.2 Methods and Materials

The research was conducted in accordance with the ethical and professional guidelines as determined by the research committee of the School of Dentistry at the University of Pretoria.

Ethical clearance was obtained by the Ethics committee of the University. The protocol reference number is 222/2012.

The Dean/Manager of the Dental School had given permission to access and analyze radiographic records for the purpose of this study.

The sample size consisted of ninety patients. Thirty patients in each of the three different growth patterns namely, the normal mesofacial, the horizontal brachyfacial and the vertical dolicofacial. All the patients had an orthopantomograph and a cephalogram.

The patients were categorized as vertical, normal and horizontal. The cephalogram was used as the gold standard for the three different categories.

3.3 Sample Selection

3.3.1 Inclusion Criteria

- Male and female patients
- Adult patients over the age of 20 years
- Both a cephalogram and an orthopantomograph should be available

3.3.2 Exclusion Criteria

- The patient should have had no previous orthodontic treatment
- No posterior teeth extractions
- No race distinction

3.4 Measurements

Scanned pictures of a cephalogram and an orthopantomograph were used.

Figure 27: Lateral cephalogram

Figure 28: Orthopantomograph

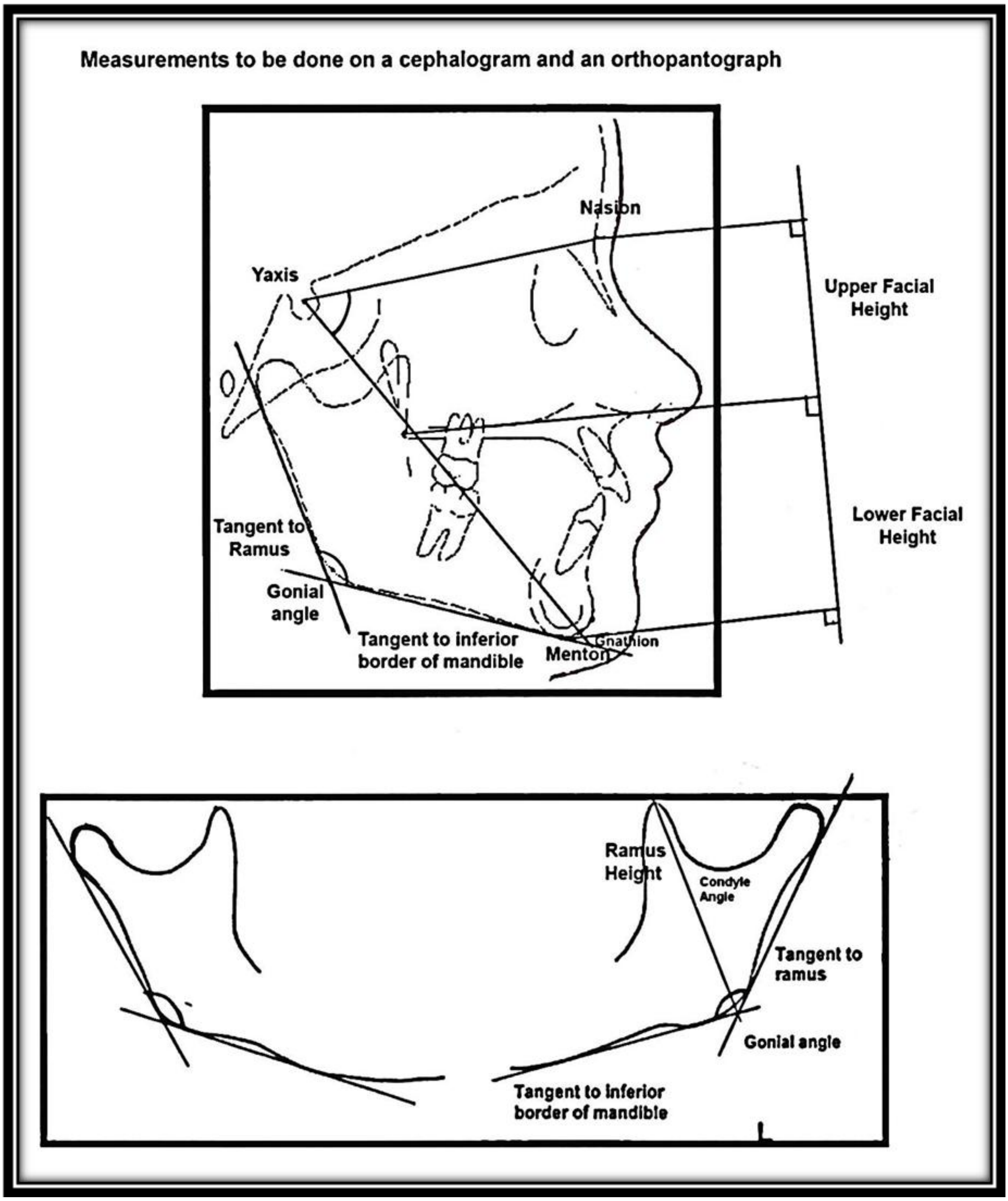


Figure 29: Measurements that were documented from the Cephalogram and the Orthopantomograph

- Personal identity of the diagnostic radiographic records of the subjects were hidden and patient anonymity was respected
- The records were numbered and only gender and age of the subject will be displayed
- The gonial angle which is the angle between the tangents of the inferior border and posterior border of the mandible were measured on both the cephalogram and the orthopantomograph
- The upper and lower facial heights were be measured on the cephalogram
- The Y-Axis was measured on the cephalogram
- The condyle angle which is an angle formed at the intersection of the ramus height and a line parallel to the posterior tangent line were be measured on the orthopantomograph and on the lateral cephalogram
- The ramus height was will be measured on the orthopantomograph
- Ramus height on the cephalogram was measured
- Standardization was done on every fifth tracing and its measurements was evaluated by a member of the department to ensure accuracy

3.5 Study Design

- The design is a retrospective diagnostic cross-sectional study

3.6 Setting

- This investigation was undertaken at the University of Pretoria – Oral and Dental Hospital, Department of Orthodontics

CHAPTER 4

RESULTS

The data was analyzed using the SAS program, release 92 running under the Microsoft windows for the personal computer.

A total of ninety orthopantomograph and ninety cephalometric radiographs were obtained, thirty each for the three different growth types. The gonial angle was determined by the tangent of the inferior border of the mandible and the distal border of the ascending ramus and the condyle on both the orthopantomograph and cephalometric radiographs. The ramus height and the condyle angle were measured in both the radiographs.

Mean values were compared by the two-sample t test. Median values were compared by the nonparametric Wilcoxon rank sum test. P values ≤ 0.05 were considered significant.

Comparisons were made of the mean and standard deviation and the median values from the gonial angle, the ramus height and the condyle angle, measured in the three different growth types.

In the tables that follow:

P5 = percentile 5 of the distribution of values for the variable concerned, and

P95 = percentile 95 of the distribution of values for the variable concerned.

Therefore 90% of the values occurred in the interval P5 – P95. In the graph following each table, the vertical bars reflect the P5 – P95 intervals, with the median values in between, for the gonial angle, ramus height and condyle angle from the cephalogram (denoted by C Gonial, C Ramus and C Condyle) and orthopantomograph (denoted by O Gonial, O Ramus and O Condyle) respectively.

4.1 Normal growth pattern

Table 3: **Descriptive statistics for normal growth pattern**

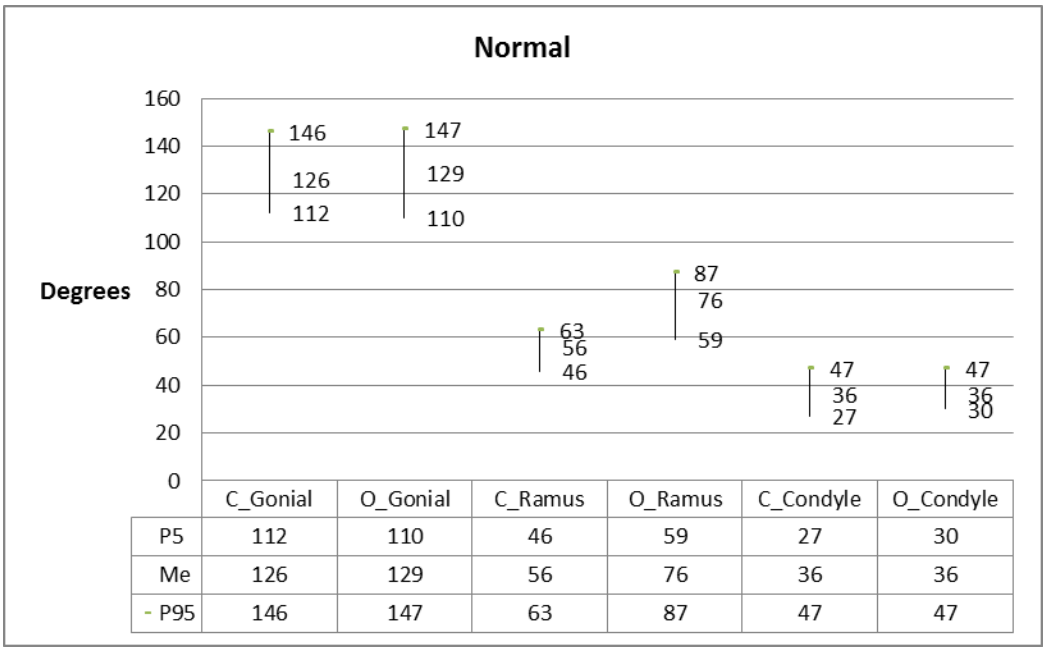
	Cephalograph	**Orthopantomograph**	**P Value**
Gonial angle, degrees			
N	30	30	
Mean	127.6	128.2	0.832*
Standard deviation	10.58	12.41	
Median	126	129	0.935**
P5 – P95	112 – 146	110 – 147	
Minimum / Maximum	111 / 147	110 / 149	
Correlations	Pearson correlation = 0.533		0.002
	Spearman correlation = 0.527		0.003
Condyle angle, degrees			
N	30	30	
Mean	37.1	37.5	0.822*
Standard deviation	6.38	6.16	
Median	35.5	36.5	0.853**
P5 – P95	27 – 47	30 – 47	
Minimum / Maximum	27 / 47	29 / 49	
Correlations	Pearson correlation = 0.098		0.605
	Spearman correlation = 0.119		0.530

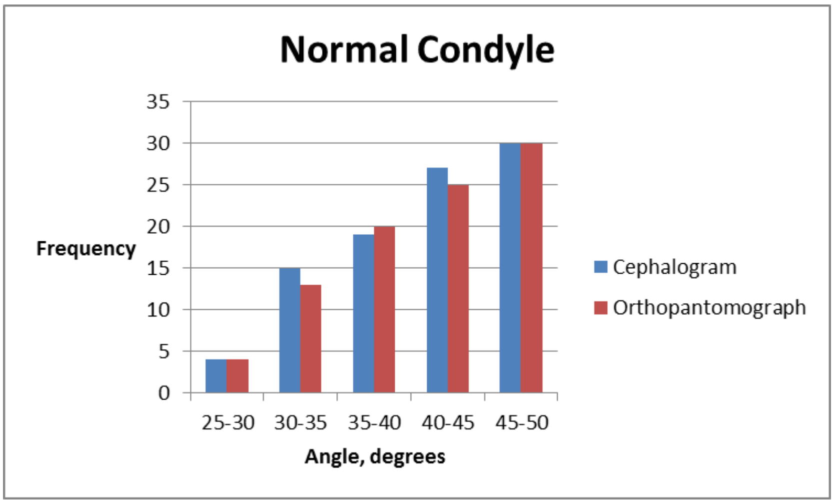
Ramus, mm			
N	30	30	
Mean	54.9	72.8	< 0.001*
Standard deviation	5.35	9.25	
Median	55.5	75.5	< 0.001**
P5 – P95	46 – 63	59 – 87	
Minimum / Maximum	45 / 63	59 / 88	
Correlations	Pearson correlation = 0.363		0.049
	Spearman correlation = 0.376		0.041

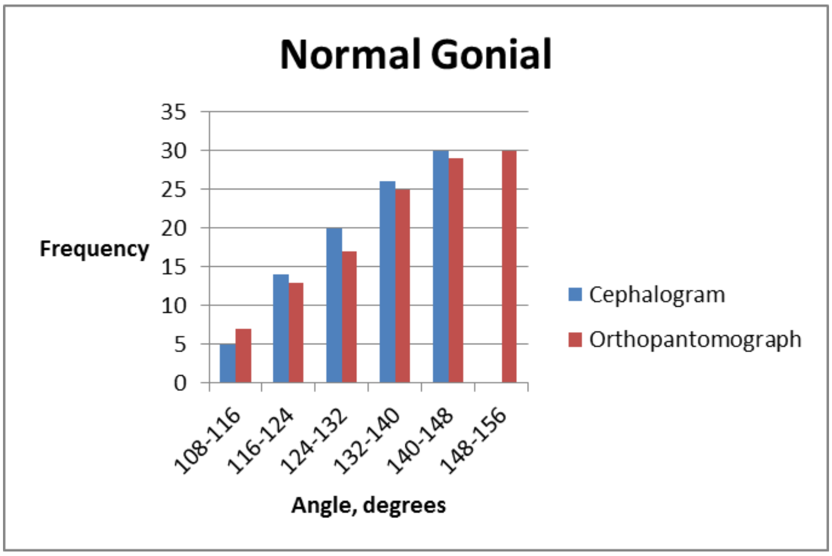
* Two-sample t test

** Wilcoxon rank sum test

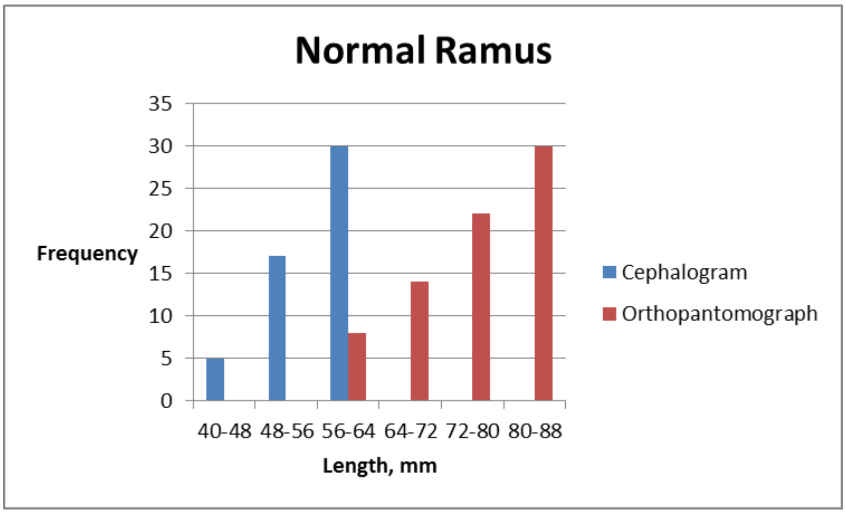
The P5 – P95 intervals are graphically displayed in the following figure.







The maximum value for the lateral cephalogram was 147



The maximum value for the lateral cephalogram was 63

NORMAL GROWTH

- The mean as well as the median values of the gonial angles for the lateral cephalogram and orthopantomograph do not differ significantly
- The mean as well as the median values of the ramus height for the lateral cephalogram and orthopantomograph differ significantly
- The mean as well as the median values of the condyle angles for the lateral cephalogram and orthopantomograph do not differ significantly
- The P5 – P95 interval bars overlap minimally for C Ramus and O Ramus, in contrast to the overlap between the lateral cephalogram and orthopantomograph bars for the gonial and condyle angles. This indicates a significant and positive correlation for the condyle and gonial angles, between the two radiographs. However there is no correlation between the two radiographs in respect of the ramus height. The strong correlation is for angular measurements, while linear measurements don't show a correlation

4.2. Horizontal growth pattern

Table 4: **Descriptive statistics for horizontal growth pattern**

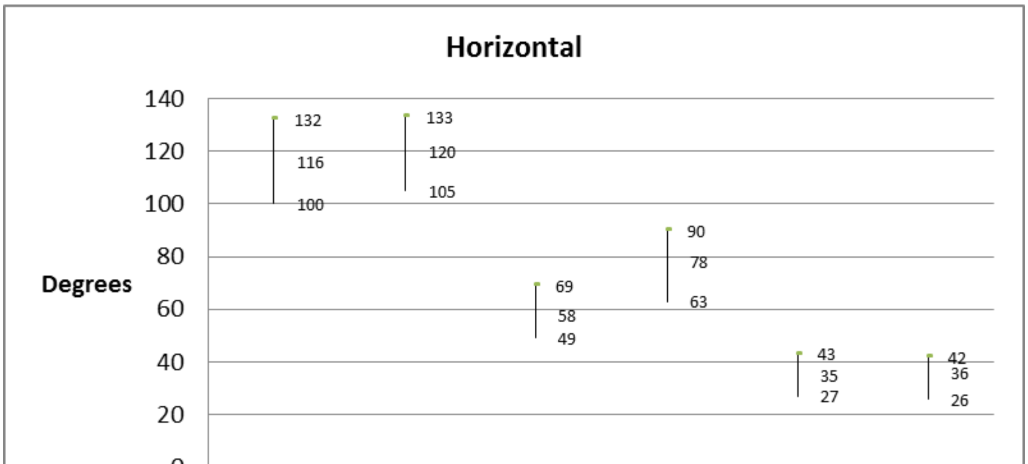
	Cephalograph	Orthopantomograph	P Value
Gonial angle, degrees			
N	30	30	
Mean	116.9	118.8	0.456*
Standard deviation	10.54	9.35	
Median	116	120	0.506**
P5 – P95	100 – 132	105 – 133	
Minimum / Maximum	99 / 133	102 / 134	
Correlations	Pearson correlation = 0.575		0.001
	Spearman correlation = 0.567		0.001
Condyle angle, degrees			
N	30	30	
Mean	34.7	34.8	0.904*
Standard deviation	5.40	5.20	
Median	35	35.5	0.929**
P5 – P95	27 – 43	26 – 42	
Minimum / Maximum	27 / 43	26 / 42	
Correlations	Pearson correlation = 0.820		< 0.001
	Spearman correlation = 0.810		< 0.001

Ramus, mm			
N	30	30	
Mean	59.1	77.1	< 0.001*
Standard deviation	6.09	9.05	
Median	58.5	77.5	< 0.001**
P5 – P95	49 – 69	63 – 90	
Minimum / Maximum	45 / 69	62 / 93	
Correlations	Pearson correlation = 0.509		0.004
	Spearman correlation = 0.519		0.003

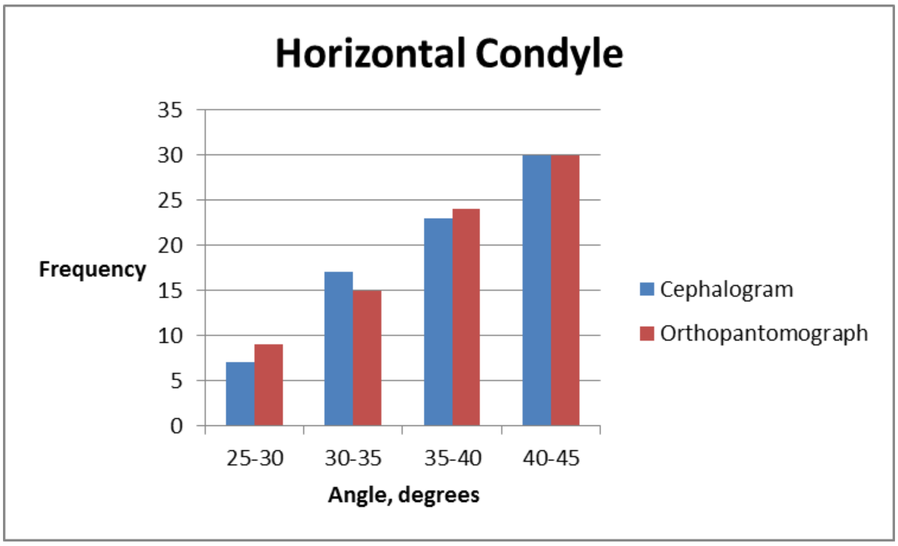
* Two-sample t test

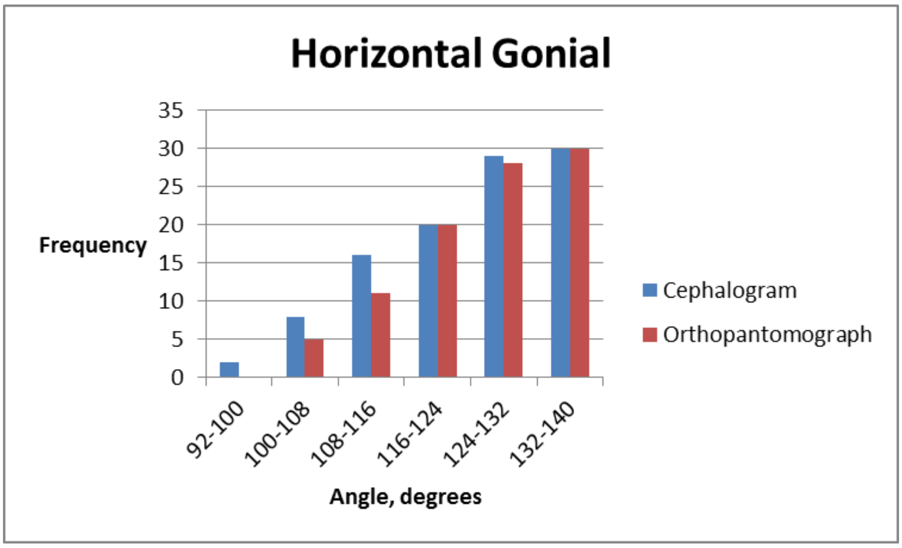
** Wilcoxon rank sum test

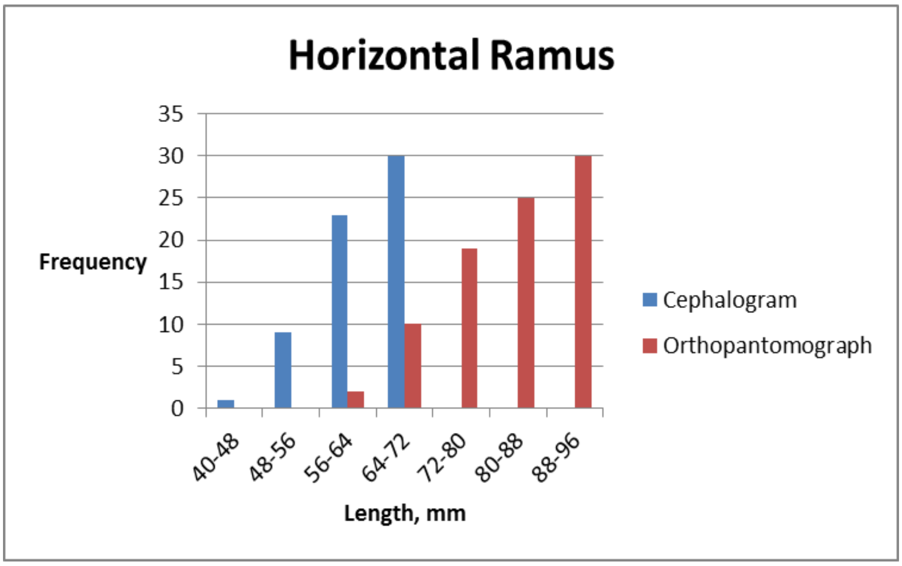
The P5 – P95 intervals are graphically displayed in the following figure.



	C_Gonial	O_Gonial	C_Ramus	O_Ramus	C_Condyle	O_Condyle
P5	100	105	49	63	27	26
Me	116	120	58	78	35	36
P95	132	133	69	90	43	42







The maximum value for the lateral cephalogram was 69

HORIZONTAL GROWTH

- The mean as well as the median values of the gonial angles for the lateral cephalogram and orthopantomograph do not differ significantly
- The mean as well as the median values of the ramus height for the lateral cephalogram and orthopantomograph differ significantly
- The mean as well as the median values of the condyle angles for the lateral cephalogram and orthopantomograph do not differ significantly
- The P5 – P95 interval bars overlap minimally for C Ramus and O Ramus, in contrast to the overlap between the lateral cephalogram and orthopantomograph bars for the gonial and condyle angles. Thus significant and positive correlations between the two radiographs were found for the gonial angles and the condyle angles. With regards the ramus measurements, no correlation was found

4.3 Vertical growth pattern

Table 5: **Descriptive statistics for vertical growth pattern**

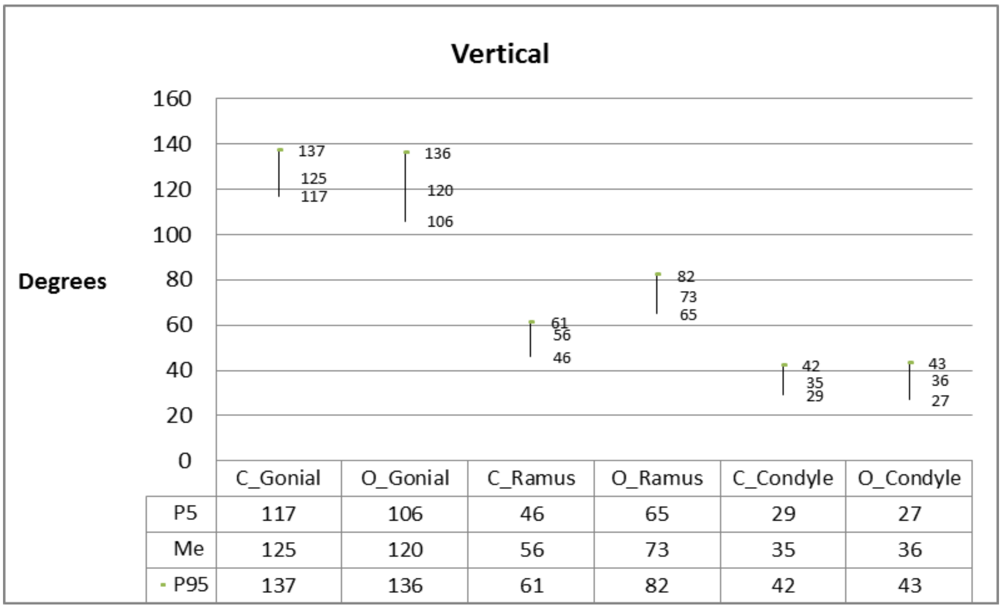
	Cephalogram	**Orthopantomograph**	**P Value**
Gonial angle, degrees			
N	30	30	
Mean	125.7	120.7	0.023*
Standard deviation	6.87	9.53	
Median	125	120	0.043**
P5 – P95	117 – 137	106 – 136	
Minimum / Maximum	110 / 143	105 / 136	
Correlations	Pearson correlation = 0.749		< 0.001
	Spearman correlation = 0.759		< 0.001
Condyle angle, degrees			
N	30	30	
Mean	35.7	35.6	0.977*
Standard deviation	4.16	4.56	
Median	35	35.5	0.947**
P5 – P95	29 – 42	27 – 43	
Minimum / Maximum	28 / 43	27 / 44	
Correlations	Pearson correlation = 0.938		< 0.001
	Spearman correlation = 0.936		< 0.001

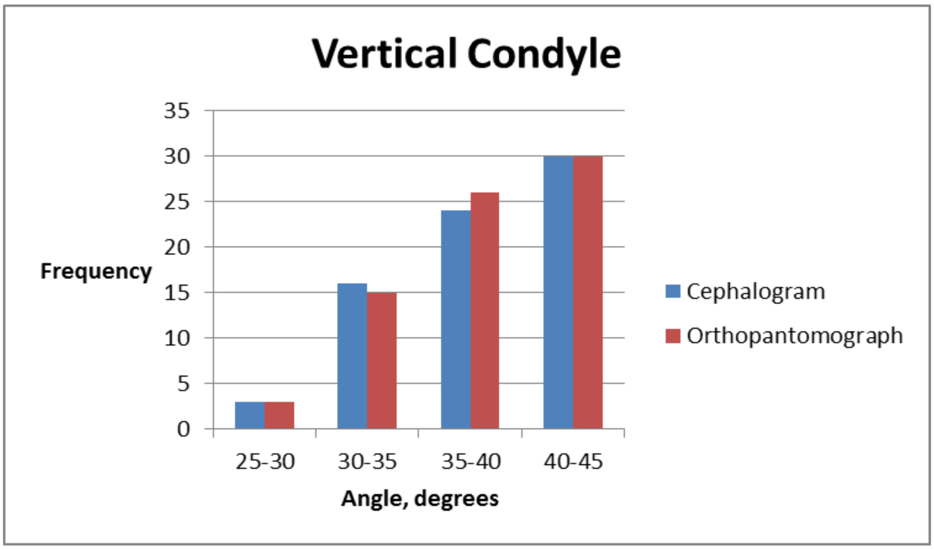
Ramus, mm			
N	30	30	
Mean	55.5	72.1	< 0.001*
Standard deviation	5.02	6.15	
Median	56	73	< 0.001**
P5 – P95	46 – 61	65 – 82	
Minimum / Maximum	39 / 64	57 / 90	
Correlations	Pearson correlation = 0.635		< 0.001
	Spearman correlation = 0.422		0.020

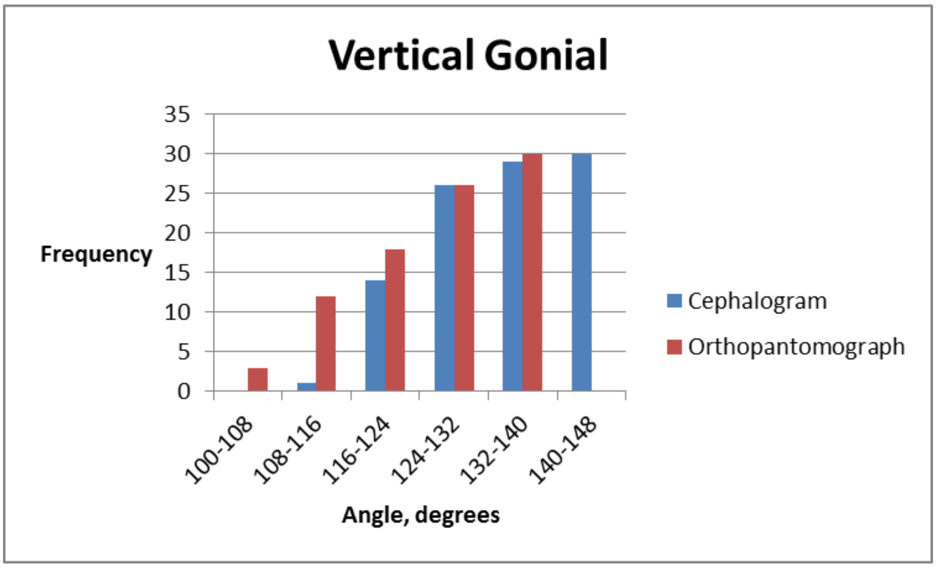
* Two-sample t test

** Wilcoxon rank sum test

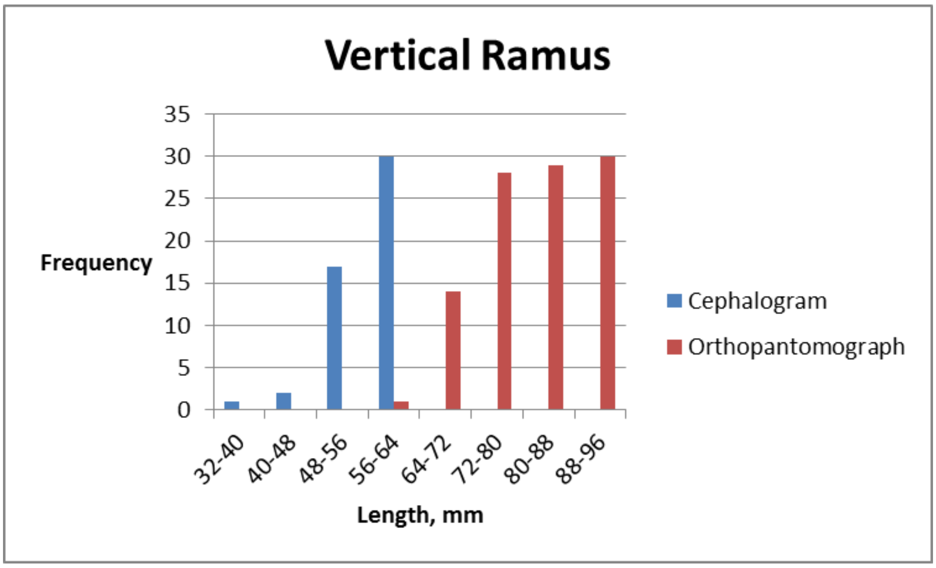
The P5 – P95 intervals are graphically displayed in the following figure.







The maximum value for the orthopantomograph was 136



The maximum value for the lateral cephalogram was 64

VERTICAL GROWTH

- The mean as well as the median values of the gonial angles for the lateral cephalogram and orthopantomograph differ significantly
- The mean as well as the median values of the ramus height for the lateral cephalogram and orthopantomograph differ significantly
- The mean as well as the median values of the condyle angles for the lateral cephalogram and orthopantomograph do not differ significantly
- The P5 – P95 interval bars for C Ramus and O Ramus do not overlap, in contrast to the overlap between the lateral cephalogram and orthopantomograph bars for the gonial and condyle angles. Again, significant and positive correlations between the two radiographs were found for the gonial angles and the condyle angles. For the ramus measurements, no correlation was found

CHAPTER 5

DISCUSSION

The purpose of the study was to evaluate the value on the accuracy of the measurements taken from the orthopantomograph as compared to that of the lateral cephalogram for investigating the vertical jaw relationship patterns of individuals. The sample size consisted of ninety patients, thirty each for each of the different growth patterns. All the patients used in the study, had an orthopantomograph and a lateral cephalogram radiograph.

The patients were categorised as vertical, normal and horizontal. The lateral cephalogram was used as the gold standard for the three different categories
The gonial angle which is the angle between the tangents of the inferior border and posterior border of the mandible was measured on the lateral cephalogram and the orthopantomograph. The upper and lower facial heights was measured on the lateral cephalogram, The Y-axis was also measured on the lateral cephalogram. The condyle angle which is an angle formed at the intersection of the ramus height and a line parallel to the posterior tangent line was measured on both the orthopantomograph and the lateral cephalogram. The ramus height was also measured on both the cephalogram and orthopantomograph.

Comparisons were made of the mean and standard deviation and the median values from the gonial angle, the ramus height and the condyle angle, measured for the three different growth types. With respect to the normal growth pattern and the horizontal growth pattern the mean and median for the gonial and the condyle angles, there was no significant difference. However there was a significant difference in the mean and median values for the ramus height.

The results were different for the vertical patient. The mean and median values for both the gonial angle and the ramus height differed significantly for the two radiographs. While the mean and median values for the condyle angle did not differ significantly.

The results with respect to the correlations showed significant correlations between the gonial angle and the condyle angle for all three growth patterns. However this was not the case for the ramus height.

The orthopantomograph was introduced during the 1960's. It presents all anatomic landmarks in a panoramic view, thus demonstrating the right and left landmarks for bilateral structures. In addition, it displays many anatomic landmarks with great detail and enables the diagnosis of mandibular asymmetries. Therefore, the panoramic radiograph is a valuable orthodontic screening tool and a means for planning any type of jaw surgery. However, for many years authors have contemplated about the limitations of orthopantomographs, such as, image magnification, geometric distortion and superimposed images, which limit their accuracy (Akcam *et al.,* 2003).

Figure 30: Scanned image of an Orthopantomograph

Consequently, there are very few studies that involve the use of orthopantomographs in evaluating dentoskeletal measurements (Larheim and Svanaes, 1986; Piedra, 1995).

Some studies have shown that vertical and horizontal linear measurements in orthopantomographs are unreliable. Van Elslande *et al.,* (2008), claimed that although vertical measurements were more accurate than horizontal or angular measurements, they were not true representations of the real objects to which they corresponded, and therefore caution is advised when using conventional or digital panoramic images to assess mandibular asymmetry. Larheim and Svanaes in 1986, found acceptable reproducibility for vertical and angular variables on panoramic radiographs that did not exceed 1% of the total variance, however horizontal variables were less reliable. For this reason, many studies have focused only on angular measurements (Akcam *et al.,* 2003).

Levandoski was one of the first to introduce a method of orthopantomograph analysis for evaluating facial asymmetry. In these cases of asymmetry, it was especially challenging to achieve reliable skeletal measurements owing to interference presented by superimposed images of the lateral cephalogram. (Levandoski, 1993). Since then, few studies have been conducted to investigate the possibility of enhancing the clinical versatility of panoramic radiographs to evaluate changes in craniofacial morphology in comparison with lateral cephalograms (Ongkosuwito *et al.,* 2009).

Orthopantomography, as discussed above, is a very popular and widely accepted technique of panoramic radiography of the oral region, producing a single image of the facial structures that include both maxillary and mandibular arches with the temperomandibular joints and their supporting structures. It has a wide variety of uses, including the screening of patients before prosthetic treatment for evidence of roots, cysts, foreign bodies, and neoplasms. Furthermore, it helps in the evaluation of the resorptive and the osteopenic processes of the jaws. In addition, orthopantomography plays an important role in implantology, in as much as it offers information about the vertical dimension of the bone and the locations of certain anatomic structures in the orofacial region (Kaffe *et al.,* 1994).

With respect to orthodontics, dimensional measurements made on an orthopantomograph can involve considerable methodological error. One major limiting factor in the clinical use of orthopantomography is its inability to confirm whether the dimensions of structures shown on radiographs correspond to the real dimensions of the structures. The position of an object between the x-ray source and the film is responsible for the magnification seen on a radiograph. In the focal area the image is free of distortion, which means that the magnification factor is the same for both vertical and horizontal planes. Objects outside this layer will appear distorted in the image because of the difference between the velocity of the film and the velocity of the projection of the object on the film and also because of the position of the object in relation to the tube and the film. The orthopantomographic image is affected by both magnification errors and displacement. Horizontal distances are particularly unreliable as a result of nonlinear variation in the magnification at different object depths, whereas vertical distances are relatively reliable.

Distortion, displacement and in a special way, magnification can cause changes in the dimensions of filmed structures on radiographic images in comparison with those of the actual structures (Brooks *et al*., 1997; Tronje *et al.,* 1981).

There are a large number of orthopantomograph radiographic machines available from a variety of manufacturers, and the magnification factor varies from one manufacturer to another because of the different projection geometries that they use. This variation results in differences in magnification and in the amounts of distortion and displacement of structures. In addition, the magnification factor can vary from one machine to another even if they are made by the same manufacturer. It is therefore essential to use the same type of panoramic machine for the longitudinal assessment of cases, as was the case with our study. All the patients that were analysed were from the Oral and Dental hospital. Thereby ensuring the position of the patient between the x-ray source and the film was standardized.

Cephalometric radiography is an essential tool in the diagnosis and treatment of dental malocclusions and underlying skeletal discrepancies. The use of serial cephalometric radiographs makes it possible to study and predict growth, orthodontic treatment progress and surgical outcome of dentofacial deformity treatment (Vig, 1998).

Figure 31: Scanned image of a Lateral cephalogram

Two approaches may be used to perform a cephalometric analysis: a manual approach, and a computer-aided approach. The manual approach is the oldest and the most widely used. It consists of placing a sheet of acetate over the cephalometric radiograph, tracing salient features, identifying landmarks, and measuring distances and angles between landmark locations.

The other approach is computer-aided. Afterwards, the computer software completes the cephalometric analysis by automatically measuring distances and angles.

The evolution from full manual cephalometrics to computer assisted-cephalometric analysis is aimed at improving the diagnostic value of cephalometric analysis by reducing errors and saving time.

However, the inconsistency in landmark identification is still an important source of random errors both in computer-aided digital cephalometry and in manual cephalometric analysis. Last, but not least, both methods are time-consuming, although to a different extent.

For these reasons there have been efforts to automate cephalometric analysis with the aim of reducing the time required to obtain an analysis, improving the accuracy of landmark identification and reducing the errors due to clinicians' subjectivity. Most of these efforts are meant initially for research only, but very soon completely automatic methods will become increasingly available for clinical purposes in addition to the computer-assisted method already described.

The main source of errors includes technical measurements, radiographic acquisition and identifying landmarks. Most errors occur in landmark identification and are influenced by clinician experience, landmark definition, image density and sharpness. The reduction of a three-dimensional (3D) structure to a two-dimensional (2D) image adds to the difficulty.

Since the introduction of cephalometry in the early 1900's, the lateral cephalometric radiograph has become a standard tool in orthodontic assessment and treatment planning. This is despite the acknowledged health risks associated with exposure to ionizing radiation, (White, 1992), in particular the somatic effects that increase the risk of cancer during the patient's lifetime. It is well established that there is significant everyday background radiation that accounts for large amounts of radiation exposure. Nevertheless, as stated in the introduction, since radiation is cumulative, health care professionals must limit diagnostic radiation exposure to an absolute minimum and all exposures should be justifiable in terms of management of the patient (Tanner *et al*., 2001). As cited by Isaacson *et al*., (2008), the current guidelines in the United Kingdom for clinical orthodontics give the following indications for use of a lateral cephalometric radiograph:

1) a skeletal discrepancy when functional or fixed appliances are to be used for labiolingual movement of incisors
2) patients with moderate skeletal discrepancies in a teaching environment

3) the location and assessment of unerupted, malformed, or ectopic teeth

4) limited serial radiographs for assessing growth and planning orthognathic surgery

The need for lateral cephalometric radiographs in certain patients has always been controversial. Many authors are of the opinion that study models alone provide adequate information for treatment planning, and the incremental addition of other diagnostic records make minimal difference. More recently, studies have noted that, for most patients, the clinical examination, supplemented with study models and photographs, provided adequate information for orthodontic treatment planning (Brown *et al*., 1977*).* It should be stressed that individually based selection criteria should be used for radiographic examination. Pae *et al.*, (2001) stated that the lateral cephalometric radiograph might influence treatment planning in patients with bimaxillary protrusion and class II division 2 malocclusion, however cephalometrics does not appear to influence orthodontic treatment planning for class II division 1 adolescents.

With the rapid evolution of computer radiography, digital tracing is slowly replacing the manual tracing methods.

Figure 32: Digital markings on a Cephalogram

According to Polat-Ozsoy *et al.,* (2009), three techniques are commonly reported:

- the first uses digitizer pads for tracing conventional cephalometric films and software programs to compute the measurements
- the second uses scanners or digital cameras to export cephalometric images to measurement programs and
- the third transmits digital radiographs directly to a computer database

The use of both digital radiography and conversion of manual film to a digital format offers several advantages:

- it is easy to use
- allows several analyses to be performed at a time
- allows convenience when generating treatment predictions

- takes up less storage space
- allows superimposition of images
- provides the option to manipulate the size and contrast of the image and
- provides the ability to archive and improve access to images to overcome the problem of film deterioration, which has been a major source of information loss in craniofacial biology (Santoro *et al.,* 2006)

Moreover, patients benefit from reduced radiation dose and elimination of chemicals and associated environmental hazards when a direct digital cephalogram is used for image capture. However, several drawbacks are also present, such as difficulty in landmark identification related to the 2D representation of a 3D structure, superimposition of bilateral structures and the need for a digital cephalometric radiographic machine as well as a software program. Furthermore, the quality of digital images is affected by their resolution, pixel size, shades of grey (bit) and compression format.

Many practices worldwide have not yet switched to the use of direct digital cephalograms and therefore, the digitization process of conventional films is the only option if the benefits of digital cephalometric analysis are to be maximally achieved. Various studies have been conducted to compare the accuracy of digitized, scanned and digitally obtained radiographs with conventional methods (Power *et al.,* 2005). Few of them have compared angular and linear measurements, mostly because the analysis of the reproducibility of lines and angles is more challenging in relation to multiple sources of error than landmark studies (Celik *et al.,* 2009). However, results of comparisons between the digitizing methods compared with conventional radiographs are contradictory, probably because of the variety in the methods of obtaining digital images and the use of different cephalometric software.

Despite its widespread use in orthodontics, radiographic analysis is time-consuming and has the disadvantage of being subject to random and systematic error.

Our study was conducted using the manual tracing method for determining the landmarks and doing the measurements.

The literature would benefit from more data with direct clinical applications and an answer to whether a digital cephalometric analysis provides a diagnostic product equivalent to the conventional one. As alluded earlier, further studies are needed to confirm the reliability of digital cephalometric analysis.

Automatic land marking of cephalograms

With the conventional cephalometric techniques, complex 3D structures are projected onto a 2D plane. Consequently there are restrictions including superimposition of anatomical structures resulting in obstacles with respect to the landmark identification, magnification and distortion. Also with conventional cephalometric techniques information concerning anatomical relationships in the coronal plane is not provided.

Until recently, conventional tracings were considered the best method for accurate cephalometric analysis. Nowadays, the widespread use of computerized software programs has highlighted the need to evaluate their consistency and compare them with conventional tracing methods. According to Santoro *et al,* (2006) any investigation aiming to demonstrate the consistency of digital cephalometrics should focus on several significant factors, such as the use of measurements instead of landmarks as well as the sources of error. Ongkosuwito *et al,* (2009) stated that digital pictures that originate from poor quality analogue cephalometric radiographs often appear even poorer on screen and consequently influence landmark identification. Errors with the digital technique can also result from using digital radiographs with unknown formats and unknown grey shades. Image quality of a cephalogram scanned in standard resolution is comparable to conventional cephalograms, while a high-resolution (six hundred dpi) version does not show better results and a grey scale less than seven-bit may lead to unreliable decisions on reproducibility of measurements. The non-correspondence between conventional and digital values could be attributed to the investigator identifying some anatomical structures differently when projected on screen, even if they could be repeated consistently in each method. Although a lack of calibration between images could also contribute to error.

The accuracy of cephalometric analysis is essential so that the clinician can assess the results and provide the patient with various treatment options and outcomes.

Studies have shown intra-examiner and inter-examiner variability in treatment planning, even with the same records. (Silling *et al.,* 1979)

Orthodontists are however confident in diagnosing and treatment planning without the use of a radiograph and are consistent in their treatment plan decisions for cases they have treated in the past. Prior research has demonstrated a radiograph is not always indicated for self-assurance when diagnosing and treatment planning (Han *et al.,* 1991).

Therefore the exposure of patients to unnecessary radiation to determine their growth is questionable, when alternative tools for diagnoses are available. This could result in a reduction of patient radiation doses before and during orthodontic treatment.

Another burning issue is the future direction of the use of digital radiographs for treatment planning and diagnosis. Studies should be focused in this vast arena where a whole new vista awaits both the researcher and the clinician.

Vertical discrepancies are to some extent the result of growth that was programmed in that direction, but their expression is influenced by form-function interactions. The orthodontic clinician must make a careful differential diagnosis for each patient who seeks his or her care.

The diagnosis must analyse all three components of a malocclusion:

- facial
- dental and
- skeletal.

Each component must be carefully studied and understood so that the correct diagnostic decisions are made to lead to an effective treatment plan.

CHAPTER 6

CONCLUSION

There is no aspect of the health sciences that is not influenced by the discovery of radiographs. Orthodontics is no exception. Radiographs are a valuable tool in orthodontic diagnosis.

Ideally, panoramic and cephalometric radiographs should be taken when information from the clinical examination is considered insufficient.

As an orthopantomograph is routinely requested by dentists during dental examination, it would seem to be a useful feature to use for determining growth direction, so that dentists can detect vertical growth problems.

This study compared certain linear and angular measurements obtained from lateral cephalograms and orthopantomographs to determine whether the use of the orthopantomograph could be extended to evaluate vertical jaw relationships. The objective of this study used radiographs to investigate whether the orthopantomograph can be used instead of a lateral cephalogram to assess the three different facial forms in respect to the vertical plane.

Based on the findings of our study it can be concluded that angular measurements could be correlated between the two radiographs. There was no significant difference between the angles measured in the groups. So angular distortion in both the images is within the acceptable range and they could be used for clinical measurements if the images are prepared perfectly and without technical errors.

There is however, little consistency between the linear measurements taken from an orthopantomograph and that of a lateral cephalogram radiograph.

These findings also showed that there were no statistically significant differences between the angle measurements of the two radiographs in normal and horizontal growth patterns. However this did not apply to the vertical growth pattern. Larger samples may show a different result.

The present study was undertaken in an attempt to answer whether panoramic radiograph can be used instead of lateral cephalogram to assess dentoskeletal pattern of the patient.

Both the angular parameters measured on the orthopantomograph showed high correlation and predictability when compared with similar parameters measured on lateral cephalogram. Thus the orthopantomograph can be used for angular measurements of both the gonial angle and the condyle angle, instead of lateral cephalogram.

The study conducted was not was not race or gender specific. With respect to race and gender, future studies could be investigated to include these criteria.

Although a correlation was observed for the angular measurements, further investigations would have to be undertaken to establish a formula to create norm values to determine the vertical dimension from the orthopantomograph.

Guidelines for orthodontic radiographs permit panoramic radiographs as part of an orthodontic assessment to determine the condition of the dentition and presence or absence of unerupted teeth (Isaacson *et al.*, 2008). Therefore, it seems that an orthopantomograph which is a simple, inexpensive and an extensive diagnostic tool can be investigated and studied more extensively for determination of angular as well as linear measurements as an indicator of vertical jaw relations.

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ADDENDA

ADDENDUM A - Access to information

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Health Sciences
School of Dentistry
P O Box 1266, Pretoria, 0001

TO WHOM IT MAY CONCERN

CONSENT TO CONDUCT A STUDY TITLED: "CAN AN ORTHOPANTOMOGRAPH BE USED AS AN INDICATOR OF VERTICAL JAW RELATIONS?"

In terms of the requirements of the Promotion of Access to Information, Act 2 of 2000, I, Prof AJ Ligthelm, Dean/Manager of the School of Dentistry, hereby gives permission to Dr MF Suliman to access and analyse radiographic records of patients kept in the Orthodontic and other departments in the Faculty.

PROF AJ LIGTHELM

DEAN/MANAGER

Date:

ADDENDUM B – Biostatistician's letter of clearance

Date: 14 / July /2014

LETTER OF CLEARANCE FROM THE BIOSTATISTICIAN

This letter is to confirm that the student(s),

with the Name(s) DR MF SULIMAN

Studying at the University of PRETORIA

discussed the Project with the title CAN AN ORTHOPANTOMOGRAPH BE USED AS AN INDICATOR OF VERTICAL JAW RELATIONS

with me.

I hereby confirm that I am aware of the project and also undertake to assist with the Statistical analysis of the data generated from the project.

The analytical tool that will be used will be SAS: PROC MEANS, PROC CORR, PROC UNIVARIATE, PROC TTEST, PROC NPARIWAY AND MICROSOFT EXCEL

to achieve the objective(s) of the study.

Name PROF H S SCHOEMAN Date 14 July 2014

Signature [signature] Tel: 082 896 3606

Department or Unit BIOSTATISTICIAN: PROFESSIONAL STATISTICAL SERVICES

PROFESSIONELE STATISTIESE DIENSTE BK
PROFESSIONAL STATISTICAL SERVICES CC

Official Stamp of Biostatistician

ADDENDUM C – Protocol approval

The Research Ethics Committee, Faculty Health Sciences, University of Pretoria complies with ICH-GCP guidelines and has US Federal wide Assurance.

* **FWA** 00002567, Approved dd 22 May 2002 and Expires 20 Oct 2016.
* **IRB** 0000 2235 IORG0001762 Approved dd 13/04/2011 and Expires 13/04/2014.

Universiteit van Pretoria
University of Pretoria

Faculty of Health Sciences Research Ethics Committee Fakulteit Gesondheidswetenskappe Navorsingsetiekkomitee

DATE: **22/11/2012**

NUMBER	**222/2012**
TITLE OF THE PROTOCOL	Can an Orthopantomograph be used as an indicator of Vertical Jaw Relations
PRINCIPAL INVESTIGATOR	**Student Name & Surname:** Dr Mohamed Faried Suliman **Dept:** Orthodontics Oral and Dental Hospital;University of Pretoria. **Cell:**0827865786 **E-Mail:** faried.suliman@up.ac.za
SUB INVESTIGATOR	Not Applicable
STUDY COORDINATOR	Not Applicable
SUPERVISOR	Prof S M Dawjee **E-Mail:** s.dawjee@up.ac.za
STUDY DEGREE	MSc
SPONSOR COMPANY	Not applicable
CONTACT DEATAILS OF SPONSOR	Not Applicable
SPONSORS POSTAL ADDRESS	Not applicable
MEETING DATE	21/11/2012

The Protocol was approved on 21/11/2012 by a properly constituted meeting of the Ethics Committee subject to the following conditions:

1. The approval is valid for 2 years period [till the end of December 2014], and
2. The approval is conditional on the receipt of 6 monthly written Progress Reports, and
3. The approval is conditional on the research being conducted as stipulated by the details of the documents submitted to and approved by the Committee. In the event that a need arises to change who the investigators are, the methods or any other aspect, such changes must be submitted as an Amendment for approval by the Committee.

Members of the Research Ethics Committee:

Prof M J Bester (female)BSc (Chemistry and Biochemistry); BSc (Hons)(Biochemistry); MSc(Biochemistry); PhD (Medical Biochemistry)

Prof R Delport (female)BA et Scien, B Curationis (Hons) (Intensive care Nursing), M Sc (Physiology), PhD (Medicine), M Ed Computer Assisted Education

Dr NK Likibi MBB HM – Representing Gauteng Department of Health) MPH

Dr MP Mathebula	(female)Deputy CEO: Steve Biko Academic Hospital; MBCHB, PDM, HM
Prof A Nienaber	(female) BA(Hons)(Wits); LLB; LLM; LLD(UP); PhD; Dipl.Datametrics(UNISA) – Legal advisor
Mrs MC Nzeku	(female) BSc(NUL); MSc(Biochem)(UCL, UK) – Community representative
Prof L M Ntlhe	MbChB (Natal) FCS (SA)
Snr Sr J Phatoli	(female) BCur(Eet.A); BTec(Oncology Nursing Science) – Nursing representative
Dr R Reynders	MBChB (Prêt), FCPaed (CMSA) MRCPCH (Lon) Cert Med. Onc (CMSA)
Dr T Rossouw	(female) MBChB (cum laude); M.Phil (Applied Ethics) (cum laude), MPH (Biostatistics and Epidemiolog (cum laude), D.Phil
Dr L Schoeman	(female) B.Pharm, BA(Hons)(Psych), PhD – Chairperson: Subcommittee for students' research
Mr Y Sikweyiya	MPH; SARETI Fellowship in Research Ethics; SARETI ERCTP; BSc(Health Promotion)Postgraduate Dip (Health Promotion) – Community representative
Dr R Sommers	(female) MBChB; MMed(Int); MPharmMed – **Deputy Chairperson**
Prof TJP Swart	BChD, MSc (Odont), MChD (Oral Path), PGCHE – School of Dentistry representative
Prof C W van Staden	MBChB; MMed (Psych); MD; FCPsych; FTCL; UPLM - **Chairperson**

DR R SOMMERS; MBChB; MMed(Int); MPharmMed.
Deputy Chairperson of the Faculty of Health Sciences Research Ethics Committee, University of Pretoria

◆ Tel:012-3541330 ◆ Fax:012-3541367 / 0866515924 ◆ E-Mail: manda@med.up.ac.za
◆ Web: //www.healthethics-up.co.za ◆ H W Snyman Bld (South) Level 2-34 ◆Private Bag x 323, Arcadia, Pta, S.A., 0007

d

ADDENDUM D - Data collection sheets

N_ID	NC_Gonial	NO_Ratio	NC_Y_ Axis	NC_Ramus	NO_Gonial	NO_Condyle	NO_Ramus	NC Condyle
1	147	5:06	68	45	146	39	61	36
2	112	4:06	68	59	110	35	78	32
3	132	5:07	68	57	129	36	76	33
4	122	5:07	68	60	110	34	81	35
5	139	4:07	68	50	140	36	76	37
6	137	5:07	68	53	136	32	65	31
7	111	5:05	66	54	116	37	68	39
8	132	6:07	66	63	127	30	88	31
9	122	5:07	66	56	149	47	59	47
10	115	5:06	66	55	121	29	82	27
11	130	5:06	67	46	129	40	62	41
12	119	5:06	68	57	113	31	77	33
13	137	5:07	68	52	139	37	64	35
14	124	5:06	68	54	120	34	69	35
15	115	4:07	67	46	112	33	63	33
16	120	5:06	66	47	121	42	75	37
17	133	5:06	68	56	135	30	77	41
18	135	6:06	68	52	137	46	68	27
19	140	6:07	67	59	140	42	84	45
20	141	5:07	67	60	145	45	82	45
21	119	6:06	68	62	147	30	80	43
22	123	4:06	66	63	115	46	60	29
23	113	5:05	67	53	121	31	61	45
24	117	5:06	67	60	119	49	59	29
25	121	6:07	67	59	130	45	77	47
26	127	6:07	68	55	133	32	85	47
27	131	6:06	66	57	111	31	72	33
28	146	5:06	66	61	117	46	82	33
29	143	5:07	66	47	137	39	87	45
30	125	4:07	67	49	142	41	65	43

V_ID	VC_Gonial	VC_Ratio	VC_Y_ Axis	VC_Ramus	VO_Gonial	VO_Condyle	VO_Ramus	VC Condyle
1	118	4:06	70	53	110	27	73	29
2	133	5:07	69	58	136	35	70	33
3	129	5:05	70	49	132	39	66	36
4	120	6:06	77	59	112	27	77	28
5	131	6:06	70	53	129	41	78	42
6	122	5:07	71	56	115	36	70	37
7	120	6:07	75	64	111	28	90	29
8	124	6:07	70	61	105	32	82	33
9	120	5:06	74	56	109	35	74	33
10	143	4:07	75	49	135	32	70	31
11	124	5:07	74	55	116	41	71	42
12	124	5:07	73	56	118	40	75	41
13	125	5:06	72	51	133	37	65	35
14	127	5:06	76	56	116	31	73	33
15	126	5:07	70	56	125	31	71	32
16	137	4:06	70	46	129	33	65	31
17	130	6:07	73	60	126	44	68	43
18	131	5:07	70	59	130	36	71	37
19	130	6:07	72	53	107	36	73	35
20	131	5:07	75	59	121	31	76	33
21	118	5:07	72	59	118	39	65	40
22	120	6:07	73	57	116	35	78	37
23	128	6:06	72	56	128	39	66	37
24	117	5:06	78	59	110	35	73	35
25	137	4:05	76	39	136	43	57	41
26	110	5:07	76	56	106	34	74	35
27	125	5:06	74	60	124	40	74	39
28	124	5:06	71	52	123	33	77	35
29	121	5:07	73	59	119	39	75	37
30	127	6:07	73	58	127	40	67	41

H_ID	HC_Gonial	HC_ratio	HC_Y_ Axis	HC_Ramus	HO_Gonial	HO_ Condyle	HO_Ramus	HC Condyle
1	106	5:06	65	69	102	28	93	27
2	108	4:07	60	66	110	26	85	27
3	114	5:05	60	61	107	32	90	31
4	132	5:07	64	57	132	41	70	42
5	99	5:05	63	57	106	28	77	27
6	130	5:05	64	55	134	42	70	43
7	121	5:07	62	58	122	35	79	37
8	112	5:08	64	69	106	32	84	33
9	116	5:07	60	63	120	40	75	39
10	105	5:05	63	67	105	30	89	33
11	128	4:07	59	57	126	34	62	37
12	116	5:06	59	52	120	39	67	41
13	126	4:06	65	45	122	42	65	27
14	121	5:07	63	61	109	29	71	27
15	115	4:06	61	67	115	41	90	41
16	125	5:07	60	59	130	37	63	35
17	123	5:07	64	56	127	30	66	31
18	129	5:06	59	57	125	33	74	35
19	101	4:07	60	59	119	37	79	39
20	110	4:05	60	63	121	42	87	41
21	103	5:05	59	67	115	26	65	27
22	131	4:06	62	56	120	30	81	31
23	127	6:07	62	52	117	36	75	35
24	111	5:07	65	60	109	39	73	37
25	119	5:06	66	61	133	29	89	30
26	100	5:07	66	67	109	36	84	35
27	113	5:06	67	49	125	37	80	37
28	127	4:07	64	51	127	40	83	41
29	105	5:07	61	55	132	41	69	43
30	133	4:07	62	58	119	33	78	31

ADDENDUM E - Statistical results

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RESEARCH STUDY: DR MF SULIMAN: UP 2014 6

PROGRAM FILE CRUZER BLADE H:\UP Suliman\HORIZONTAL_CO
BASIC STATISTICS FOR HORIZONTAL GONIAL, CONDYLE AND RAMUS
PRINTOUT H1 13:13 Saturday, July 5, 2014

-- Image=Cephalogram --

The MEANS Procedure

Variable	N	Mean	Std Dev	Median	5th Pctl	95th Pctl	Minimum
H_Gonial	30	116.87	10.54	116.00	100.00	132.00	99.00
H_Condyle	30	34.67	5.40	35.00	27.00	43.00	27.00
H_Ramus	30	59.13	6.09	58.50	49.00	69.00	45.00

Variable	Maximum
H_Gonial	133.00
H_Condyle	43.00
H_Ramus	69.00

-- Image=Orthopatomograph --

Variable	N	Mean	Std Dev	Median	5th Pctl	95th Pctl	Minimum
H_Gonial	30	118.80	9.35	120.00	105.00	133.00	102.00
H_Condyle	30	34.83	5.20	35.50	26.00	42.00	26.00
H_Ramus	30	77.10	9.05	77.50	63.00	90.00	62.00

Variable	Maximum
H_Gonial	134.00
H_Condyle	42.00
H_Ramus	93.00

****

RESEARCH STUDY: DR MF SULIMAN: UP 2014

5

PROGRAM FILE CRUZER BLADE H:\UP Suliman\NORMAL_CO

BASIC STATISTICS FOR NORMAL GONIAL, CONDYLE AND RAMUS

PRINTOUT N1 13:13 Saturday, July 5, 2014

--------------------------------------- Image=Cephalogram ---------------------------------------

The MEANS Procedure

Variable	N	Mean	Std Dev	Median	5th Pctl	95th Pctl	Minimum
N_Gonial	30	127.60	10.58	126.00	112.00	146.00	111.00
N_Condyle	30	37.13	6.38	35.50	27.00	47.00	27.00
N_Ramus	30	54.90	5.35	55.50	46.00	63.00	45.00

Variable	Maximum
N_Gonial	147.00
N_Condyle	47.00
N_Ramus	63.00

------------------------------------ Image=Orthopatomograph ------------------------------------

Variable	N	Mean	Std Dev	Median	5th Pctl	95th Pctl	Minimum
N_Gonial	30	128.23	12.41	129.00	110.00	147.00	110.00
N_Condyle	30	37.50	6.16	36.50	30.00	47.00	29.00
N_Ramus	30	72.77	9.25	75.50	59.00	87.00	59.00

Variable	Maximum
N_Gonial	149.00
N_Condyle	49.00
N_Ramus	88.00

****

RESEARCH STUDY: DR MF SULIMAN: UP 2014 7

PROGRAM FILE CRUZER BLADE H:\UP Suliman\VERTICAL_CO

BASIC STATISTICS FOR VERTICAL GONIAL, CONDYLE AND RAMUS

PRINTOUT V1 13:13 Saturday, July 5, 2014

--------------------------------------- Image=Cephalogram --

The MEANS Procedure

Variable	N	Mean	Std Dev	Median	5th Pctl	95th Pctl	Minimum
V_Gonial	30	125.73	6.87	125.00	117.00	137.00	110.00
V_Condyle	30	35.67	4.16	35.00	29.00	42.00	28.00
V_Ramus	30	55.47	5.02	56.00	46.00	61.00	39.00

Variable	Maximum
V_Gonial	143.00
V_Condyle	43.00
V_Ramus	64.00

------------------------------------ Image=Orthopatomograph -------------------------------------

Variable	N	Mean	Std Dev	Median	5th Pctl	95th Pctl	Minimum
V_Gonial	30	120.73	9.53	120.00	106.00	136.00	105.00
V_Condyle	30	35.63	4.56	35.50	27.00	43.00	27.00
V_Ramus	30	72.13	6.15	73.00	65.00	82.00	57.00

Variable	Maximum
V_Gonial	136.00
V_Condyle	44.00
V_Ramus	90.00

****

RESEARCH STUDY: DR MF SULIMAN: UP 2014
1
PROGRAM FILE CRUZER BLADE H:\UP Suliman\HORIZONTAL
CORRELATION COEFFICIENTS: HORIZONTAL 10:28 Wednesday, July 2, 2014
PRINTOUT H5

The CORR Procedure

2 Variables: HC_Gonial HO_Gonial

Simple Statistics

Variable	N	Mean	Std Dev	Median	Minimum	Maximum	Label
HC_Gonial	30	116.86667	10.54296	116.00000	99.00000	133.00000	HC_Gonial
HO_Gonial	30	118.80000	9.35285	120.00000	102.00000	134.00000	HO_Gonial

Pearson Correlation Coefficients, N = 30
Prob > |r| under H0: Rho=0

	HC_Gonial	HO_Gonial
HC_Gonial HC_Gonial	1.00000	0.57498 0.0009
HO_Gonial HO_Gonial	0.57498 0.0009	1.00000

Spearman Correlation Coefficients, N = 30
Prob > |r| under H0: Rho=0

	HC_Gonial	HO_Gonial
HC_Gonial HC_Gonial	1.00000	0.56660 0.0011
HO_Gonial HO_Gonial	0.56660 0.0011	1.00000

****

RESEARCH STUDY: DR MF SULIMAN: UP 2014
2
PROGRAM FILE CRUZER BLADE H:\UP Suliman\HORIZONTAL
CORRELATION COEFFICIENTS: HORIZONTAL 10:28 Wednesday, July 2, 2014
PRINTOUT H5

The CORR Procedure

2 Variables: HC_Ramus HO_Ramus

Simple Statistics

Variable	N	Mean	Std Dev	Median	Minimum	Maximum	Label
HC_Ramus	30	59.13333	6.08975	58.50000	45.00000	69.00000	HC_Ramus
HO_Ramus	30	77.10000	9.04910	77.50000	62.00000	93.00000	HO_Ramus

Pearson Correlation Coefficients, N = 30
Prob > |r| under H0: Rho=0

HC_Ramus HO_Ramus

```
                    HC_Ramus        1.00000        0.50911
                    HC_Ramus                        0.0041

                    HO_Ramus        0.50911        1.00000
                    HO_Ramus         0.0041


                 Spearman Correlation Coefficients, N = 30
                         Prob > |r| under H0: Rho=0

                                   HC_Ramus       HO_Ramus

                    HC_Ramus        1.00000        0.51866
                    HC_Ramus                        0.0033

                    HO_Ramus        0.51866        1.00000
                    HO_Ramus         0.0033
```

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*****

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                       RESEARCH STUDY: DR MF SULIMAN: UP 2014
3
                 PROGRAM FILE CRUZER BLADE H:\UP Suliman\HORIZONTAL
                        CORRELATION COEFFICIENTS: HORIZONTAL   10:28 Wednesday, July 2,
2014
                                    PRINTOUT H5

                                The CORR Procedure

                        2  Variables:     HC_Condyle HO_Condyle


                                 Simple Statistics
```

Variable	N	Mean	Std Dev	Median	Minimum	Maximum	Label
HC_Condyle	30	34.66667	5.40328	35.00000	27.00000	43.00000	
HC_Condyle							
HO_Condyle	30	34.83333	5.20002	35.50000	26.00000	42.00000	
HO_Condyle							

```
                 Pearson Correlation Coefficients, N = 30
                         Prob > |r| under H0: Rho=0

                                  HC_Condyle       HO_Condyle

                 HC_Condyle          1.00000          0.82022
                 HC_Condyle                            <.0001

                 HO_Condyle          0.82022          1.00000
                 HO_Condyle           <.0001


                 Spearman Correlation Coefficients, N = 30
                         Prob > |r| under H0: Rho=0

                                  HC_Condyle       HO_Condyle

                 HC_Condyle          1.00000          0.81021
                 HC_Condyle                            <.0001

                 HO_Condyle          0.81021          1.00000
                 HO_Condyle           <.0001
```

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RESEARCH STUDY: DR MF SULIMAN: UP 2014

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PROGRAM FILE CRUZER BLADE H:\UP Suliman\NORMAL_CO

CORRELATION COEFFICIENTS: NORMAL 10:57 Wednesday, July 2, 2014

PRINTOUT N5

The CORR Procedure

2 Variables: NC_Gonial NO_Gonial

Simple Statistics

Variable	N	Mean	Std Dev	Median	Minimum	Maximum	Label
NC_Gonial	30	127.60000	10.58170	126.00000	111.00000	147.00000	NC_Gonial
NO_Gonial	30	128.23333	12.41435	129.00000	110.00000	149.00000	NO_Gonial

Pearson Correlation Coefficients, N = 30
Prob > |r| under H0: Rho=0

	NC_Gonial	NO_Gonial
NC_Gonial	1.00000	0.53334
NC_Gonial		0.0024
NO_Gonial	0.53334	1.00000
NO_Gonial	0.0024	

Spearman Correlation Coefficients, N = 30
Prob > |r| under H0: Rho=0

	NC_Gonial	NO_Gonial
NC_Gonial	1.00000	0.52735
NC_Gonial		0.0027
NO_Gonial	0.52735	1.00000
NO_Gonial	0.0027	

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RESEARCH STUDY: DR MF SULIMAN: UP 2014

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PROGRAM FILE CRUZER BLADE H:\UP Suliman\NORMAL_CO

CORRELATION COEFFICIENTS: NORMAL 10:57 Wednesday, July 2, 2014

PRINTOUT N5

The CORR Procedure

2 Variables: NC_Ramus NO_Ramus

Simple Statistics

Variable	N	Mean	Std Dev	Median	Minimum	Maximum	Label
NC_Ramus	30	54.90000	5.34564	55.50000	45.00000	63.00000	NC_Ramus
NO_Ramus	30	72.76667	9.25010	75.50000	59.00000	88.00000	NO_Ramus

Pearson Correlation Coefficients, N = 30
Prob > |r| under H0: Rho=0

	NC_Ramus	NO_Ramus
NC_Ramus	1.00000	0.36284
NC_Ramus		0.0488

NO_Ramus	0.36284	1.00000
NO_Ramus	0.0488	

Spearman Correlation Coefficients, N = 30
Prob > |r| under H0: Rho=0

	NC_Ramus	NO_Ramus
NC_Ramus	1.00000	0.37613
NC_Ramus		0.0405
NO_Ramus	0.37613	1.00000
NO_Ramus	0.0405	

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RESEARCH STUDY: DR MF SULIMAN: UP 2014
3
PROGRAM FILE CRUZER BLADE H:\UP Suliman\NORMAL_CO
CORRELATION COEFFICIENTS: NORMAL 10:57 Wednesday, July 2, 2014

PRINTOUT N5

The CORR Procedure

2 Variables: NC_Condyle NO_Condyle

Simple Statistics

Variable	N	Mean	Std Dev	Median	Minimum	Maximum	Label
NC_Condyle	30	37.13333	6.38281	35.50000	27.00000	47.00000	NC_Condyle
NO_Condyle	30	37.50000	6.15742	36.50000	29.00000	49.00000	NO_Condyle

Pearson Correlation Coefficients, N = 30
Prob > |r| under H0: Rho=0

	NC_Condyle	NO_Condyle
NC_Condyle	1.00000	0.09827
NC_Condyle		0.6054
NO_Condyle	0.09827	1.00000
NO_Condyle	0.6054	

Spearman Correlation Coefficients, N = 30
Prob > |r| under H0: Rho=0

	NC_Condyle	NO_Condyle
NC_Condyle	1.00000	0.11919
NC_Condyle		0.5304
NO_Condyle	0.11919	1.00000
NO_Condyle	0.5304	

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RESEARCH STUDY: DR MF SULIMAN: UP 2014

1

PROGRAM FILE CRUZER BLADE H:\UP Suliman\VERTICAL_CO

CORRELATION COEFFICIENTS: VERTICAL 10:31 Thursday, July 3, 2014

PRINTOUT V5

The CORR Procedure

2 Variables: VC_Gonial VO_Gonial

Simple Statistics

Variable	N	Mean	Std Dev	Median	Minimum	Maximum	Label
VC_Gonial	30	125.73333	6.86788	125.00000	110.00000	143.00000	VC_Gonial
VO_Gonial	30	120.73333	9.53011	120.00000	105.00000	136.00000	VO_Gonial

Pearson Correlation Coefficients, N = 30
Prob > |r| under H0: Rho=0

	VC_Gonial	VO_Gonial
VC_Gonial VC_Gonial	1.00000	0.74857 <.0001
VO_Gonial VO_Gonial	0.74857 <.0001	1.00000

Spearman Correlation Coefficients, N = 30
Prob > |r| under H0: Rho=0

	VC_Gonial	VO_Gonial
VC_Gonial VC_Gonial	1.00000	0.75897 <.0001
VO_Gonial VO_Gonial	0.75897 <.0001	1.00000

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RESEARCH STUDY: DR MF SULIMAN: UP 2014

2

PROGRAM FILE CRUZER BLADE H:\UP Suliman\VERTICAL_CO

CORRELATION COEFFICIENTS: VERTICAL 10:31 Thursday, July 3, 2014

PRINTOUT V5

The CORR Procedure

2 Variables: VC_Ramus VO_Ramus

Simple Statistics

Variable	N	Mean	Std Dev	Median	Minimum	Maximum	Label
VC_Ramus	30	55.46667	5.02225	56.00000	39.00000	64.00000	VC_Ramus
VO_Ramus	30	72.13333	6.14611	73.00000	57.00000	90.00000	VO_Ramus

Pearson Correlation Coefficients, N = 30
Prob > |r| under H0: Rho=0

VC_Ramus VO_Ramus

VC_Ramus	1.00000	0.63468
VC_Ramus		0.0002
VO_Ramus	0.63468	1.00000
VO_Ramus	0.0002	

Spearman Correlation Coefficients, N = 30
Prob > |r| under H0: Rho=0

	VC_Ramus	VO_Ramus
VC_Ramus	1.00000	0.42159
VC_Ramus		0.0203
VO_Ramus	0.42159	1.00000
VO_Ramus	0.0203	

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RESEARCH STUDY: DR MF SULIMAN: UP 2014

3

PROGRAM FILE CRUZER BLADE H:\UP Suliman\VERTICAL_CO
CORRELATION COEFFICIENTS: VERTICAL 10:31 Thursday, July 3,
2014

PRINTOUT V5

The CORR Procedure

2 Variables: VC_Condyle VO_Condyle

Simple Statistics

Variable	N	Mean	Std Dev	Median	Minimum	Maximum	Label
VC_Condyle	30	35.66667	4.15504	35.00000	28.00000	43.00000	
VC_Condyle							
VO_Condyle	30	35.63333	4.55982	35.50000	27.00000	44.00000	
VO_Condyle							

Pearson Correlation Coefficients, N = 30
Prob > |r| under H0: Rho=0

	VC_Condyle	VO_Condyle
VC_Condyle	1.00000	0.93792
VC_Condyle		<.0001
VO_Condyle	0.93792	1.00000
VO_Condyle	<.0001	

Spearman Correlation Coefficients, N = 30
Prob > |r| under H0: Rho=0

	VC_Condyle	VO_Condyle
VC_Condyle	1.00000	0.93632
VC_Condyle		<.0001
VO_Condyle	0.93632	1.00000
VO_Condyle	<.0001	