A retrospective study comparing the Holdaway and Ricketts Visual Treatment Objectives (VTOs) to orthodontic treatment outcomes.

RESPICE PROSPICE

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A retrospective study comparing the Holdaway and Ricketts Visual Treatment Objectives (VTOs) to orthodontic treatment outcomes.

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Declaration

I,…**Yoemna Khatib**………. declare that this thesis entitled "A retrospective study comparing the Holdaway and Ricketts Visual Treatment Objectives (VTOs) to orthodontic treatment outcomes" is my own original work and has not been submitted for a higher degree to any other institution. The sources I have quoted have been acknowledged by means of references.

Student number: 9826345

Signature:

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1. My husband, Allie; thank you for your love, being my pillar of strength and support and the voice of reason when I needed it the most.
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Dedication

To the Almighty, without His divine guidance nothing would be.

To my parents; for all the prayers, years of sacrifice, support and undying love.

Abstract

Traditionally orthodontic treatment planning was predominantly based on the dental occlusion without too much emphasis on and consideration for facial proportions and aesthetics. Predicting treatment outcomes has always been part of science. The ability to predict is important in other areas of science and medicine, and it is important in the treatment of orthodontic patients.

Holdaway coined the term “visualized treatment objective” (VTO), to describe his predicted treatment outcome. Ricketts stated that all treatment planning constituted some sort of prediction. His prediction analysis allowed for forecast of the soft tissue profile which was based on the reactions of the skeletal and dental components due to orthodontic treatment.

The aim of this study was to compare the predicted outcomes of two popular VTO’s, viz Ricketts and Holdaway, to the actual outcomes of adult patients. The complete Holdaway VTO and Ricketts VTO were done on each pre-treatment cephalogram using the space analysis values from the records. These VTOs predicted where the soft tissue profile (nose tip to chin) would be, in relation to the H-line and E-plane respectively. The post-treatment tracings were done. The two tracings for each patient were then superimposed.

The measurements evaluated were: (1) Facial convexity angle, (2) Holdaway Soft tissue Facial angle, (3) Upper lips to E-line and (4) Lower lips to E-line, (5) Lower lip to H-line,(6) upper- and (7) lower incisors to A-Po line and (8) the Holdaway H-angle.

There was a statistical significant difference between the predicted and resultant facial convexity angles indicating the prediction values were not precise. The measurements taken from the Holdaway VTO analysis proved not to be statistically significant. The standard deviation was 3.5 and the t value (44) = 0.034 and p value = .973 ($p < 0.5$).

Ricketts VTO were elevated when compared to the resultant measurements. The mean value for the predicted value for the lower lips to E-line in Ricketts analysis was 0.94 whereas for the resultant the value was 0.74. The standard deviation was 0.399, the t value (44) = 3.384 and p value = 0.002 ($p < 0.05$), which indicates a statistical significance.

From this study it can be noted that Ricketts' VTO is statistically better at predicting the soft tissue outcome than the Holdaway VTO. The mean values were 35.01^{o} and 33.43^{o} respectively for the predicted Upper Incisor to APo line and the resultant measurement. The standard deviation was 2.43 and the t value (44) = 4.37 and p value = 0.000 and was therefore statistically significant ($p < 0.05$).

Therefore, from this study it appears that Ricketts VTO is a more appropriate prediction method for the adult sample from this studied Cape Town community. As two VTOs compared were based on a North

American Caucasian sample, the difference noted in the present study may be due to the difference in the ethnicity.

Keywords

- Visualized Treatment Objectives (VTOs)
- Treatment prediction
- Holdaway
- Ricketts
- Soft tissue outcomes
- Adult sample

Chapter One

Introduction

Traditionally orthodontic treatment planning was predominantly based on the dental occlusion without too much emphasis on and consideration for facial proportions and aesthetics.

Watson (1979) described prediction as follows, “Although science starts with observations and the recording of data, it is basically concerned with finding patterns of facts and, in particular, with finding patterns that repeat. It is in the understanding of such patterns that we achieve the capacity to do one of the things that distinguish human beings from animals: to predict”.

Baumrind (1991) suggested that the ability to predict assists the orthodontist psychologically in the treatment planning process by removing some of the art and adding a little more science.

Predicting treatment outcomes has always been part of science. The ability to predict is important in other areas of science and medicine, and it is important in the treatment of orthodontic patients. However, the variation in patient’s growth, development and treatments results in treatment prediction is difficult (Sample *et al*, 1998).

Holdaway coined the term “visualized treatment objective” (VTO), to describe his predicted treatment outcome (Holdaway, 1984).

Ricketts (1960a) suggested that all treatment planning constituted some sort of prediction. His prediction analysis allowed for forecast of the soft tissue profile which was based on the reactions of the skeletal and dental components due to orthodontic treatment.

The aim of this study was to compare the predicted outcomes of two popular VTO's, viz Ricketts and Holdaway, to the actual outcomes of adult patients.

The literature review in Chapter 2 will describe studies that have been conducted exploring the prediction of soft tissue profiles and the influence and significance thereof as well as a description of the VTOs. The aims and objectives along with the explanation of the research methodology including the ethics statement will be detailed in Chapter 3. The results of this study will be described in Chapter 4 and be further discussed in Chapter 5. The conclusion and recommendations from this study will be presented in Chapter 6.

Chapter Two

Literature Review

Introduction

The importance of soft tissue assessment in orthodontics is widely recognized (Saxby and Freer, 1985). Consideration for changes in the soft tissue associated with changes in the hard tissues during treatment is an important aspect in pre-treatment evaluation.

The treatment planning of facial aesthetic changes and soft tissue outcomes can be challenging as there are times when an attempt to correct a malocclusion may worsen the facial balance.

A Balanced Facial Profile

Physical appearance is an important characteristic of the face. It has long been established that self-esteem is strongly influenced by facial appearance (Hershon and Giddon, 1980). According to Sahin Saglam and Gazilerli (2001), cited by Anic-Milosevic (2008), the perception of an attractive face is largely subjective, with ethnicity, age, and gender, culture, and personality influencing average facial traits.

In a review of the American literature conducted by Mejia-Maidl and Evans (2000) on 35 cephalometric analyses from 1937 to 1969, it was found that only one study used a sample that reflected the general public's judgment of beauty. It was only Riedel (1950) who used 30 beauty contest winners for his sample, while all the other cephalometric analyses used samples characterized by a good occlusion only and/or the author's perception of an average or balanced face (Mejia-Maidl and Evans, 2000).

The perception of beauty may be influenced by society and culture. A study that showed American blacks to have a stronger preference for Caucasian features than do African blacks, which may be due to living in a majority white society, was conducted by Martin (1964). The general theoretical premise of this study was that “the standards for judgment of female facial beauty are essentially cultural in character”, but they are also influenced by "racial" averages of features (Martin, 1964).

In 1970, Peck and Peck set out to determine the public's concept of beauty as related to the white profile. They found that the general public admires a fuller, more protrusive dentofacial pattern compared with our customary orthodontic standards which refers to a straighter profile. Peck and Peck (1970) stressed the importance of the public's opinion stating that the "ultimate source of our esthetic values should be the people, not just orthodontists." They also mentioned that very few studies at the time have attempted to reflect the general public's judgement of the face in selecting a "normal" sample for orthodontic analysis.

Foster (1973) studied profile preferences among various groups by using silhouettes. These groups included blacks, whites, Chinese, art students, general dentists, and orthodontists. The results indicated that the diversified groups in this study seem to share a common aesthetic standard for posture of the lips within 1 to 2 mm in most cases. All groups were consistent in assigning fuller lips for younger ages. For adults, a straight profile was preferred (Foster, 1973).

Cephalometrics related to ethnicity

The cephalometric norms of different ethnic and racial groups established in various studies show that normal measurements for one group are not necessarily normal for another group; each racial group must be treated according to its own characteristics. A number of standards have been developed for various racial and ethnic groups (Drummond, 1968; Nanda and Nanda, 1969; Richardson, 1980 cited in Ajayi, 2005).

Alexander and Hitchcock (1978) conducted a study on fifty Black American children between ages 8 to 13 years to compare to the cephalometric values of the Alabama Analysis for Caucasians. Their study found no difference between Caucasoid and Black American children when the mean values of the Facial Plane to SN angle were compared. However, it was found that the upper and lower incisors were more procumbent and protrusive in the Black American group.

Cephalometric studies of the skeletal and soft tissue relationships of Caucasian people with bimaxillary dental protrusion have revealed similarities with those of other ethnic groups exhibiting the same dentofacial morphology (Keating 1985; Richardson, 1980 and Ajayi, 2005).

Sutter and Turley (1998) reported on the comparison of Caucasian and African American facial profiles. They deduced that the Caucasian group had a straighter profile as compared with the African American group who had fuller profile with more prominent lips. Furthermore, they showed that the Caucasians were more brachyfacial than the African American when the vertical soft tissue proportions were measured and assessed.

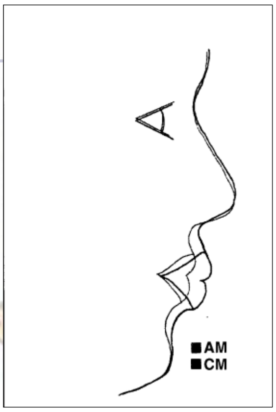


Figure 1: Sutter and Turley's Superimpositions of Caucasian Models (CM: lighter line) and African American Models (AM: darker line) profiles

Brock et al (2005) investigated and reported on ethnic differences in the upper lip response to incisor retraction. They used 88 post-pubertal female patients (44 black and 44 white) matched by age and the amount of incisor retraction at “incisor superius” (the tip of the crown of the most anterior maxillary central incisor).

Their results also showed that although significant pre-treatment differences existed between the groups in some cephalometric measurements, analysis of the treatment changes demonstrated significant differences only in incisor inclination (Brock et al 2005).

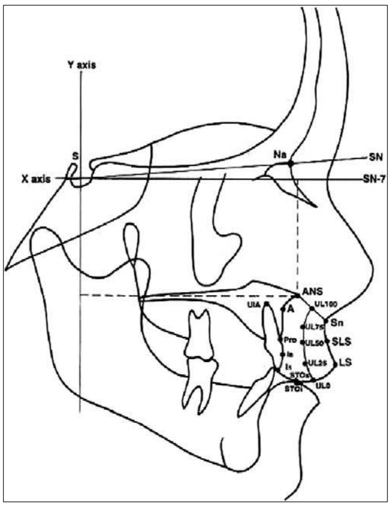


Figure 2: Brock's cephalometric landmarks and planes.

They concluded that the hard and soft tissue treatment changes of the black group were more significant in the vertical plane and those of the white group were inclined to be in the antero-posterior direction.

Additionally, ethnic differences in the soft tissue response to hard tissue changes in the upper lip, and at subnasale and the superior labial sulcus were noted. However, these response differences at superior labial sulcus may be explained by ethnic differences in initial lip thickness and incisor inclination; as they may not necessarily be due to ethnicity per se (Brock et al 2005).

With the introduction and use of cephalometrics it came to light that imperfect jaw relations as well as maloccluded teeth contributed to malocclusions (Proffit et al, 2013). Additionally, more recently, the goals and the limitations of modern orthodontics and orthognathic treatment have been focussing on the soft tissue and not only on the teeth and bones (Proffit et al, 2013).

Cephalometrics and Treatment Planning

Treatment planning plays a vital role in achieving optimal orthodontic treatment outcomes. Treatment planning is individualized and need not adhere to "strict anatomic norms of occlusion and facial configuration" (Moorrees, 2006).

Steiner (1953) was of the opinion that cephalometrics were an important diagnostic tool more so than the study models at that time. Although he considered cephalometrics to be important the problem with his analysis is that it is based on a single Caucasian female's cephalometric values. Nevertheless, cephalometric analysis of a lateral cephalogram is still thought to be an essential tool used to diagnose and assist in treatment planning (Nijkamp et al, 2008).

Cephalometric prediction or Visualised Treatment Objectives (VTOs) is used to aid in treatment planning. It is used as a tool to predict the soft tissue profile in response to orthodontic treatment especially in the growing patient as growth of the dentofacial region will affect orthodontic treatment.

The VTO can provide a graphic representation of the individual impact of the most probable pattern of growth and, by so doing, permit the clinician to visualize more readily the effect of various treatment alternatives. The

VTO has also frequently been used as a "blueprint" from which a treatment sequence has been derived (Thames et al 1985).

Visualized Treatment Objective (VTOs) of craniofacial growth has been proposed by various authors. These prediction methods have been based on mathematical models of the growth process (Jacobson, 2006). These include Jacobson and Sadowsky method, Holdaway and Ricketts analyses amongst others.

Ricketts (1972) recognized that there was a deficit in predicting treatment outcomes due to the complexity of craniofacial growth prediction for the individual. He then developed the computerized growth-prediction systems. He advocated the use of computers to predict growth because of the time required to compare, organize, and sort data and then retrieve the information in a clinically useful form (Ricketts, 1972).

He also stressed the need for individualizing measurements according to age, gender, ethnic type, and degree of maturation of each patient.

The Ricketts' approach to computerized growth prediction, which takes into account the initial individual facial pattern and then adds a variety of constants representing mean changes, has been available for several years as part of a commercial diagnostic service.

Steyn (1979 as cited in Murphy 2008) devised his own VTO and described some norms for South African Caucasian patients. Steyn's VTO was due to ethnicity differences in these patients compared to European

Caucasians. His VTO uses the S-N and Ba-Na planes and is gender specific. He allocated different increments of growth, in certain areas, for males and females. The lower incisor is positioned according to A-Pog and then the upper incisor is positioned relative to this (Steyn 1979).
One of the major shortcomings with these VTO studies is that the study samples were based on a South African Caucasian sample.

Later, Magness (1987) proposed a mini-VTO as a simple tool or method in predicting the incisor and molar relations on the basis of growth and treatment changes to the dentoskeletal framework but not with as much emphasis on the soft tissue profile as did the Holdaway and Ricketts analyses.

Description of VTO's

a) Ricketts VTO

Initially, Ricketts (1957) proposed a method using cephalometric radiography in which craniofacial growth and orthodontic treatment effects were predicted. Ricketts' treatment prediction also allowed for a forecast of the integumental profile, which was based on the reaction of the skeletal elements and the teeth to orthodontic treatment.
He claimed that his technique "appeared to be sensibly accurate in more than ninety percent of routine clinical cases to date."
Later, Ricketts (1960b) emphasised that since all treatment planning constituted some type of prediction estimating the amount of change that

would occur should include both the prediction changes due to tooth movement and that of facial changes.

Ricketts called this method of prediction a "dynamic synthesis" in which craniofacial growth and tooth movement were predicted (Ricketts 1960b) (Appendix 2).

Ricketts *et al* (1982) based their VTO on the positioning of the teeth. They first place the lower incisor in the correct position and in the preconceived ideal relations and depended on the soft tissue to drape over these new tooth positions in a harmonious relation. They put their approach very succinctly and aptly as "Begin with the end in mind."

b) Holdaway VTO

Holdaway (1983, 1984) on the other hand took a different approach to his cephalometric prediction method.

The goal of his "dynamic" cephalometric analysis and prediction was to establish a balanced facial profile with pleasing facial aesthetics and to evaluate the orthodontic correction necessary to obtain the latter goals.

The main difference between Holdaway's VTO and other types was that Holdaway predicted the soft tissue profile first then positioned the maxillary incisors accordingly. Holdaway re-emphasized the importance of soft tissue analysis as he quantified certain soft tissue relationships in harmonious faces (Holdaway 1983, 1984) (Appendix 1).

In contrast to Ricketts, Holdaway believed that the mandibular incisor could not be rigidly fixed to any anatomical landmark such as the A-Pogonion line (APo). Instead, the mandibular incisors should be placed relative to the maxillary incisors where adequate lip support had been established (Holdaway 1983, 1984).

Advantages of VTO's

Several authors have discussed the advantages of VTO's (Jacobson and Sadowsky 1980, Magness 1987, Sarver 1993 and Ackerman and Proffit 1995), and some of these can be summarized as follows:

- Establishment of specific treatment goals,
- Formulation of a specific treatment plan to reach treatment goals,
- Assistance in determining if the ideal treatment result is attainable orthodontically or surgically,
- Assistance in making mid-treatment corrections,
- Enhancing communication between patients and clinicians,
- Allowing quantification of proposed movements to reduce the difficulties in planning facial response to different movements, and
- Allowing rapid comparisons of different treatment options before arriving at a final treatment plan.

Limitations of VTO's

Despite the listed advantages of VTO, limitations exist in their implementation. Several authors (Ricketts 1960b, Johnston 1968, Jacobson and Sadowsky 1980, Holdaway 1984 and Sarver et al 1998) have described inadequacies of VTO, including:

- The use of average growth increments in growth prediction,
- The use of existing morphological traits to predict future growth events, and
- The fallibility of presenting VTO analysis as an exact representation of the treatment outcome.

Most authors agree that the experience of the clinician also plays a large role in the accuracy of the VTO prediction (Ricketts 1960b, Johnston 1968, Jacobson and Sadowsky 1980, Holdaway 1984 and Sarver et al 1998).

Sample et al (1998) in assessing the reliability of manual and computer generated VTO found that both the manual and computer VTO methods were accurate when predicting skeletal changes that occurred during treatment. However, the computer generated method proved slightly more accurate with the soft tissue prediction. The software used was Quick Ceph Imaging™ to trace the landmarks, planes and prediction of the soft tissue.

Soft tissue response to orthodontic treatment

One of the first investigations of the soft tissue response to orthodontic treatment was done by Riedel in 1950. Studying 30 patients' lateral cephalograms, Riedel used various hard tissue landmarks which influence the facial profile outline such as nasion, anterior nasal spine, subspinale (point A), and the most anterior point of the labial surface of the upper central incisor, the lower central incisor, supramenton (point B), pogonion and gnathion.

He deduced that the relationship of the maxillary and mandibular apical bases and the relationship of the anterior teeth to their respective apical bases have a marked influence on the soft-tissue profile.

Yogosawa (1990) stated that to properly predict post-treatment change, each individual case must be studied carefully for soft tissue movement patterns. He believed that it is important to study the relaxed lip posture due to its accuracy in determining post-treatment posture as Burstone (1958) has prescribed (Yogosawa, 1990).

Burstone (1958) presented a method to analyse the soft tissue profile by means of angular and linear measurements. These measurements (Fig.1) consist of (1) establishing integumental (soft-tissue) landmarks, (2) forming line segments that represent components of the profile, and (3) relating these line segments to each other and to planes of the skull by angular readings.

From his study he described the average morphology and various acceptable profiles. He also concluded that the dento-skeletal framework influences the facial contour.

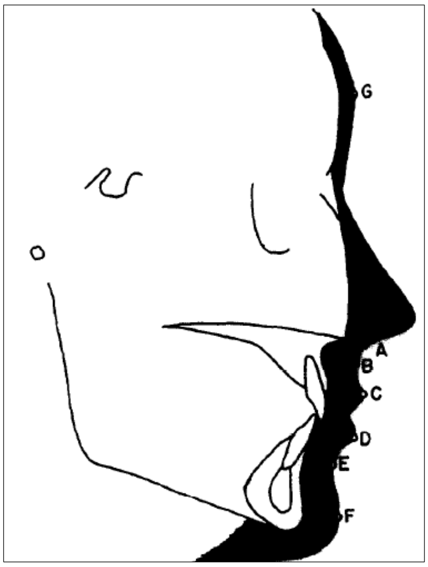


Figure 3: Burstone's Integumental Landmarks; A: subnasale, B: superior labial sulcus, C: superior labialis, D: inferior labialis, E: Lower labial sulcus, F: menton and G: frontal point.

From a later study, he recommended that cephalograms be taken with patients in a relaxed (repose) lip position (Burstone, 1967).

In theory, Burstone stated that the relaxed lip position represents a state where there is no contraction of lip musculature. In the relaxed lip position, the lips are relaxed, apart, and hanging loosely with no effort made at lip contraction. An interlabial gap forms between the inferior surface of the upper lip and the superior surface of the lower lip.

In the closed-lip position, the lips are lightly touching in order to produce an anterior seal of the oral cavity (Burstone, 1967). The relaxed-lip posture of the lower lip has been suggested as a possible guide for the positioning of the upper incisors. Burstone stated that the incisor cannot be placed forward of the relaxed position of the lower lip, provided the overjet is normal and the patient maintains a habitual lip seal.

Stoner and Lindquist (1956) found that the soft-tissue changes which occurred during treatment were (1) a downward movement of the chin pad to about the same degree as the hard tissue and (2) a downward movement of the upper lip in the majority of cases.

Stoner and Lindquist (1956) said that the lower incisors have a definite relationship to facial aesthetics. This relationship may be indirect, but it is important.

Holdaway (1956) found a significant relationship between the lower incisor measured to the line NB and Pogonion measured to line NB. He said that facial contour is most ideal when these two measurements are equal. His work, using the line NB extended downward, gave the profession an excellent assessment, of the bony chin (Holdaway, 1956).

Neger (1959) conducted a study on forty-eight young males and females with clinically excellent occlusions according to examinations of their dentitions by the author. It was found that in the analysis conducted on persons with excellent occlusions, many were found with deficient chins. Furthermore, he explained that this indicates that there is not necessarily a positive correlation with excellent occlusions and straight profiles.

He elaborated that it is particularly important, when making an initial examination of Class II cases, to examine the facial profile on the oriented photograph and to note whether or not there is a marked deficiency in the chin area (Neger, 1959).

Neger noted that in some Class II cases involving retruded mandibles, even though the occlusion has been corrected, there is no measurable improvement in the chin area. He stated that if a marked dysplasia is recognized and explained to the patient at the start of treatment, he will have a realistic concept of the possibilities of improving his facial profile.

In the cephalometric analysis proposed by Ricketts (1961), the relationship of the lips to the soft tissues of the nose and the chin is described and analysed by using his proposed “Esthetic plane”. He suggested that in Caucasian adults the lips should be contained within this line drawn from the chin to the tip of the nose referred to as the E-line.

In terms of the soft tissue response to upper incisor retraction, he reported that the upper lip thickened 1 mm with 3 mm of retraction of the upper incisors.

Ricketts based VTO on the position of the lower incisors which was set up first (0.5mm ±2.5mm from the APo line) followed by setting upper incisor so that it was aligned to a normal overjet and overbite relationship (Ricketts *et al*, 1982). Ricketts believed that when teeth are well related, the soft tissue will fall into good aesthetics (Ricketts, 1961).

During growth, changes to the soft tissue covering the skeletal profile do occur. These changes in the thickness of the soft tissue covering the midsagittal bony structures can affect the configuration of the facial profile

(Subtleny, 1959). Additionally, he deduced that soft tissue points overlying the upper facial region did not reflect the changes to the underlying skeletal structures (Subtleny, 1959). However, the soft tissue components of the lower facial regions (inferior to the maxillary denture base) were observed to show changes in the underlying skeletal and denture.

Anderson *et al* (1973) found that the soft-tissue thickness of the upper lip increased during treatment at the same time the incisor was being retracted. Their sample consisted of seventy patients treated orthodontically at the University of Washington and in the private practice of Dr Reidel. No mention was included of the gender or age of the patients. They reported that during and after retention, upper lip thickness decreased, but not to its original dimension. They found that the thickness of the lower lip was not affected by orthodontic treatment (Anderson et al 1973).

They also found that the soft tissues of the facial profile were closely related and dependent on the underlying dentoskeletal framework.

Orthodontic treatment resulted in a reduction of dentofacial protrusion with both upper and lower lips becoming less procumbent during treatment. This alteration in position was due to the lingual movement of maxillary and mandibular incisors. It was also noted that the soft tissue profile continued to flatten with additional nasal and chin growth during maturation following treatment (Anderson et al 1973).

The thickness of the upper lip increased considerably during treatment and this change was related to maxillary incisor retraction (1.0 mm lip thickening for every 1.5 mm of maxillary incisor retraction). During and after retention this lip thickness decreased, but not back to the original dimension.

They also found that a significant increase remained ten years post-retention. It was noted that the thickness of the lower lip was not affected by orthodontic treatment. Males showed significantly more growth than females in soft tissues of the nose, base of the upper lip and chin (Anderson et al 1973).

They concluded that Holdaway's H line seemed to be the most practical approach to soft tissue analysis.

Chaconas and Bartroff (1975) argued that there was a lot of controversy around the relation of the dental occlusion to soft tissue contour and aesthetics. Some authors such as Angle and Tweed believed that the dental relation depicted the facial profile. However, this was disputed by some others (Chaconas and Bartroff, 1975).

Holdaway (1983) postulated that with a patient that has an unstrained upper lip, the thickness of the soft tissue point A should be within one millimetre of the distance from the labial surface of the upper incisor to the vermilion border of the upper lip (Holdaway, 1983).

Holdaway proposed that soft tissue point A should be 5mm to the H-line. The H-line is Holdaway's Harmony line which refers to the line that touches unstrained upper and lower lips (below subnasale) to an unstrained chin thereby, showing a balance between the perioral musculature and the tooth positions (Holdaway, 1983). The Holdaway VTO shows the ideal lower lip position to be one millimetre short of the H-line, that which was accepted as ideal and as being aesthetically pleasing by the orthodontic fraternity early 1980s (Holdaway, 1983).

However, when looking at these values one has to bear in mind that his study sample was Caucasian, and thus the likelihood of this study sample having thinner lips is high.

Later, Bishara and his associates (1985) highlighted that the Holdaway's Soft Tissue angle should be considered to be an age-dependent variable, whereby it decreased with age.

Ricketts *et al* believed that the orthodontist needs to anticipate the changes to soft tissue when the teeth have been moved and has to factor that into the expected outcome (Ricketts *et al*, 1982). Ricketts stated that as a "rule of thumb" as the upper incisor is retracted the upper lip follows by two-thirds.

VTOs are used for planning the best soft tissue profile outcome followed by determining the placement of the incisor into the ideal position. Furthermore, together with the assessment of the arch length discrepancy, the VTO assists in determining whether there is a need to extract or not as well as determining whether the patient would require any orthognathic surgery (Jacobson and Sadowsky, 1980). Thus planning the biomechanics for the case becomes easier.

Bishara et al (1998) conducted a longitudinal study on soft tissue profile changes of subjects of North European descent from 5 to 45 years of age. They analysed five soft tissue parameters that were commonly used by orthodontic practitioners in their diagnosis and treatment planning as well as in their evaluation of profile changes that occur with growth and orthodontic treatment. Their conclusions of the study were the following:

- The angle of soft tissue convexity that excludes the nose expressed a small average change between 5 and 45 years.
- The Holdaway soft tissue angle progressively decreased between 5 and 45 years of age.
- The upper and lower lips became significantly more retruded in relation to the "Esthetic line between 15 and 25 years of age". The same trends continued between 25 and 45 years of age.

This indicated that the soft tissue profile reduces or flattens with age. However, due to the study subjects being Caucasian, it indicates the deficiency in studies on soft tissue profile changes or outcomes in non-Caucasoid individuals.

For patients who require orthognathic surgery planning, a VTO or a Surgical Treatment Objective (STO) would be required for predicting and planning treatment. This aims to predict facial changes after surgical repositioning of the jaws.

Smith et al (2004) investigated the perceived differences in the ability of current software to simulate the actual outcome of orthognathic surgery.

The programs that were used were; programs—Dentofacial Planner Plus, Dolphin Imaging, Orthoplan, Quick Ceph Image, and Vistadent. Although the results showed differences in simulation ability, selecting a software package depended on many factors. Performance and ease of use, cost, compatibility, and other features such as image and practice management tools are all important considerations. Smith *et al* (2004) suggested that if users are concerned with operating system compatibility and practice management integration might want to consider Dolphin Imaging and Quick Ceph programs (Smith et al, 2004).

Magro-Filho et al (2010) subjectively compared the soft tissue simulations of two software programs viz; Dentofacial Planner and Dolphin Imaging Software. The predictive images were compared with the actual final photographs. Orthodontists, maxillofacial surgeons and dentists evaluated the images and were asked which of the two software programs they would use to plan treatment for or educate their patients (Magro-Filho et al, 2010). Dolphin Imaging software had better prediction of nasal tip, chin and submandibular area. Dentofacial Planner Plus software was better in predicting nasolabial angle, and upper and lower lips. The total profile comparison showed no statistical difference between the software programs. The 2 types of software are similar for obtaining 2-dimensional predictive profile images of patients with Class III malocclusion treated with orthognathic surgery (Magro-Filho et al, 2010).

There is a wealth of literature available reporting on the comparison between surgical treatment prediction and actual treatment outcomes (Veltkamp et al, 2002). However, according to the author's knowledge, there is a paucity of reported studies that investigate the actual soft tissue outcomes of orthodontic treatment predictions.

There is a tendency to rely only on the analysis of the hard tissue for the orthodontic treatment. But this does not always provide the best results for the soft tissue. Therefore, the author investigated whether the VTOs are accurate in predicting soft tissue outcomes of orthodontic treatment. The problem with these VTOs is that the population sample used by Ricketts and Holdaway was Caucasian Americans only which is limited with ethnic diversity.

The literature review indicates that many cephalometric analyses have been proposed to evaluate and quantify and predict the soft tissue profile (Ricketts, 1961; Jacobson and Sadowsky, 1980 and Holdaway, 1983). Though all merit recognition, most of these analyses describe the soft tissue profile during adolescence and hence the author decided to conduct the study on an adult sample in order to exclude growth as an influencing factor.

Chapter Three

Methodology:

Aim

The aim of this study was to compare which of the Holdaway and Ricketts VTO is more suitable in predicting soft tissue profile outcomes in a select adult patient sample.

Objectives:

- To determine the Holdaway VTO.
- To determine the Ricketts VTO.
- To measure the actual outcomes of the patients.
- To compare the Holdaway and Ricketts VTOs to the actual outcomes.

Study Design and Population

The study design was a retrospective cross-sectional analytic study. The study population was comprised of adult orthodontic patients (i.e. post-growth) with Class II dental malocclusions, who attended the Orthodontic clinic at the UWC Oral Health Centre. The sample comprised of so-called coloured patients.

Inclusion Criteria:

- Patients were post-growth i.e. women: older than 17years and men: older than 19years before treatment commenced.
- Class II Dental malocclusion
- Extraction and Non-extraction cases

- Patients treated by either Orthodontic clinic consultants or Orthodontic registrars.

Exclusion Criteria:

- Growing patients at start of orthodontic treatment
- Fuzzy or poor quality analogue cephalograms whether pre-treatment or post-treatment
- Patients with congenital and craniofacial deformities
- Class I and III malocclusions

The study sample constituted the records (i.e. pre- and post-treatment lateral cephalograms and space analyses) of 45 patients who were treated between the periods of January 2010 to December 2014. The sample size was determined by the necessary records availability.

Data Collection

The data collection was done by the author. The space analysis of the patient was captured in order to do the VTO. Cephalograms were collected and numbered sequentially e.g. 1A (pre-treatment) and 1B (post-treatment). A record was kept of the corresponding patient folder numbers (in order to replace the cephalograms and space analyses into the correct folders).

The lateral cephalograms were scanned into a Jpeg format using a flatbed scanner (Canon MG4240) at 300dpi with a 100mm calibration ruler linked to an Acer computer (Acer Aspire V15 running on Windows10). Once captured using the Dolphin Imaging Version 8.0 (Dolphin Imaging, Chatsworth, CA), the image was repositioned parallel to the Frankfort Horizontal, and finally stored in the Dolphin Imaging archive.

Radiographic images were subsequently opened using the Dolphin Imaging program and digitized on a 17-in. colour monitor at a screen resolution of 1074 x 728 pixels. The landmarks were digitized as prompted by the Dolphin system directly on-screen using a cross-hair locator controlled by the mouse after locating two fiducial points located 100 mm apart on the calibration ruler. Manipulation and enhancement was used to assist in point identification when difficulty was encountered.

The Dolphin Imaging Software system was used because it has been proved to be reliable and precise (Smith *et al*, 2004).

Landmarks

The following landmarks were identified on each cephalogram (Figure 4)

1) ***Sella (S)*** *- The centre of the sella turcica, determined by inspection.*

2) ***Nasion (N)*** *- The most anterior part of the fronto-nasal suture as seen in the lateral skull radiograph.*

3) ***Anterior Nasal Spine (ANS)*** *– The anterior tip of the sharp bony process of the maxilla at the lower margin of the anterior nasal opening.*

4) ***Point A*** *- Also known as subspinale, the most posterior midline point in the concavity between anterior nasal spine and the prosthion (the most inferior point on the alveolar process overlying the maxillary incisors).*

5) ***Point B*** *- Also known as supramentale, the most posterior midline point [in the concavity on the mandible] between the most superior point on the alveolar process overlying the lower incisors (infradentale) and pogonion.*

6) ***Pogonion (Pog)*** *- The most anterior point on the chin.*

7) ***Gnathion (Gn)*** *- A point located by taking the midpoint between the anterior (pogonion) and inferior (menton) points of the bony chin.*

8) ***Menton (M)*** *- The lowest point on the symphyseal shadow of the mandible seen on the lateral cephalogram.*

9) ***Gonion (Go)*** *- A point on the curvature of the angle of the mandible located by bisecting the angle formed by lines tangent to the posterior ramus and inferior border of the mandible.*

10) ***Basion*** *-The lowest point on the anterior rim of foramen magnum.*

11) ***Porion (Po)*** *- The uppermost point of the bony external auditory meatus.*

12) ***Ptm –*** *The contour of the pterygomaxillary fissure formed anteriorly by the retromolar tuberosity of the maxilla and posteriorly by the anterior curve of the pterygoid process of the sphenoid bone.*

13) ***Orbitale (O)*** *- The lowest point of the infra-orbital margin. Where two orbitalia were visible a point mid-way between the two was used.*

14) ***Posterior Nasal Spine (PNS)*** *- Posterior spine of the palatine bone constituting the hard palate.*

15) ***Incisor (upper)*** *- The tip of the crown of the most anterior upper central incisor.*

16) ***Maxillary incisor apex*** *- The tip of the root of the most anterior maxillary central incisor.*

17) ***Incisor (lower)*** *- The tip of the crown of the most anterior lower central incisor.*

18) ***Mandibular incisor apex*** *- The tip of the root of the most anterior mandibular central incisor.*

19) ***Mesial cusp of upper 6*** *- The mesial cusp of the upper first molar.*

20) ***Mesial cusp of lower 6*** *- The mesial cusp of the lower first molar.*

21) ***Pronasale*** *- The most prominent or anterior point of the nose (tip of the nose).*

22) ***Subnasale*** *- The point at which the columella (nasal septum) merges with the upper lip in the midsagittal plane.*

23) ***Superior labial sulcus*** *- The point of greatest concavity in the midline of the upper lip between subnasale and labrale superius.*

24) ***Labrale superius*** *- A point indicating the mucocutaneous border of the upper lip. The most anterior point of the upper lip (usually).*

25) ***Stomion superius*** *- The lower- most point on the vermilion of the upper lip.*

26) ***Stomiun inferius –*** *The upper-most point on the vermilion of lower lip.*

27) ***Inferior labial sulcus*** *- The point of greatest concavity in the midline of the lower lip between labrale inferius and soft-tissue pogonion, also known as labiomental sulcus (SI).*

28) ***Soft tissue pogonion*** *- The most prominent or anterior point on the chin in the midsagittal plane.*

29) ***Soft tissue Glabella –*** *It is the most anterior mid-point on the fronto-orbital soft tissue contour, which is identical to the bony landmark Glabella on the frontal bone.*

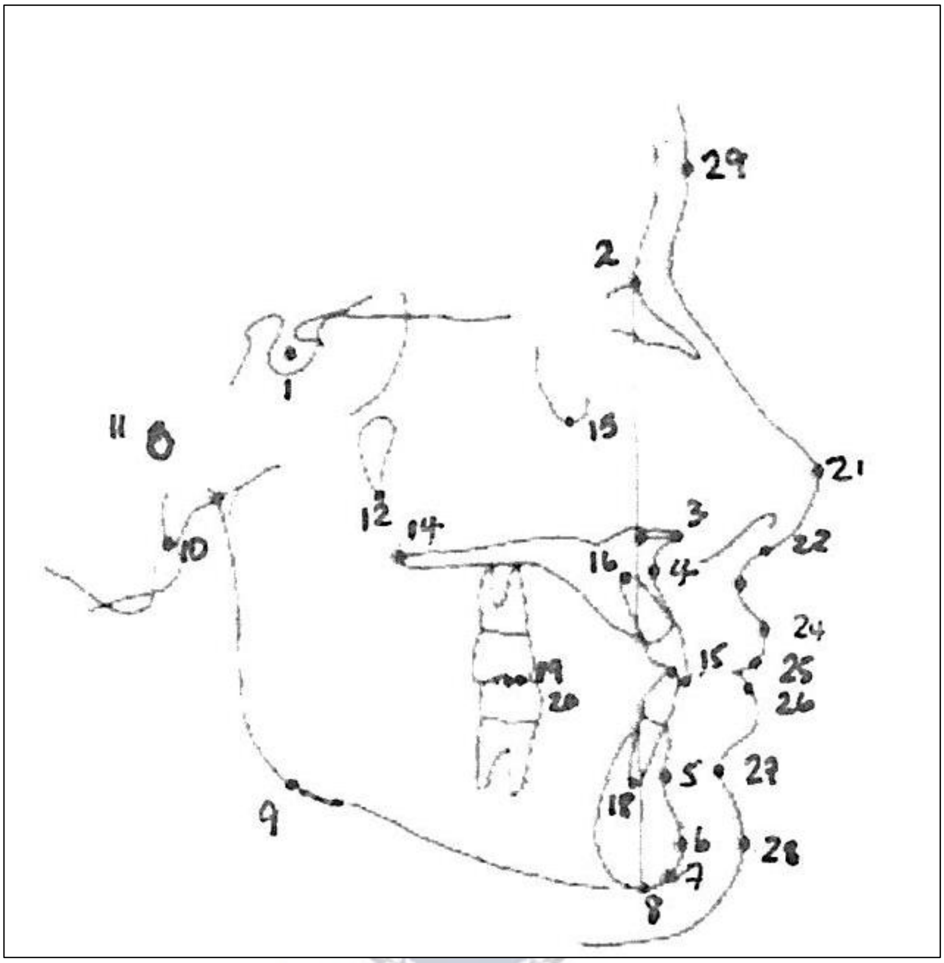


Figure 4 Landmarks traced

Landmark planes

The following planes (Figure 5) were traced and recorded:

S-Na: *Sella turcica- Nasion*

Ba-Na: *Basion-Nasion*

Frankfort Horizontal (FH): *Superior aspect of Porion to Orbitale*

SNA: *Sella-Nasion-A point*

SNB: *Sella-Nasion-B point*

Occlusal Plane: *through contact points of maxillary and mandibular premolars and molars*

Mandibular: *Gonion- Gnathion*

A-Pog: *A point to Pogonion*

E-line: *Tip of nose to soft tissue Pogonion*

H-line: *Upper lip to soft tissue Pogonion*

Upper incisor: *Line drawn from apex to incisal edge*

Lower incisor: *Line drawn from apex to the incisal edge*

Soft tissue Glabella through Subnasale

Soft tissue Nasion to Soft tissue Pogonion

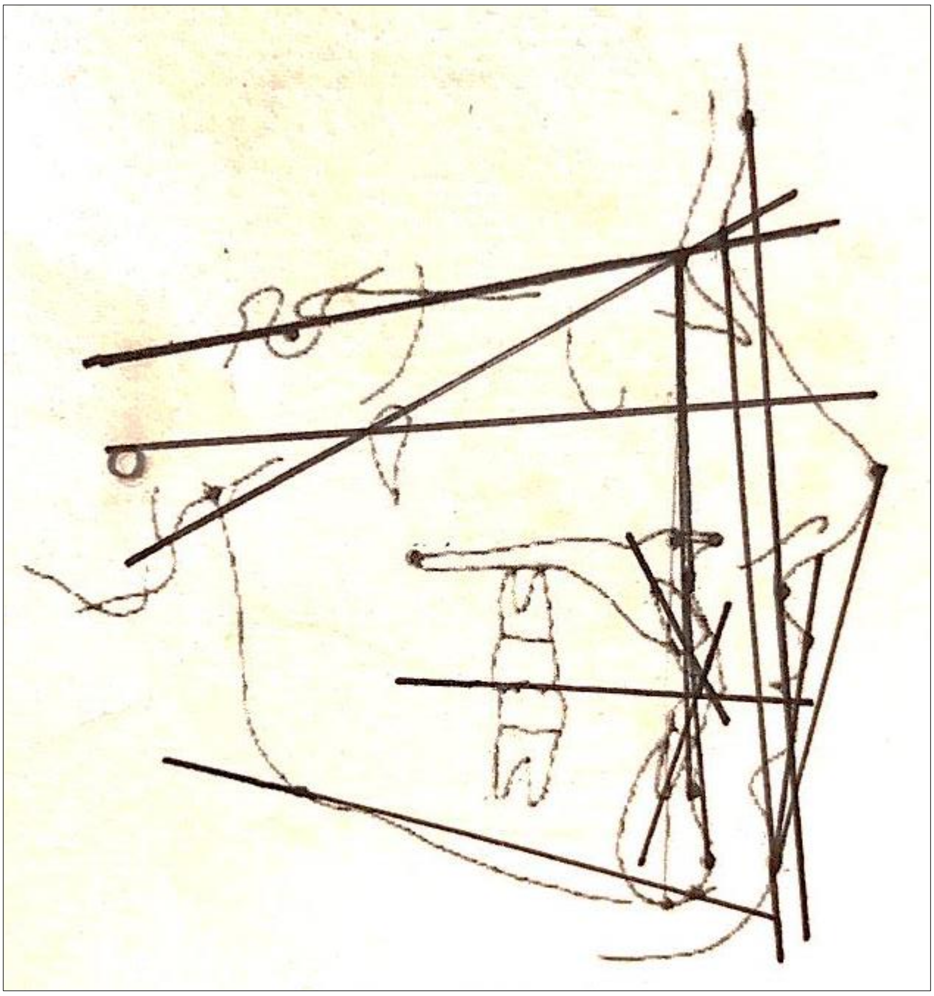
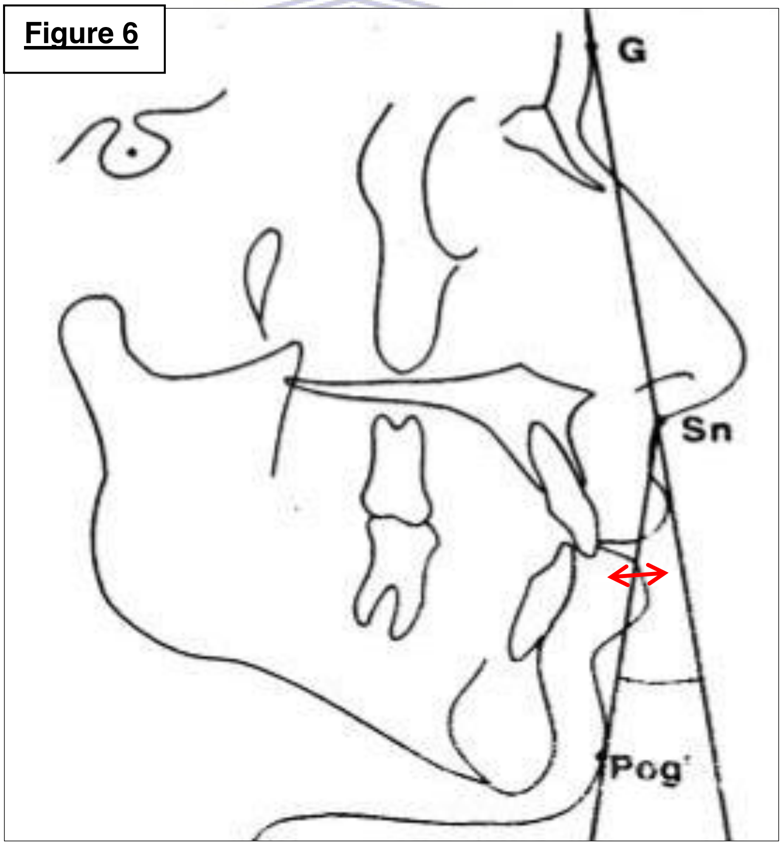


Figure 5: Landmark Planes

The complete Holdaway VTO (description of this in Appendix 1) and Ricketts VTO (description of this in Appendix 2) were done on each pre-treatment cephalogram using the space analysis values from the records. These VTOs predicted where the soft tissue profile (nose tip to chin) would be, in relation to the H-line and E-plane respectively. The post-treatment tracings were done. The two tracings for each patient were then superimposed.

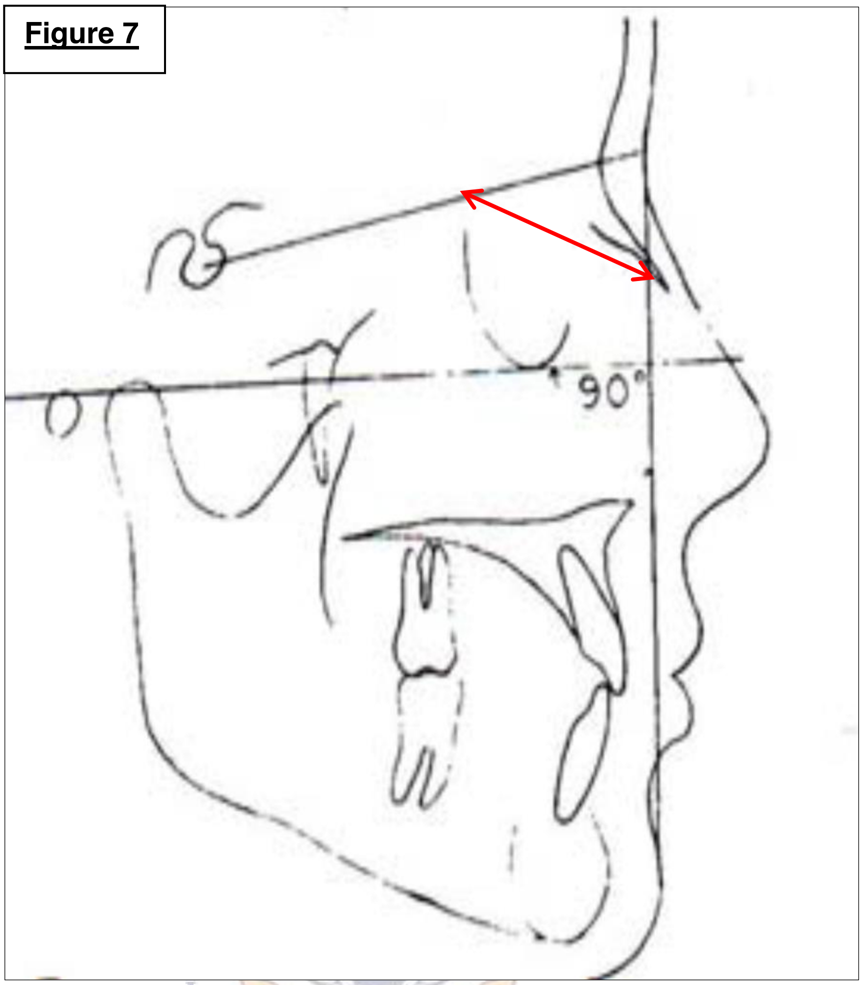
The following measurements were taken from the tracings (Figures 6 to 13):

Figure 6

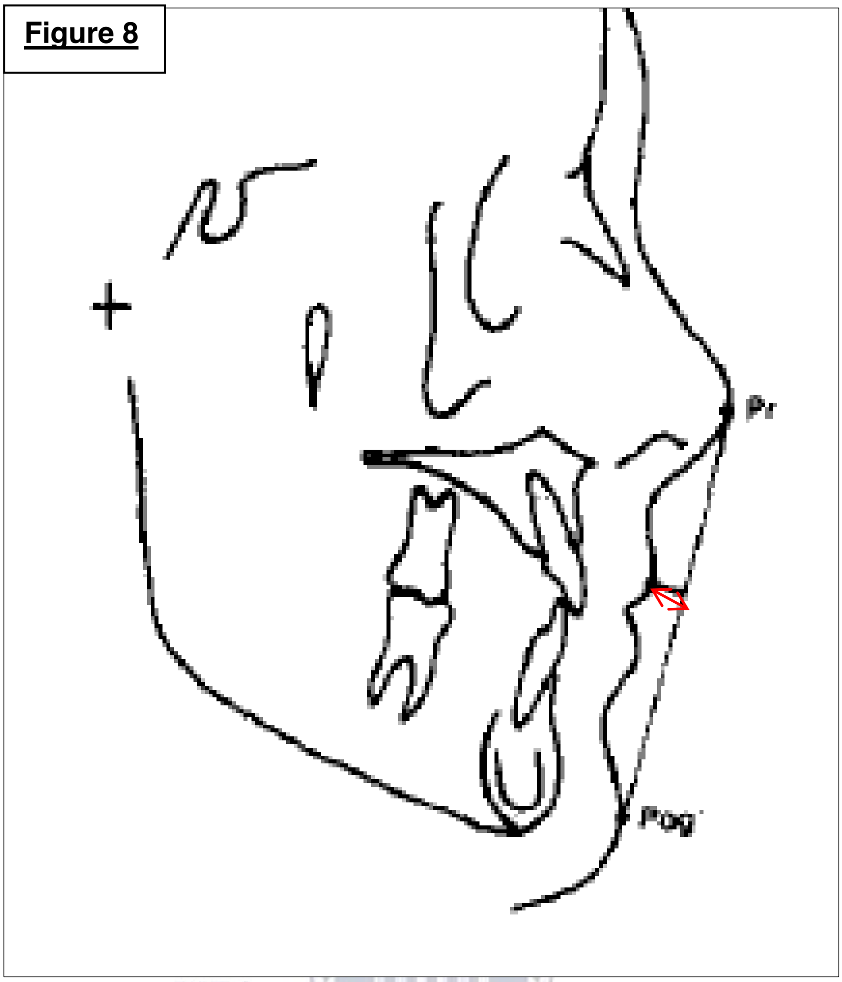


1. **Facial Convexity angle** (Soft tissue Glabella – Subnasale – Pogonion)

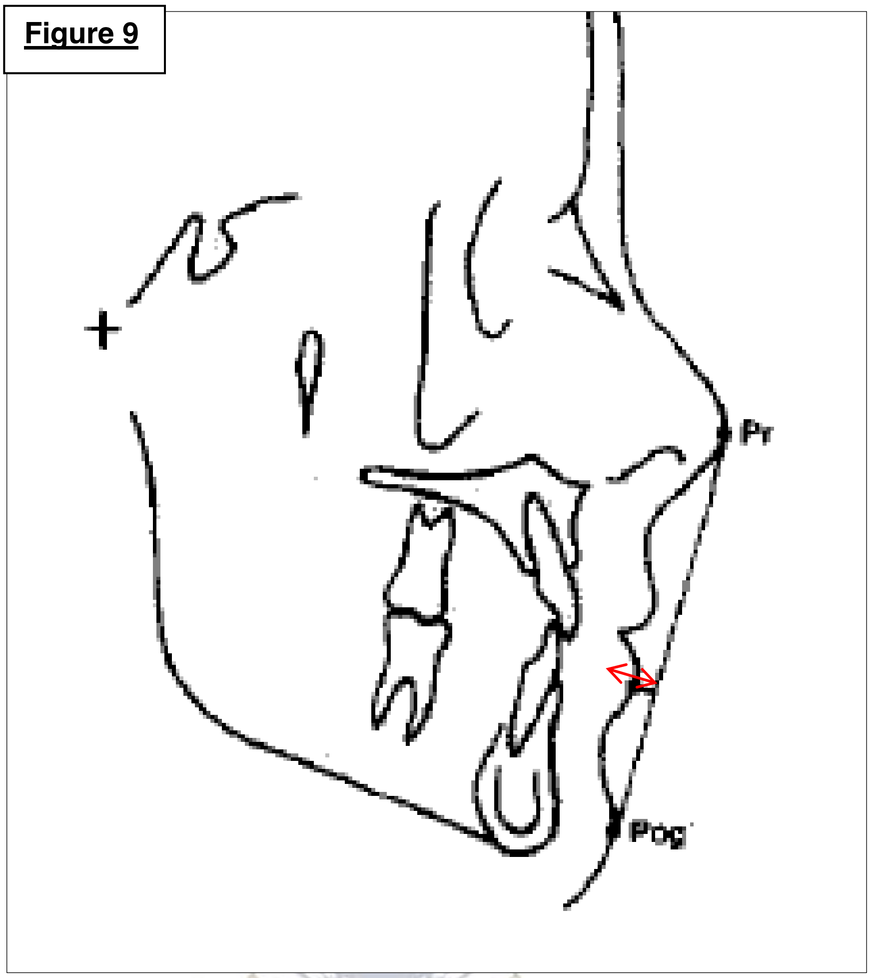
Figure 7



2. **Holdaway Soft-tissue Facial angle** (intersection between Soft tissue Nasion and Pogonion plane with FH)

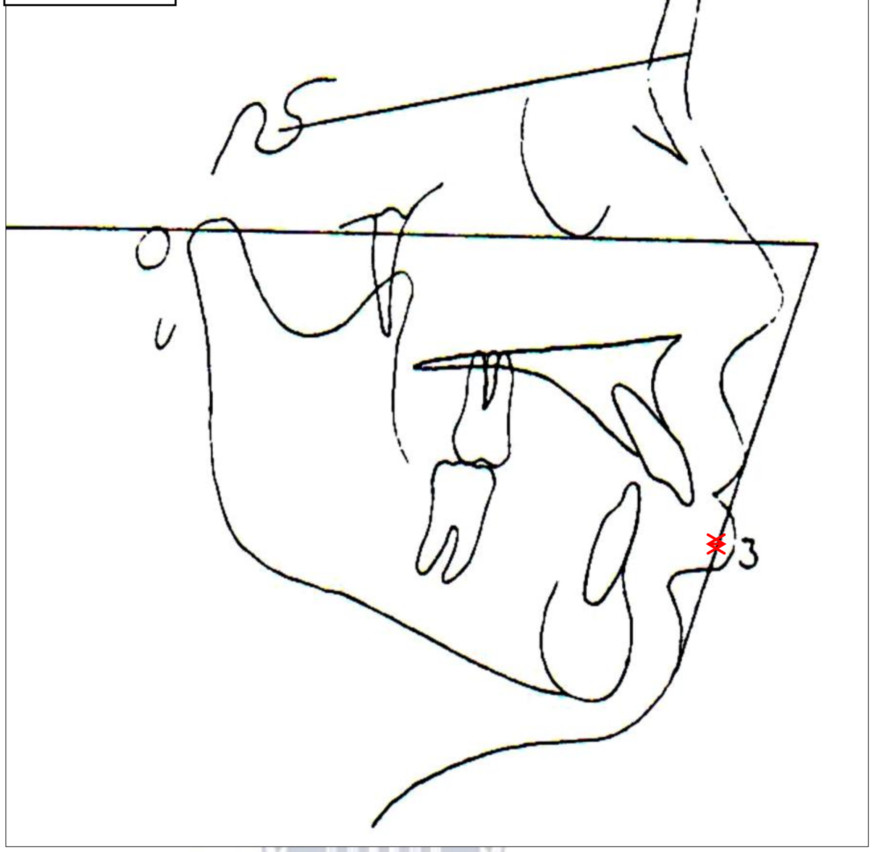


3. **Upper lip to Ricketts E-line** (mm)



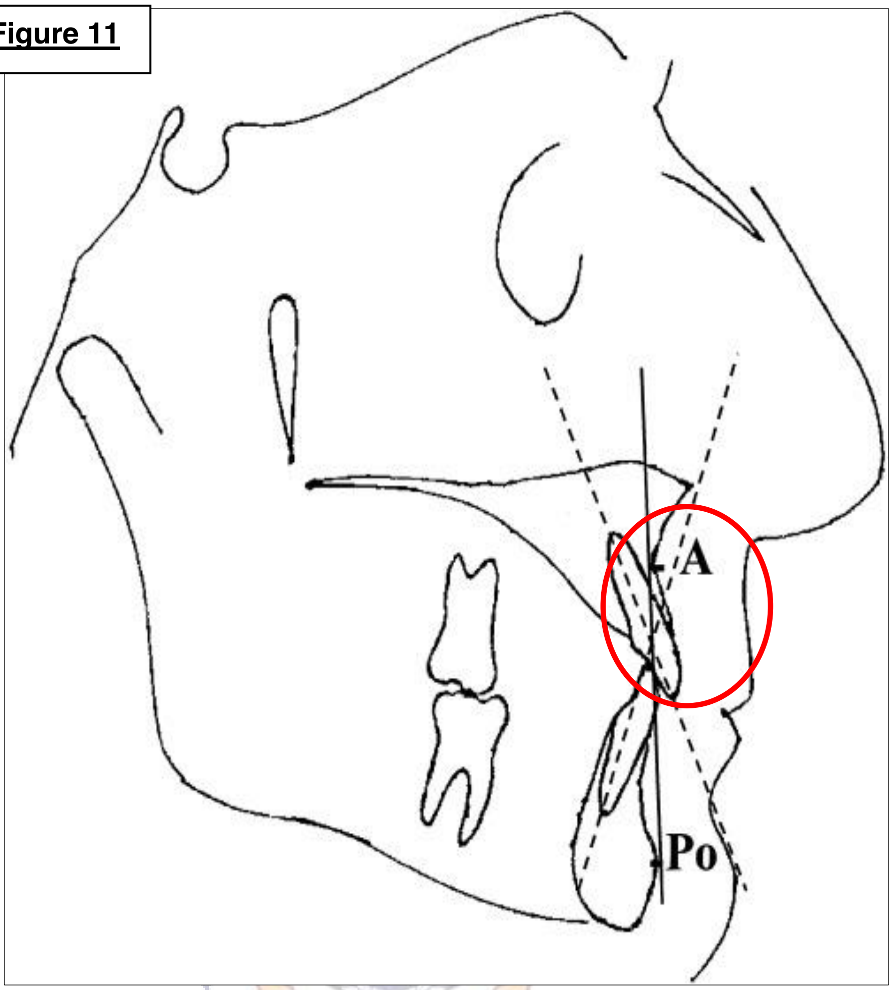
4. **Lower lip to Ricketts E-line** (mm)

Figure 10



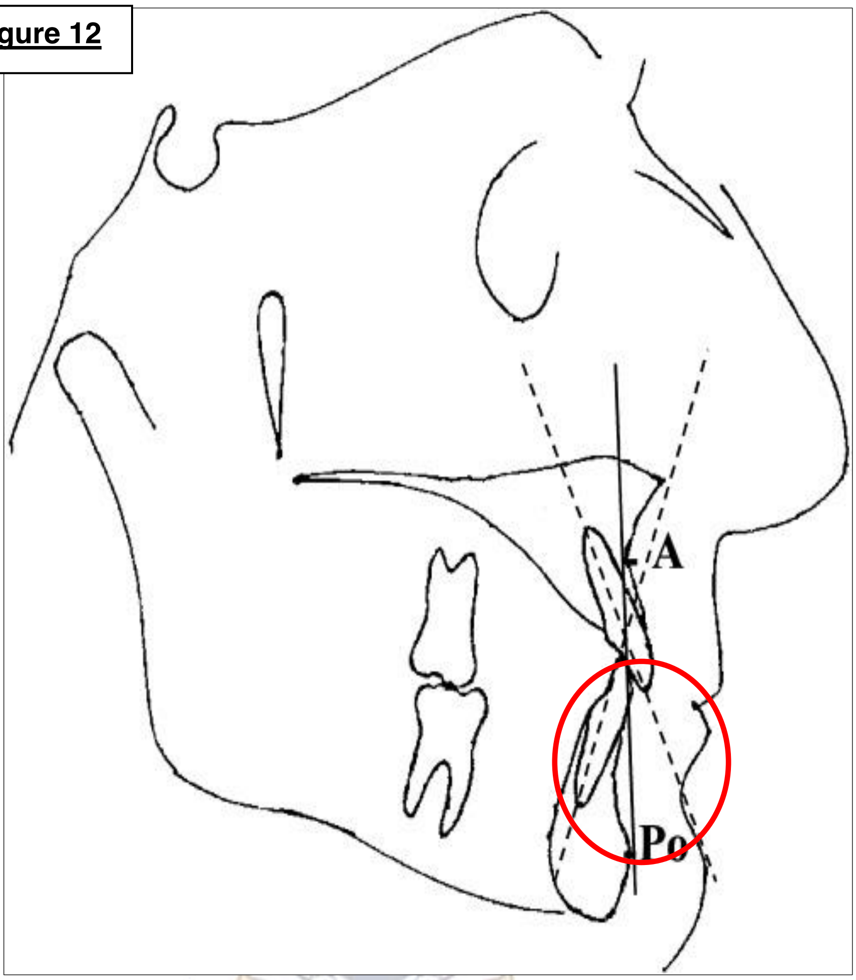
5. **Lower lip to Holdaway H-line** (mm)

Figure 11



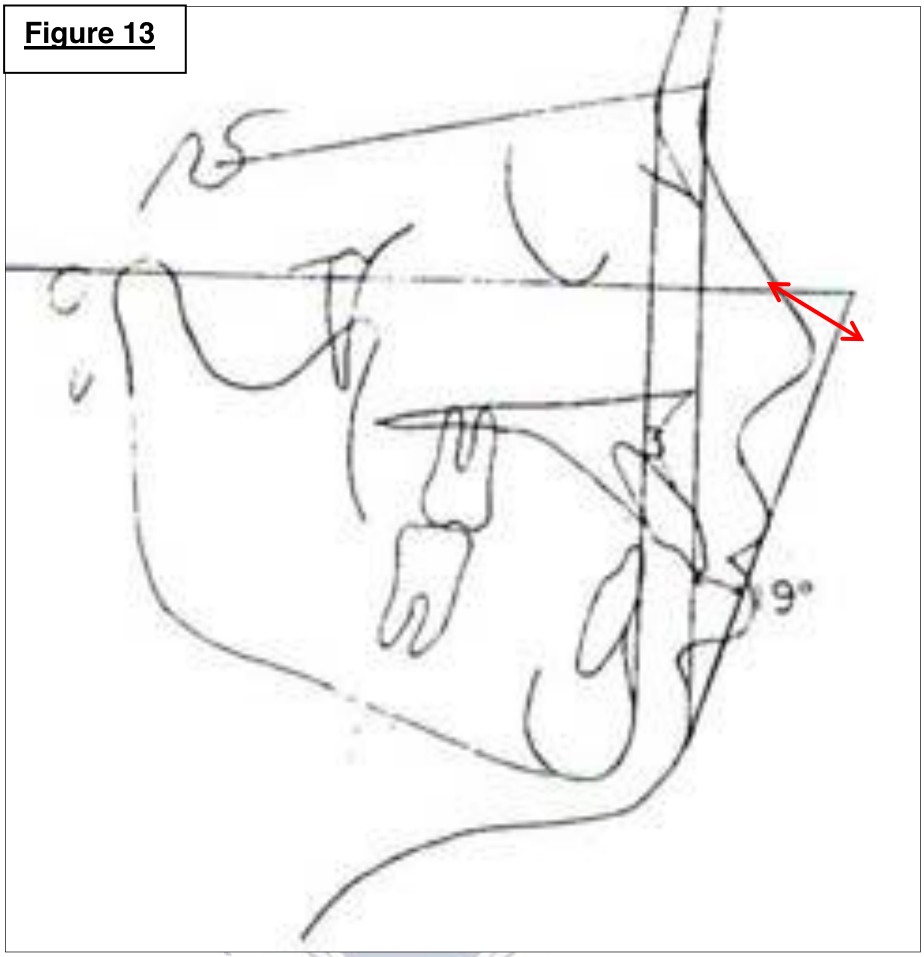
6. **Upper incisor to A-Pog line** (angle)

Figure 12



7. **Lower incisor to A-Pog line** (angle)

Figure 13



8. **Holdaway H-angle** (H-line intersects with Frankfort Horizontal Plane)

The first four measurements i.e. (1) Facial convexity angle, (2) Holdaway Soft tissue Facial angle, (3) Upper lips to E-line and (4) Lower lips to E-line, were based on the Bishara (1998) study highlighted in the literature review and the remainder are measurements which influence the soft tissue according to the Holdaway and Ricketts VTO, included; Lower lip to H-line, upper and lower incisors to A-Po line and the Holdaway H-angle.

Data Analysis

The values for the **Predicted** (VTO measurement) and **Resultant** (end of treatment measurement) tracings were captured onto an Excel® spreadsheet (see Appendix 1). The mean was then calculated on the measurements listed above. T-tests were performed using R-Core Team (2013) statistics programme (R Foundation for Statistical Computing). Other data captured included: age of patient, gender, record number, clinician and the date each cephalogram was taken.

Intra-examiner variability

The reproducibility of the digitized cephalograms and VTO were determined from duplicate measurements of five randomly selected cases from the total sample, which were re-digitized and compared with the corresponding digitized cephalogram and VTO previously done. This was done to determine the intra-examiner variability. The differences between the first and second measurements were computed and the occurrence of a systematic difference was determined. Errors in landmark identification (tracing error) and digitization were evaluated statistically and a high degree of intra-examiner reliability was found.

Ethical Considerations

The author had no vested interests in any part of the research other than attaining the data for research purposes. Permission and clearance from the UWC Ethics Committee was attained. Patient consent was not necessary as the records were archived and belong to the Dental faculty and the study is not clinical based. The patients' records were kept confidential and in a secure place until research data was attained and then returned to archives.

Chapter Four

Results

The results will be displayed with charts, tables and a short description of each pair of measurements. The pair consists of the Predicted as the measurement from the VTO and the Resultant as the actual outcome measurement.

Pair One:

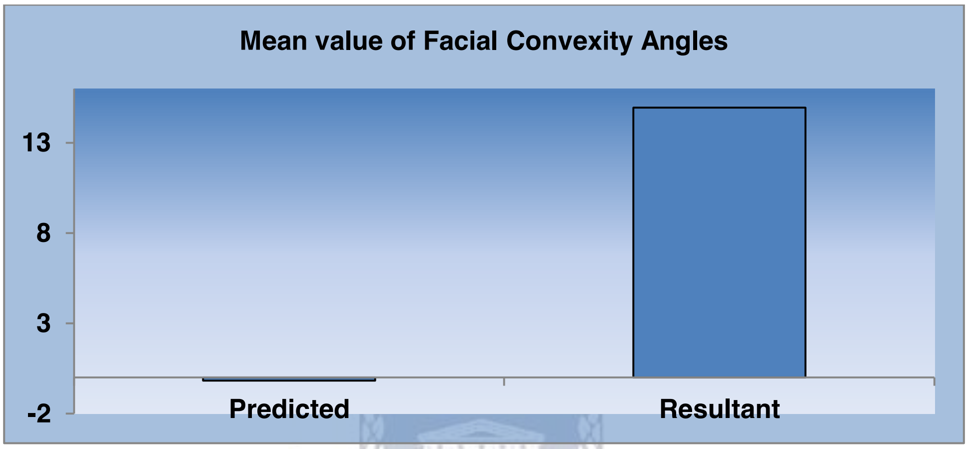


Chart 1: Predicted and Resultant Facial Convexity Angles

		Paired Differences				
		Mean	Std. Deviation	Std. Error Mean	t	*P* value
Pair 1	Facial convexity (Gl-Sn-Po) angle (P) – Facial convexity (Gl-Sn-Po) angle (R)	15.12222	6.63660	.9893263	-15.285	.000

Table 1: Predicted and Resultant measurements of Facial Convexity Angles

The mean values for the predicted measurement was a negative amount of -0.175^0 whereas the resultant value was 14.95^0. The standard deviation was 6.64 and the t value (44) = -15.29 and p value = zero, therefore indicated a statistical significance ($p < 0.05$). This indicated the predicted value was far less than the treatment outcome measurement.

Pair Two:

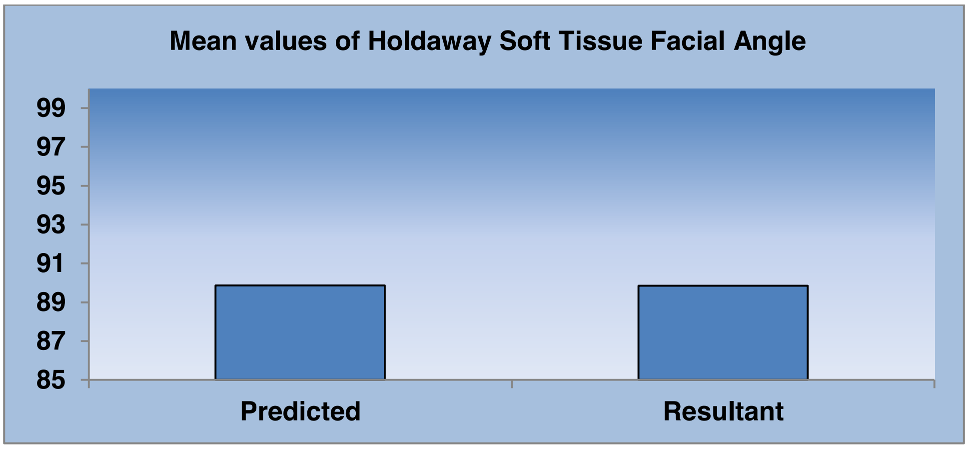


Chart 2: Predicted and Resultant Holdaway Soft-tissue Facial Angle.

		Paired Differences				
		Mean	Std. Deviation	Std. Error Mean	t	*P* value
Pair 2	Holdaway Soft Tissue Facial Angle (P) - Holdaway Soft Tissue Facial Angle (R)	.0178	3.5037	.5223	.034	.973

Table 2: Holdaway's Predicted and Resultant measurements for Soft-tissue Facial Angle.

The mean values for the predicted measurement was 89.87^{o} and the resultant measurement was 89.8 = 0.973 which indicated no statistical significance ($p < 0.05$). 5^{o}. Standard deviation was 3.5 and the *t* value (44) = 0.034 and *p* value = .973, indicating no statistical significance ($p < 0.05$), these values indicated that the predicted measurements are under-estimated compared to the resultant measurements.

Pair Three:

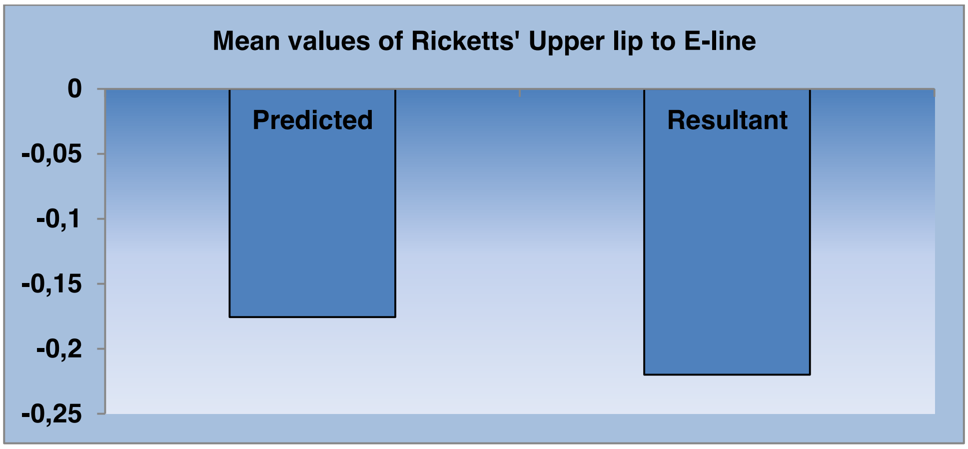


Chart 3: Predicted and Resultant Ricketts' Upper Lip to E-line (mm)

		Paired Differences				
		Mean	Std. Deviation	Std. Error Mean	t	*P* value
Pair 3	Upper lip to E-line (P) – Upper lip to E-line (R)	.0442222	.6253962	.0932286	.474	.638

Table 3: Ricketts' Predicted and Resultant measurements for Upper Lip to E-line

The mean values for both predicted and resultant were negative. The values were respectively; -0.175 and -0.22. The standard deviation was 0.63 and the t (44) = 0.474 whereas the p value = 0.64, thereby indicated no statistical significance ($p < 0.05$). These values indicated that both the predicted and resultant measurements were below normal values, and the predicted values being under-estimated too.

Pair Four:

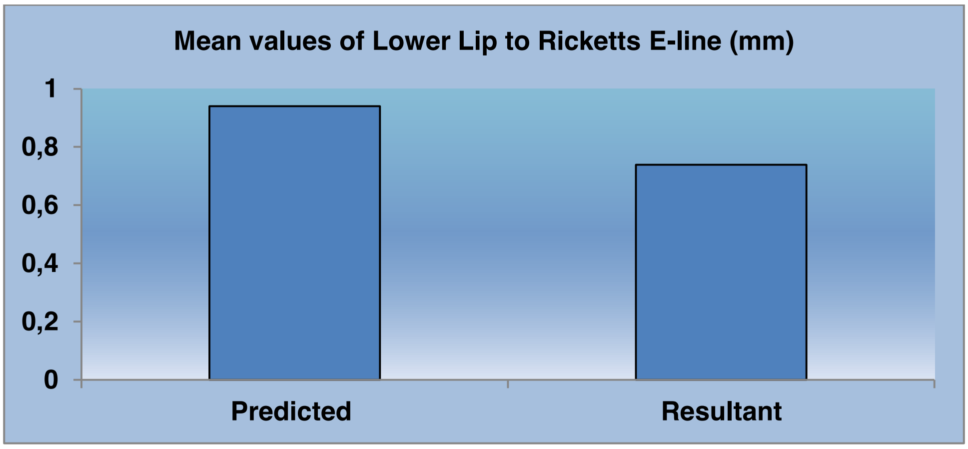


Chart 4: Predicted and Resultant Ricketts' Lower Lip to E-line (mm)

		Paired Differences				
		Mean	Std. Deviation	Std. Error Mean	t	*P* value
Pair 4	Ricketts: Predicted Lower Lip to E-line (mm) - Resultant Lower Lip to E-line (mm)	.2011111	.3986467	.0594267	3.384	.002

Table 4: Ricketts Predicted Lower Lip to E-line and Resultant Lower Lip to E-line

The mean value for the predicted value for the lower lips to E-line in Ricketts analysis was 0.94 whereas for the resultant the value was 0.74. The standard deviation was 0.399, the t value (44) = 3.384 and p value = 0.002 ($p < 0.05$), which indicated a statistical significance. The predicted values were significantly larger than the resultant measurements.

Pair Five:

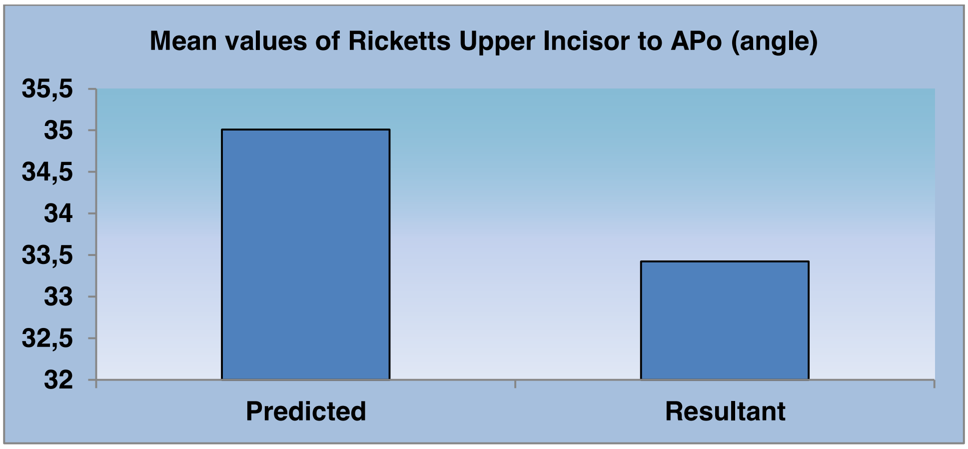


Chart 5: Ricketts Predicted Upper Incisor to APo and Resultant Upper Incisor to APo (angle)

		Paired Differences				
		Mean	Std. Deviation	Std. Error Mean	t	*P* value
Pair 5	Ricketts: Predicted Upper Incisor to APo (angle) – Resultant Upper Incisor to APo (angle)	1.584444	2.4316059	.3624824	4.371	.000

Table 5: Ricketts Predicted Upper Incisor to APo and Resultant Upper Incisor to APo (angle)

The mean values were 35.01^{o} and 33.43^{o} respectively for the predicted Upper Incisor to APo line and the resultant measurement. The standard deviation was 2.43 and the *t* value (44) = 4.37 and *p* value = 0.000 and was therefore statistically significant (p < 0.05). The predicted measurements were over-estimated compared to the resultant values.

Pair Six:

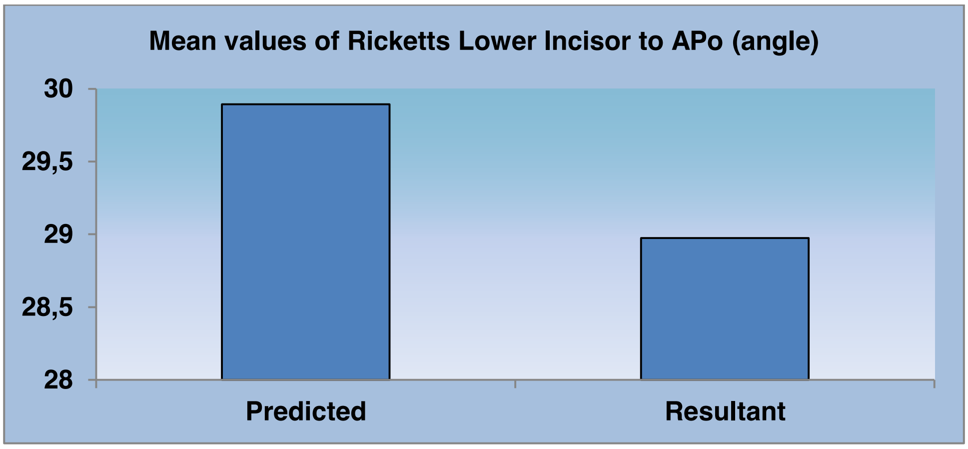


Chart 6: Ricketts Predicted Lower Incisor to APo and Resultant Lower Incisor to APo (angle)

		Paired Differences				
		Mean	Std. Deviation	Std. Error Mean	t	*P* value
Pair 6	Ricketts: Predicted Lower Incisor to APo (angle) - Resultant Lower Incisor to APo (angle)	.9177778	2.1561001	.3214124	2.855	.005

Table 6: Ricketts Predicted Lower Incisor to APo and Resultant Lower Incisor to APo (angle)

The mean values for the predicted measurement was 33.43^{o} and the resultant measurement was 29.89^{o}. The standard deviation was 2.156 and the *t* value (44) = 2.85 and *p* value = 0.05 which indicated a statistical significance ($p < 0.05$). The predicted values were significantly higher than the resultant measurements.

Pair Seven:

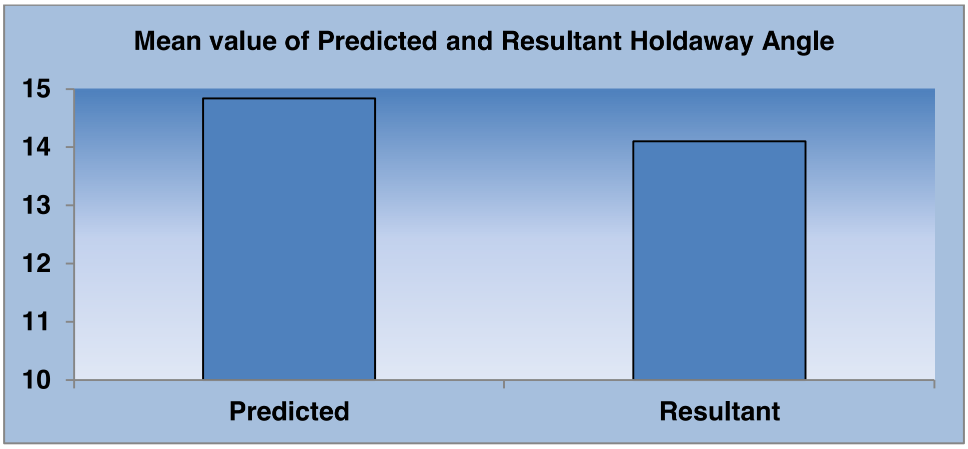


Chart 7: Predicted and Resultant Holdaway H- Angle

		Paired Differences				
		Mean	Std. Deviation	Std. Error Mean	t	*P* value
Pair 7	Holdaway H-angle (P) – Holdaway H-angle (R)	.7377778	2.821370	.4205851	1.754	.086

Table 7: Holdaway Predicted and Resultant H-Angle measurements

The mean values for the predicted and resultant measurements were 14.84^0 and 14.10^0, respectively. The standard deviation was 2.82 and the t (44) = 1.75 and p value = 0.086. This indicates that there is no statistical significance (p < 0.05). The predicted measurements were not that different to the resultant values.

Pair Eight:

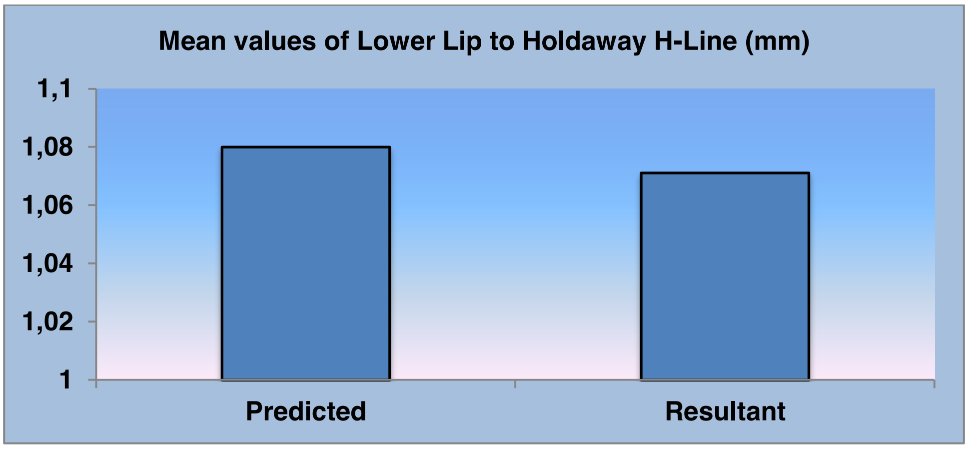


Chart 8: Holdaway Predicted Lower Lip to H-line and Resultant Lower Lip to H-Line (mm)

		Paired Differences				
		Mean	Std. Deviation	Std. Error Mean	t	*P* value
Pair 8	Holdaway: Predicted Lower Lip to H-line (mm) - Resultant Lower Lip to H-line (mm)	.0088889	.3604430	.0537317	.165	0.869

Table 8: Holdaway Predicted Lower Lip to H-line and Resultant Lower Lip to H-line

The results showed a mean value of 1.08 for the predicted measurement compared to 1.07 for the resultant. The standard deviation was 0.36 and the *t-value* (44) = 0.165, *p* value = 0.869 and was therefore no statistical significance ($p < 0.05$). It indicated that the predicted values were not that much more than the resultant measurements.

Chapter Five

Discussion

Angle was one of the first to write about facial harmony and the importance of the soft tissue integument.

He used the terms *balance*, *harmony*, *beauty*, and *ugliness* to note that "The study of orthodontia is indissolubly connected with that of art as related to the human face…" as cited by Bishara (1998).

The present study attempted to compare the Holdaway and the Ricketts VTOs to the actual soft tissue treatment outcomes and evaluate which of the two prediction methods is more precise.

The orthodontist is often confronted with the need to predict soft-tissue profile changes that may result from orthodontic treatment. The problem arises because the contribution of many of the factors influencing the soft-tissue profile is still not fully understood. The complexity of the problem is increased in growing patients in whom the post-treatment soft-tissue profile is the result of both growth and orthodontic treatment (Talass *et al* 1987). Therefore, the adult sample of the present study allowed for the influence of growth to be eliminated.

A limitation of the sample collection was the lack of both the pre- and post-treatment cephalograms as well as the space analysis (in order to complete a VTO on each patient) which were not archived correctly. Thus the lack of complete records influenced the sample size.

There was a statistical significant difference between the predicted and resultant facial convexity angles indicating the prediction values were not precise.

The measurements taken from the Holdaway VTO analysis proved not to be statistically significant. Ricketts VTO were elevated when compared to the resultant measurements but proved to be statistically significant despite one measurement. This was the mean value for the Upper Lip to the E-line measurement. This is most likely due to Ricketts emphasising the importance of placing the lower incisor and lower lip in the correct position and the upper incisor and lip will follow despite the amount of incisor retraction needed (Ricketts, 1960b).

The Ricketts' Lower lip to E-line showed no statistical difference between the predicted and resultant values whereas, Holdaway's Lower Lip to H-line showed a distinct difference between the predicted and resultant values.

It would have been expected that the Holdaway VTO would have fared better than the Ricketts', because of the emphasis on soft tissue balance within the Holdaway VTO. A possible reason for this is because of the method of first draping the soft tissue and then positioning the upper incisor followed by the lower incisor being positioned according to the upper (Holdaway, 1984).

Ricketts VTO fared better possibly due to Ricketts first predicting the result without treatment and then subsequently predicts the final VTO with treatment. This VTO showed elevated prediction values but closer to the resultant value than Holdaway's VTO.

Lu et al (2003) found that the computer-generated image prediction was suitable for patient education and communication. However they stressed that efforts are still needed to improve the accuracy and reliability of the prediction program and to include the consideration of, as with this study, changes in soft tissue tension and muscle strain. The accuracy of this system in soft tissue prediction should therefore be carefully interpreted (Lu et al 2003).

Toepel-Sievers and Fisher-Brandies (1999) also found that the Ricketts VTO yielded satisfactory results for the skeletal variables tested but were unsuccessful in predicting the dental relations, of dentoskeletal relations or of soft-tissue configuration. They concluded that the VTO is capable of giving a largely valid prognosis of skeletal growth tendencies. However, in view of the large number of parameters affected by therapeutic measures, the VTO prognosis must be expected to differ from the actual treatment outcome (Toepel-Sievers and Fisher- Brandies 1999).

Chapter Six

Conclusion and recommendations

Predicting the final treatment outcome especially the soft tissue would be extremely beneficial to the orthodontic profession. Not only does it assist in the treatment planning procedure, but it also helps the patient to visualize the final result.

From this study it can be noted that Ricketts' VTO is statistically better at predicting the soft tissue outcome than the Holdaway VTO.
The response of the upper and lower lip to incisor retraction needs to be studied in an adult sample. Ethnicity difference can influence a study. The two VTOs compared were based on a North American Caucasian sample.
Therefore, from this study it appears that Ricketts VTO is a better form of prediction for an adult sample from a Cape Town community.

It is however, recommended that further studies with a larger sample size be done in order to evaluate the difference between the two VTOs as there is a deficiency quoted in literature.

Chapter Seven

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Appendix 1: Holdaway VTO

Step I

The first step is to place a clean sheet of tracing material over the original tracing, copying (1) the frontonasal area, both hard- and soft-tissue, with the soft tissue nose carried down to near the point where the outline of the nose starts to change directions; (2) the sella-nasion line; and (3) the nasion-point A line.

Step II

First, superimpose on the SN line and move the tracing to show expected growth (0.66 to 0.75 mm per year unless a pubertal growth spurt is expected from wrist plate studies). Second, copy the outline of sella. Third, either copy or change the facial axis (Ricketts' foramen rotundum to gnathion) as you expect it to behave according to the facial type of the patient and the treatment mechanics that you customarily use in such cases. (The facial axis line is usually opened about 1°, but it may even be closed if one is confident that mandibular growth of the forward rotational type will occur during treatment.)

Note: It is important to understand that the prediction of growth at nasion, along the SN line, is actually an overall prediction for all midfacial structures, including the nasal bone, the maxilla, and the soft tissues.

Step III

First, superimpose the VTO facial axis on the original and move the VTO up so that the VTO SN line is above the original SN. The amount of movement will usually be 3 mm per year of growth, except in accelerated growth-spurt periods.

(Note: Since the facial axis may be opened or closed as judged from the facial pattern, the SN lines will not be parallel if we have changed the facial axis.)

Second, copy the anterior portion of the mandible, including the symphysis and anterior half of the lower border. Also draw the soft-tissue chin, eliminating any hypertonicity evident in the mentalis area. *(Slightly round out this area.)*

Third, copy the Downs mandibular plane.

Step IV

First, superimpose on the mandibular plane and move the VTO forward until the original sella and the VTO sella are in a vertical relation. Next, with the tracing in this position, copy the gonial angle, the posterior border, and the ramus. Finally, superimpose on sella to complete the condyle.

Note: At this point total vertical height has been forecast, as has the forward location of the chin structures, both hard and soft, and consideration will have been given to effects of treatment mechanics on vertical dimension. One should not open the facial axis more than 1° to 2° because greater opening than this is usually inconsistent with good treatment mechanics.

Step V

First, superimpose the VTO NA line on the original NA line and move the VTO up until 40% of the total growth is expressed above the SN line and 60% below the mandible. *(Note: This may be varied as you perceive the facial type to be short or long.)*

Second, with the tracing in this position, copy the maxilla to include the posterior two thirds of the hard palate, PNS to ANS to 3 mm below ANS.

Third, also with the tracing in this same position, complete the nose outline around the tip to the middle of the inferior surface. *Note: The vertical growth of the nose over the usual 18 to 24 months of estimated treatment time keeps pace with the growth from the maxilla vertically to the anterior cranial base. Thus, its relationship to ANS is relatively constant. In some cases there may be an elevation of the nasal bone and greater development of the nasal bulk, but this is difficult to predict and thus some noses will have changed from more than this VTO procedure suggests.*

Step VI

First, with the VTO still superimposed on the line NA, move the VTO so that vertical growth between the maxilla and the mandible is expressed 50% above the maxilla and 50% below the mandible.

Second, with the tracing in this position, copy occlusal plane.

Note: Ideally, the occlusal plane is located about 3mm below the lip embrasure.

This permits the lower lip to envelop the lower third of the crowns of the upper incisor teeth. If the cant of the occlusal plane is correct it should be maintained. If not, then it can be altered accordingly at this stage. In cases involving short upper lips, it may not be practical to intrude the upper incisors to this extent, but the vertical relationship of the teeth and gingival tissue will be more aesthetically pleasing if we can reach this goal.

Step VII

Note: When there is a uniform distribution of --soft tissues in the profile and the upper lip is of average length, and where the cant of the H line is not adversely affected by excessive facial convexity or concavity, the depth of the superior sulcus measured to the H line is most ideal at 5 mm. A range of 3 to 7 mm allows one to maintain type with short and/or thin lips and long and/or thick lips.

Additional refinement of the technique, which covers all of the above, is gained by use of the vertical line from Frankfort plane to the vermillion border of the upper lip, which is ideal at 3 mm with a range from 1 to 4 mm. To find the point along the lower border of the nose outline at which the new H line will intersect it, both perspectives are used in the exceptional cases just mentioned.

First, line up a straight-edge tangent to the chin and angle it back to a point where there is a 3 to 3.5 mm. measurement to the superior sulcus outline of the original tracing and draw the H line to this. As one redrapes the superior sulcus area to the new tip of the upper lip point, a 5 mm superior sulcus depth develops almost automatically. If you have trouble with this, the use of the Jacobson-Sadowsky lip-contour template is recommended.

Second, with the tracing still superimposed on the maxilla and line NA and using the occlusal plane as a guide for the lip embrasure, draw the upper lip from the vermilion border to the embrasure. Then from the point on the lower border of the nose where its outline stopped on the VTO, draw in the superior sulcus area.

This is a gradual draping to the new vermilion border outline.

Third, superimpose on line NA and the occlusal plane. Form the lower lip, remembering that from 1 mm behind the H line to 2 mm anterior can be excellent, depending on variations of thickness of the two lips. Again, most cases will fall on the H line or within 0.5 mm of it.

Finally, complete the inferior sulcus drape from the lower lip to the chin in a form harmonious with the superior sulcus. *(Note: The lips are not expected to have* *fully adapted to this position in more than about one half of the cases at the time of retention.)*

Step VIII

First, with the exceptions noted earlier, lip strain that shows up as excessive upper lip taper is our first consideration. In the case of the example he used, the basic lip thickness measurement was 15 mm and the thickness at the vermilion border was 10 mm. One millimetre of taper is normal, leaving a lip strain factor of 4 mm.

Next we are concerned with how many millimetres the upper lip is back from its original position. This is measured with the tracings superimposed on line NA and the maxilla. In the present case this also amounts to 4 mm.

The third consideration is maxillary incisor "rebound." When the maxillary incisors have been retracted 5 mm or more and the case has been slightly over treated to a near edge-to-edge incisor overbite and overjet relationship, we can expect about 1.5 mm relapse tendency. Obviously, there will be no tendency to move labially in those cases in which the upper incisor is not retracted or in those cases, such as anterior crossbites and/or Class III cases, in which the maxillary incisors have been expanded labially. Here the incisor retraction is significant, and we will use 1.5 mm for incisor rebound. In this particular patient, then, calculations would be as follows: (I) Elimination of lip strain, 4 mm. (2) Upper lip change, 4 mm. (3) Maxillary incisor rebound, 1.5 mm.

Finally, with the tracing still superimposed on line NA and the maxilla, place the maxillary incisor template, taking cognizance of the amount that it is to be repositioned (9.5 mm in this case), its axial inclination, and the relationship of the incisal edge to the occlusal plane, and draw the tooth.

Step IX

First, superimpose the VTO on the mandibular plane and symphysis. Using the template, reposition the lower incisor to be in ideal retention occlusion with the maxillary incisor, using the occlusal plane a, a guide and by tipping the tooth about the apex unless bodily movement is needed to improve the form of the inferior sulcus area.

Second, with the tracing in this same position, measure the amount of lingual movement of the lower incisors. Twice this amount is the arch length loss due to lower incisor (uprighting) lingual tipping or gain from labial tipping when indicated.

This loss of arch length is now combined with the arch length discrepancy determined from the model to obtain the total arch length discrepancy. In this case, the calculations would be:

(1) arch length loss from reposition, 2 x 4 = 8 mm;

(2) model discrepancy, 2 mm;

(3) total discrepancy, 10 mm.

Step X

With the tracing superimposed on the mandibular plane and symphysis and using the occlusal plane as a vertical guide, draw the lower molar where it must be to eliminate remaining space if extractions must be part of the treatment plan.

In the case illustrated, each lower molar must be moved forward 2.5 mm.

Note: By using the VTO approach, you will come upon many cases where mesially tipped lower molars can be uprighted to gain all of the model arch length discrepancy when the incisor position is adequate. Distal tipping of lower molars 2.5 mm can allow nonextraction treatment in cases of a model discrepancy of 5 mm. In other cases, especially those having a history of thumb- or lip-sucking or in which serial extraction is contraindicated, the VTO will show that the lower incisors need to be moved forward, thus also increasing arch length and reducing the need to extract. On occasion both approaches can be used. In his opinion, lower incisors should not be moved forward to a point more than 1 mm anterior to the A-pogonion line, as post-treatment stability and long-term periodontal health are usually endangered by so doing.

The use of the VTO at this point to study and evaluate anchorage and arch length is one of its great advantages. If the lower molar must be moved anteriorly as much as 3.5 mm, the lower second premolars will be removed. There are cases in which there is an extremely thin alveolar process, particularly those cases that have deficient lower face height where the lower molars seem to get locked up in cortical bone if the second premolars are extracted.

Extraction of the second premolars instead of the first premolars actually increases the lower molar anchorage. When these two factors combine as contraindications to forward lower molar movement, it is sometimes better to look at judicious narrowing of the teeth through stripping and polishing than to extract at all.

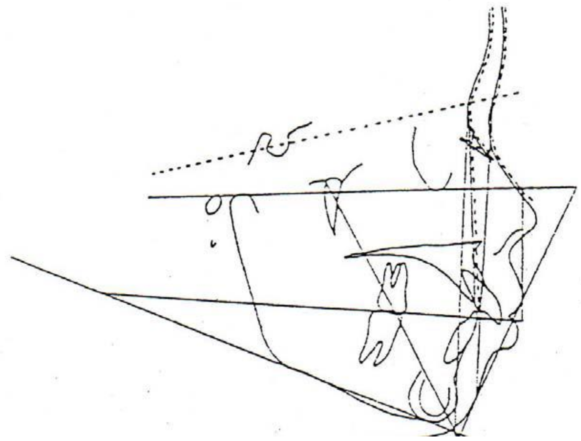
Step XI

First, using the occlusal plane and the lower first molar as a guide, with a tooth template, position the upper first molar in ideal Class I occlusion with the lower first molar.

Second, superimposing tracings on the original NA line and the outline of the maxilla, evaluate the extent of upper molar movement. In cases that worked out as lower arch non-extraction cases, one may still need to think about other extraction alternatives in the upper arch, such as upper second molars when good third molar buds are developing or upper first premolars.

Step XII

Note: As to how point A changes with incisor retraction, it is imperative that the clinician study the before and after tracings of many cases superimposed on the original NA line and best fit of the maxilla to get the"feel" for this step. Obviously the change in point A is greater when the upper incisor root apices are moved a considerable distance than when the upper incisors are tipped lingually. More change in A point is also evident when the tracing is superimposed in this manner if we are going to use heavier orthopaedic forces, especially in younger patients (in the mixed dentition).



Appendix 2: Ricketts VTO

1. Trace the Basion-Nasion Plane. Put a mark at point CC.
2. Grow Nasion 1mm/year (average normal growth) for 2 years (estimated treatment time)
3. Grow Basion 1mm/year (average normal growth) for 2 years (estimated treatment time.
4. Slide tracing back so Nasions coincide and trace Nasion area.
5. Slide tracing forward so Basions coincide and trace Basion area.
6. Superimpose at Basion along the Basion-Nasion plane. Rotate “up” at Nasion to open the bite and “down” at Nasion to close the bite using point DC as the fulcrum. This rotation depends on anticipated treatment effects (whether treatment can be expected to open or close the facial axis).
7. Trace Condylar Axis, Coronoid Process and Condyle.
8. On condylar axis, make mark 1mm per year down from point DC.
9. Slide mark up to the Basion-Nasion plane along the condylar axis.

Extend the condylar axis to XI point, locating a new XI point.

10. With old and new XI points coinciding, trace corpus axis, extending it

2mm per year forward of old PM point. (PM moves forward 2mm/year in normal growth.)

11. Draw posterior border of the ramus and lower border of the mandible.
12. Slide back along the corpus axis superimposing at new and old PM.

Trace the symphysis and draw in mandibular plane.

13. Construct the facial plane from NA to PO.
14. Construct facial axis from CC to GN (where facial plane and mandibular plane cross).

15. To locate the “new” maxilla within the face, superimpose at Nasion along the facial plane and divide the distance between “original” and “new” Mentons into thirds by drawing two marks.
16. To outline the body of the maxilla, superimpose mark #1 (superior mark) on the original Menton along the facial plane. Trace the palate (with the exception of point A).
17. Point A can be altered distally with treatment. Place according to
orthopaedic problem and treatment objectives. For each mm of distal movement, Point A will drop 2mm.
18. Construct new APo plane.
19. Superimpose mark #2 on original Menton and facial plane, then parallel Mandibular planes rotating at Menton. Construct occlusal plane (may tip 3 degrees either way depending on Class II or Class III treatment). The lower incisor is placed in relationship to the symphysis of the mandible, the occlusal plane and the APO plane. The arch length requirements and realistic results dictate its location.
For this exercise, superimposed on the corpus axis at PM. Place a dot representing the tip of the lower incisor in the ideal position to the new occlusal plane, which is 1mm above the occlusal plane and 1mm ahead of the APO plane.
21. Aligning over the original incisor outline or using a template, draw in the lower incisor in the final position as required by arch length. The angle is 22º at 1 mm to the APo plane and + 1mm to occlusal plane, but the angle increase 2º with each mm of forward compromise.
Without treatment, the lower molar will erupt directly upward to the new occlusal plane. With treatment 1mm of molar movement equals 2mm of arch length. We moved the lower incisor forward 2mm in this case.
There was also 4mm of leeway space. Therefore, the following calculation allows us to move the lower molar forward 4mm on each side: lower incisor forward 2mm = + 4mm arch length leeway space = + 4mm arch length
+ 8mm arch length
22. Superimpose the lower molar on the new occlusal plane at the molar (*), slide forward 4mm, upright molar and draw it in.
23. Trace the upper molar in good Class I position to the lower molar. Use the old molar as a template. Place upper incisor in good overbite/overjet position (2½mm

overbite, 2½mm overjet) with an interincisal angle of 130º ± 10º. Open bite patterns at a greater angle, deep bite patterns at a lesser angle.

24. Trace the upper incisor in its proper relationship, aligning over the original incisor or by use of a template.

25. Superimpose at Nasion along the facial plane. Trace bridge of nose.

26. Superimpose along the facial plane at the occlusal plane. Using the same technique as for marking the symphysis, divide the horizontal distance between the "original" and "new" upper incisor tips into thirds by using two marks.

27. Soft tissue Point A remains in the same relation to Point A as in the original tracing. Superimpose new and old bony Point A, and make a mark at soft tissue Point A.

28. Keeping the occlusal planes parallel, superimpose mark #1 (posterior mark) on the tip of the original incisor (slide forward 2/3rds). Trace upper lip connecting with soft tissue Point A.

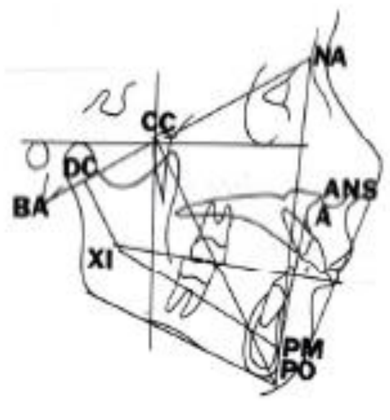
29. Superimpose interincisal points, keeping occlusal planes parallel.

Trace lower lip and soft tissue B point. The soft tissue below the lower lip remains in the same relation to point B as in the original tracing.

Soft tissue point B drops down as the lower lip recontours.

30. Superimpose on the symphyses and arrange the soft tissue of the chin.

It "drops down" and should be evenly distributed over the symphysis taking into consideration reduction of strain and bite opening.



A *- The deepest point, on the curve o1 the maxilla between the anterior nasal spine and*

the dental alveolus.

ANS *- Tip of the anterior nasal: spine.*

BA *- Most interior posterior point of the occipital bone.*

CC *- Point where the Basion-Nasion plane and the facial axis intersect.*

DC *- A point selected in the centre of the neck of the condyle where the Basion-Nasion plane crosses it.*

NA *- A point at the anterior limit of the nasofrontal suture.*

PM *- Point selected at the anterior border of the symphysis between Point B and Pogonion where the curvature changes from concave to convex.*

PO *- Most anterior point on the mid-sagittal symphysis tangent to the facial plane.*

XI *- The geometric centre of the ramus of the mandible***.**