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A CEPHALOMETRIC EVALUATION OF THE VERTICAL CHANGES ASSOCIATED WITH THE BEGG LIGHT WIRE TECHNIQUE

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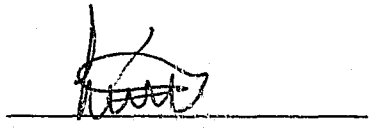
A research report submitted to the Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of Master of Science in Dentistry.

Johannesburg 1999

I hereby declare that this is my own work, and that it has not been submitted or incorporated in any other thesis or dissertation for any other degree.



LARRY URIA

This 28 day of October 1999

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ABSTRACT

Use of the Begg light wire technique in orthodontics has been implicated as causing an increase in anterior facial height. Controversy persists concerning the effects of this technique on the dentition as well as on the skeletal pattern of patients.

The present retrospective cephalometric study was undertaken to evaluate the vertical changes that occurred during, and after, treatment of patients with the Begg light wire technique. The lateral cephalometric radiographs of 31 patients, aged between 11 and 17 years were evaluated before (group A), soon after (group B), and approximately two years after treatment (group C). A series of angular and linear measurements were performed on each cephalometric tracing, and these data were statistically analysed for changes immediately post-treatment, and approximately two years later.

The null hypothesis for this study states that there is no significant change in the vertical facial dimension of patients treated with the Begg light wire technique. Paired *t* tests were used to test the hypothesis. Stepwise regression analysis of variance was used to determine which (if any) changes in the independent variables during treatment could predict changes during treatment, and could exert their influence during the retention period.

Post-treatment, the SNA angle showed an average decrease of 1.05^0 and there was a significant increase in all the linear measurements (N-ANS, ANS-Me, N-ANS(W), ANS-Me(W), S-Go). In the retention period the SNB angle increased significantly by 0.87^0, and there was a significant increase in all the linear measurements (N-ANS, ANS-Me, N-ANS(W), ANS-Me(W), S-Go). The mandibular plane showed no significant changes through treatment as well as after two years post-treatment. N-S-Gn angle also showed no significant changes through treatment and following the two year post-treatment retention period.

Several variables were evaluated to assess their influence on the changes that occurred. Regression modelling revealed that the initial value of the following variables, age at the start of treatment, time elapsed between groups A, B, and C, gender, extractions, and skeletal pattern (Class I,II and III) all influenced the extent of the vertical changes that occurred in patients treated with the Begg light wire technique.

The null hypothesis is retained. There were no significant changes in the mandibular plane angle and the Y axis angle, therefore treatment did not increase the anterior facial height when assessed by these two angles. However, changes were noted in angle SNA, SNB, occlusal plane, occlusal to mandibular plane, and palatal to occlusal plane. Significant increases in linear measurements of anterior facial height were noted, but these may be as a result of growth.

CHAPTER ONE.

INTRODUCTION AND LITERATURE REVIEW

1.1 General remarks

Studies undertaken on Stone Age Man's dentition by P.R. Begg in the middle of this century, changed his personal philosophy on occlusion and the "aetiology of malocclusion". According to Begg[1-4], and Begg and Kesling[3] a large percentage of the malocclusions of modern day man are due to a change in diet compared with that of Stone Age man. Present day refined foods do not allow for the mesio-distal tooth loss which occurred in Stone Age Man. Begg believed that it was not always necessary to maintain a full complement of teeth in the correction of dental malocclusion, a change in outlook since he had been trained by Edward Angle in the non-extraction, expansion philosophy. The Begg philosophy, first introduced and described in 1956[2], was claimed to have many advantages including : the use of light, more physiologically acceptable, orthodontic forces resulting in less patient discomfort; less damage to the periodontium of the tooth; greater efficiency of tooth movement; and a shortened treatment period. The technique was claimed to be particularly efficient for the correction of deep overbites, and for treating cases with excessive crowding.

1.2 Begg philosophy

Sims[5] discussed the Begg philosophy and its fundamental principles, and agreed with the need for premolar extraction in certain cases to mimic the loss of tooth material by attrition in Stone Age Man's dentition, as well as to balance the tooth to bone size discrepancy caused by the evolutionary reduction in bulk of the alveolar bone. According to Sims[5], the Begg light wire technique allows for the use of light forces with rapid, and painless, tooth movement, renders reduntant the need for extra-oral anchorage in the form of headgear, and eliminates the call for bite plate therapy. Intraoral anchorage supplied by the molar teeth is sufficient for this technique, and the use of extremely light inter- and intra-maxillary elastics is all that is required. Sims[5] stated

that the use of differential forces makes it possible to carry out many tooth movements simultaneously with maximum efficiency.

Orthodontic treatment with the Begg technique is divided into three distinct stages[3] :

Stage 1 - This stage deals with the correction of the overjet and overbite. The clinician attempts to achieve an upper and lower incisor edge to edge relationship. Overbite correction is due to extrusion of mandibular molars, and wherever possible intrusion of canines and incisors.

Stage 2 - During this stage the remaining spaces are closed by a combination of palatal or lingual tipping of the maxillary and mandibular anterior teeth, and by mesial bodily movement of the maxillary and mandibular molars.

Stage 3 - The finishing stage involves correction of axial inclinations of all the teeth.

According to Cadman[6] the Begg light wire technique has many advantages including :

1) Efficiency of treatment, because many corrective tooth movements occur simultaneously with relative little appliance adjustment.
2) Minimal patient discomfort and minimal trauma to hard and soft tissues as a result of the use of light and continuous forces.
3) Rapid aesthetic improvement, achieved by early reduction of overjet and alignment of the anterior teeth.
4) Early correction and overcorrection of rotations, possibly contributing to a reduced incidence of relapse after treatment.
5) Short treatment time resulting from the rapidity of tooth movement, forces continually active during extended periods of time, and simultaneous execution of many corrective tooth movements.

Williams[7] described features of the response to Begg therapy which may readily be discernible cephalometrically :

1) The lower incisors are moved bodily lingually within the alveolar bone of the mandible during treatment. This occurs in spite of the fact that a round wire is used and no torquing influence is applied.
2) The mandibular plane angle, as measured to either the Sella-Nasion line or the Frankfurt plane, typically increases during the first two stages of treatment and closes during the third stage. In the post-treatment reaction, the mandibular plane angle usually closes significantly from its value at the end of active treatment, occasionally becoming less than the original.
3) As a result of the closure of the mandibular plane angle in the post-treatment reaction, point B moves forward a substantial amount and the apical base difference is further reduced.
4) In the posttreatment reaction the occlusal plane, like the mandibular, generally reverts towards its original cant.
5) Closure of the mandibular plane angle causes the upper incisors to tip labially.
6) The incisal edge of the lower incisors come to lie very close to the AP line.
7) In spite of mandibular closure in the third stage of treatment, the overbite tends to remain very stable.
8) During the third stage of treatment the upper incisor roots are torqued palatally, which leads to a loss of anchorage.
9) The second stage or space closing stage expends the least amount of anchorage.

1.3 Cephalometrics

Since the introduction of cephalometric radiography by Broadbent[8] in 1931, the procedure has become an essential tool in orthodontics. It is important in diagnosis and treatment planning and is also a useful research technique. Different measurement systems have been designed over the years and are used to describe and measure relationships between the various soft tissue, skeletal, and dental elements[9-11], while the comparison of cephalometric head films taken at different time intervals are used to analyse changes to the craniofacial complex due to growth and/or orthodontic treatment[12].

Properly utilized, cephalometric radiographs can greatly enhance orthodontic diagnosis and treatment planning. It must be recognised that the cephalogram is a two dimensional image of a three dimensional object, so the clinician must be familiar with the gross anatomy of the head and in particular the orofacial region, in order to produce, understand, and inte[illegible] tracing of the radiograph. The completed cephalometric tracing enables an angular and line [illegible]esentation of the patient's facial structure. Various lines and angles eg. the mandibular plane angle, the sella-nasion line, are related to each other to provide this information.

Controversies regarding the value of angular and linear craniofacial measurements have been extensively discussed in the dental literature. Wylie and Johnson[13], stated that despite the fact that angular measurements are not an accurate indication of size, they are nonetheless informative. Angular measurements record the relative positions of three points and provide information on the spatial changes that may occur with the movement of one or more of those points. Wylie and Johnson[13] pointed out a reluctance to use linear measurements for research purposes, observing that growth changes, and variability amongst children will result in distortion of measurements. However, they do remark that avoiding linear measurements for these reasons, will be disregarding valuable information.

One of the most important analyses; described by Steiner[11], uses sella-nasion (SN) as a reference line representing the anterior cranial base. This reference line has been widely used for the past thirty years and has the advantage of being common to the cranial base and the facial structures.

A subsequent analysis was described by Schudy[14], who comprehensively discussed the various angular and linear measurements associated with vertical and anteroposterior facial height changes. Schudy[14] stated that with the treatment of Class II open bite malocclusions, the jaw discrepancy is often accentuated as a result of the distal movement of maxillary molars, extrusion of molars, and lingual tipping of mandibular molars. In his study, Schudy[14], described the occlusal plane relative to sella-nasion, the mandibular plane relative to sella-nasion, and the occlusal plane relative to the mandibular plane, because he considered these angles to be useful indicators of vertical variations. Schudy[14] summarises his views as "The principal thesis of this study is that the vertical dimension is the most important dimension to the clinical orthodontist and that vertical

dysplasias are inseparably related to both open and closed bites".

The importance of the vertical dimension was further emphasised by McNamara[15], who in his study of methods of cephalometric evaluation measured upper facial height from nasion (N) to anterior nasal spine (ANS), and lower facial height from anterior nasal spine (ANS) to menton (Me). He showed that, clinically, the relationship of the upper and lower jaws is influenced to a great extent by the lower anterior facial height.

Lateral cephalometric measurements, like all measurements, are subject to errors, mainly those of projection and identification[12]. Errors of projection are the result of a three-dimensional object being projected in two-dimensions, while errors of identification are the mis-identification of landmarks on the lateral cephalometric radiograph. The latter may be influenced by film density and sharpness.

Richardson[16] showed that the use of an electronic plotting system or digitizer was more accurate for measuring lateral cephalometric radiographs. Cohen[17] assessed the accuracy of the digitizer with traced and untraced lateral cephalometric radiographs and concluded that the plotting of untraced radiographs resulted in more accurate measurements than those obtained on traced lateral cephalometric radiographs. However, in contrast, Oliver[18] found that direct digitisation of a lateral cephalometric radiograph was less accurate than digitising the tracing of a lateral cephalometric radiograph. He also showed that conventional tracing and measurement of a lateral cephalometric radiograph was more accurate than directly digitising an untraced radiograph.

1.4 Review of literature concerning the vertical facial dimension

Bijlstra[19] set out to confirm statements made by Williams[7] that : "Bite opening (with the Begg technique) was accomplished chiefly by elevation of the lower first molars". In a study of twenty one patients, Bijlstra[19] observed immediately after treatment an increase in the cant of the occlusal plane relative to sella-nasion, which decreased slightly two years post-treatment, almost back to its original value. The occlusal plane to the mandibular plane angle showed a decrease immediately post-treatment, with a subsequent insignificant increase two years post-treatment. Bijlstra[19]

equated a decrease in the vertical overbite to an increasing anterior vertical height. He showed that there was a large decrease in the overbite immediately post-treatment, which change reverted back to almost half the original value two years post-treatment. In summary, Bijlstra[19] indicated that with treatment there was a large increase in anterior vertical facial height, followed by a steady decrease over a two year post-treatment period. Bijlstra[19] concluded that opening of the bite was due to intrusion of the lower anteriors, and elevation of the lower molars. He did not measure the mandibular plane to sella-nasion angle.

O'Reilly[20] reported a post-treatment increase in height from the tip of the buccal cusp of the lower molar to the mandibular plane, and an increase in height from the tip of the buccal cusp of the upper molar to the palatal plane. This extrusive change in maxillary and mandibular molar vertical height produced by the Begg light wire technique may result in an increase of the mandibular plane angle.

According to Swain and Ackerman[21] : "The two major goals of orthodontics with regard to the vertical dimension, are correction of the anterior overbite relation and prevention of adverse or clockwise rotation of the mandible. One of the unresolved controversies regarding Begg treatment is the manner in which the bite is so effectively opened". Their findings suggested that overbite correction was attained through molar extrusion, and the mandibular molar was extruded more than the maxillary molar. However, they went on to say that molar extrusion was not as evident when facial growth patterns ensued harmoniously, and therefore opening rotation of the mandible did not occur. They explained that when molar eruption exceeded mandibular growth there would be a characteristic clockwise (opening) rotation of the mandible.

In a review of the Begg technique, Weber[22] investigated various unpublished masters theses, all reporting on cases which had been treated with the Begg light wire technique. He remarked that a study by Phillips (1965-cited by Weber[22]), had shown a considerable increase in the angle of the Frankfort horizontal plane to the mandibular plane immediately post-treatment, which subsequently decreased post-retention. The most remarkable change was the cant of the occlusal plane, which tipped upward posteriorly and downward anteriorly. Weber[22], citing work done by James (1966), claimed that Begg therapy corrected the deep overbite by elevation of the lower

molars and depression of the lower anterior teeth. This 1966 study also reported an increase in the Frankfort horizontal to the mandibular plane angle immediately post-treatment, however this decreased two years post-treatment. Weber[22] further investigated two additional theses, those of Broussard (1969-cited by Weber[22]) and Harber (1970-cited by Weber[22]). Broussard (1969-cited by Weber[22]) studied fifteen patients, who each had four premolars and four first permanent molars removed for orthodontic purposes, and were then treated with the Begg light wire technique. Measurements obtained were pre-treatment and immediately post-treatment. There were no significant changes in the mandibular and palatal planes, but the occlusal plane rotated in a clockwise direction relative to the palatal, mandibular, and sella-nasion planes. He attributed this change to supraversion of the maxillary incisors and mandibular molars, and depression of the lower incisors brought about by the prolonged use of Class II intermaxillary elastics.

In a study similar to that of Broussard (1969-cited by Weber[22]), Harber (1970-cited by Weber[22]) investigated the changes in the vertical dimension of the intermaxillary space in eighteen patients. The first molars rather than the premolars had been removed for orthodontic purposes, followed by treatment with the Begg light wire technique. Measurements were also pre-treatment and immediately post-treatment. There were no significant changes in the mandibular and palatal planes relative to sella-nasion, but the occlusal plane rotated in a clockwise direction relative to the palatal, mandibular, and sella-nasion planes. The increase of the occlusal plane angle relative to these planes was attributed to prolonged use of class II elastics in the Begg treatment, which results in extrusion of lower molars and the maxillary anteriors, as well as intrusion of the lower anteriors. Bite opening occurred due to elevation of the lower molars. Harber (1970 -cited by Weber[22]) noted no significant changes in either the mandibular or palatal plane, which remained relatively constant post-treatment.

As with earlier studies Barton[23] showed that with the Begg technique, the mandibular, palatal, and especially the occlusal planes were increased relative to the cranial base (SN). He also showed that there was an increase in the anterior vertical facial height. His study did not include a post-retention phase, and he acknowledged that follow up studies on long term results were required.

Using a different approach Venezia[24] compared results of the treament of malocclusions with the Begg and the Edgewise techniques. Both techniques closed the occlusal plane angle an average of one degree. The mandibular plane angle opened very slightly in the Edgewise sample, and decreased in the Begg sample. The latter correlates well with O'Reilly's[20] findings in the post-treatment stage. In Venezia's[24] study, the lower molars were more stable in the Edgewise sample as opposed to the Begg sample, with larger mesial movement occurring in the maxillary and mandibular molars of the Begg sample. Whilst this study showed no significant difference in elongation of the maxillary molars, however the mandibular molars in the Begg sample showed a notable change with more elongation than those in the Edgewise sample.

In a study comparing bite plate therapy with treatment using the Begg light wire appliance, Menezes[25] observed that the total face height, as defined by Graber[26], increased with Begg treatment. There was also an increase in both the upper and lower anterior facial heights, and an increase in both the maxillary and the mandibular plane angles relative to the cranial base (SN). Begg treatment caused the lower molars to extrude, leading to bite opening and therefore to the ensuing increase in the mandibular plane angle. There was a further increase in this angle after treatment, but Menezes[25] attributes this long term change to growth, as well as being due to the extraction of the four premolars at the beginning of treatment. Extraction of these teeth allows the buccal segments to move forward, resulting in the molars coming to lie in an area of greater interalveolar bone height, therefore permitting an increase in molar height. In this study, both short and long term anterior bite plate therapy resulted in over-eruption of the molars, and, not surprisingly, this was associated with an increase in the height of the upper and lower molars.

In this same study Menezes[25] looked at the long term results and noted that in the class II division I cases there was an increase in the lower anterior facial height, which suggested that the Begg technique in the long term may lead to an increase in the vertical dimension of the face. The over eruption of lower molars was a major contributing factor to this effect.

Concurring with a number of earlier studies, Levin[27] attributed downward and backward rotation of the mandible to molar extrusion. In the post-treatment stage this was reversed, showing that the changes induced were temporary. The Y-axis angle also showed a significant increase.

Molar extrusion with backward rotation of the mandible, leading to a lengthening of the facial height is recognised as one of the major disadvantages of the Begg technique. In a study by O'Reilly[20], treatment and post-treatment changes with the Begg appliance were evaluated. Many observations confirmed results of previous studies, with the following changes noted :

1) The occlusal plane angle relative to the palatal plane, and the occlusal plane angle relative to sella-nasion showed increases during the treatment phase. This was attributed to molar extrusion produced by class II elastic force and the anchor bends in the arch wires. Both these angles decreased during the retention phase and this was an indication of the recovery of molar extrusion.
2) The nasion-sella-gnathion angle increased insignificantly from the pre-treatment to the end of treatment phases.
3) There was no significant increase in the mandibular plane angle relative to the cranial base (sella-nasion), from the pre-treatment stage to the end of treatment. As noted in a number of earlier studies there was a decrease in this angle, from pre-treatment to the end of retention, and from the end of treatment to the end of retention.
4) There were increases in the vertical linear measurements of anterior facial height in both the experimental and control groups. Irrespective of treatment these measurements would have increased as a result of growth.
5) Stability of the palatal plane was demonstrated by there being no statistical difference between the mean data of the experimental and control groups. However the palatal plane to sella-nasion angle did increase from the start to the end of treatment in the experimental as compared to the control group.

In a 1982 study of a cephalometric evaluation of hard and soft tissue changes during the third stage of Begg treatment, Cangiolosi and Meistrell [28] found no significance in the extent of maxillary molar extrusion which had occurred. This report was in contrast to most earlier studies.

Gianelly, Arena and Bernstein [29] compared treatment changes resulting from treatment with the Begg light wire technique, Edgewise, and Frankel appliances. All cases treated were non-extraction. Their results showed that the light wire technique resulted in a decreased sella-nasion-

A angle, and an increase in the sella-nasion-B angle. However, the findings important in assessment of vertical change were the increased mandibular plane angle (gonion to gnathion) relative to sella-nasion, the increased nasion-sella-gnathion angle, and the increased linear measurement of nasion-menton. The Edgewise, Begg and Frankel appliances showed similar treatment results. The techniques resulted in an increase in the mandibular plane angle relative to the cranial base, an increase in the nasion-sella-gnathion angle, and an increase in the anterior vertical face height measured from nasion to menton. Gianelly, Arena and Bernstein[29] acknowledged these increases, although they questioned whether the response was that of an orthodontic or of an orthopaedic nature.

In a similar study Knight[30] evaluated the effects upon several cephalometric variables of three different orthodontic appliance therapies; namely : the Andresen activator functional appliance, Begg therapy, and cervically directed extraoral forces. As with the studies of Menezes[25] and O'Reilly[20], Knight[30] found that the mandibular plane angle increased during both Begg treatment and headgear therapies, and decreased markedly in the post-retention period. This increase in mandibular plane angle as measured to sella-nasion during treatment, produces an increased facial height, and according to Knight[30] results in a downward and opening rotation of the mandible. The downward and backward rotation of the mandible during treatment was only transitory and reverted to the original state after treatment.

With research following the same pattern, Ball and Hunt[31] investigated the vertical skeletal changes associated with three different treatment modalities, namely the Andresen, Harvold, and Begg techniques. They showed that during treatment the maxillary plane angle to the anterior cranial base increased in both the Andresen and Begg groups, and decreased in the Harvold group. All groups showed minimal post-retention changes in this plane. During treatment all three groups showed an increase in the mandibular plane angle to the anterior cranial base. The Begg group showed the largest increase in this angle exhibiting downward and backward rotation of the mandible. Post-treatment, this rotation reversed with forward rotation of the mandible. Ball and Hunt[31] showed a significant increase in the Y axis of growth relative to sella-nasion during treatment with the Begg appliance. However considerable relapse occurred post-treatment. The Andresen group showed significant increases in lower anterior facial height. There were no

significant changes found for upper face height between the untreated control group and the Andresen and Begg groups in this study. There were no significant differences for either upper or lower posterior facial heights at any stage of treatment.

Arat and Iseri[32] treated anterior skeletal open bites with both Edgewise and Begg fixed appliance techniques and functional appliance therapy, namely a triple combination technique of activator, occipital high pull headgear, and vertical chin cup. Both Edgewise and Begg groups were treated on the basis of extractions. Arat and Iseri[32] noted that the mandible was rotated in a downward and backward direction in both the Edgewise and Begg techniques, and was displaced forwards in the functional groups. In this study the upper and lower posterior dentoalveolar bone heights were increased in both the Begg and Edgewise appliances, but there was a decrease with the functional appliances. There was an increase in facial height with fixed Begg and Edgewise techniques.

The literature review indicates that there is a lack of conformity regarding effects of the Begg light wire technique. Concerns of increased vertical height due to molar extrusion, and lengthening of the anterior facial height are indictments of the Begg light wire technique that need clarifying. It may be illuminating to perform a study which may further elucidate the effects of the technique, particularly on these two aspects.

1.5 Objectives of this research study.

The present investigation was undertaken to evaluate the vertical facial changes pretreatment to immediately post-treatment and to two years post-treatment from a sample of patients treated with the Begg light wire technique.

The null hypothesis for this study is that :
there is no significant change in the vertical facial dimension of patients treated with the Begg light wire technique.

CHAPTER TWO

MATERIALS AND METHODS

2.1 General remarks

The study was a retrospective record review, the protocol for which was approved by the Committee for Research on Human Subjects (Medical) of the University of the Witwatersrand.

2.2 Sample

The data for this study were obtained from the records of a private practice in Johannesburg where all the cases were treated by the same practitioner, who had been in orthodontic practice for 25 years, using the Begg light wire technique. The records of 50 patients were randomly set aside from the practice by one of the staff members. From this source, the records of 31 patients were selected based only on the completeness of the cephalometric and clinical records. Each patient record was required to include three lateral cephalometric radiographs taken as part of the routine orthodontic treatment procedure : the first taken at the beginning of treatment (Group A), the second at post-treatment (Group B) at varying time intervals following removal of fixed appliances, and the final at least two years post-treatment (Group C). Clarity of the radiographs was the final selection criterion. The radiographs were categorised in a manner similar to that used in the study by Ryan et al[33]. The selected records comprised 23 females and 8 males. Nineteen of the patients had extractions of two or more premolars to assist with the treatment, and the remaining patients retained their full dentition (Table 2.1). Active treatment time in most cases was two years approximately (mean 20.2 months, sd 4.2 months), and the retention period prior to taking the final radiograph was at least three years (mean 35.0 months, sd 11.7 months).

A study of the pretreatment records showed that of the 31 patients, 17 had a class II skeletal relationship, two had a class III skeletal relationship, and the remaining 12 patients, a class I skeletal relationship. The ANB angle determined the skeletal relationship (ANB 0^0-4^0 =Class I; ANB > 4^0 = Class II; ANB< 4^0 = Class III). All the subjects were of Caucasian origin, and of

similar age groups. The mean age of subjects at the time of the first radiograph was 11,7 years (range 10-14 years, sd 0.92 years); at post-treatment it was 14.6 years (range 13-17 years, sd 0.91 years); and at two years post-treatment the mean age was 17.4 years (range15-22 years, sd 1.52 years) (Table 2.1).

Table 2.1 Summary of patient profile

Mean Age (Years)	Skeletal Relation	Gender	Extractions
Group A = 11.7	Class I = 12	Males = 8	Extractions = 18
Group B = 14.6	Class II = 17	Females = 23	Non-extractions = 12
Group C = 17.4	Class III = 2		

All radiographs had been taken in a standard manner with the same equipment (x-ray unit : Siemens, Pleodor 4, Germany; Cephalostat : B.F. Wehmer, Franklin Park, Illinois, USA). Each patient was positioned within the cephalostat, with the ear rods placed in the external auditory meati, ensuring that the patient remained in a constant, reproducible position. The patient's head was placed so that the Frankfort plane (line connecting the superior borders of the external auditory meati to the left infra-orbital rim) was horizontally orientated. The film cassette was located at a distance of 15cm from the midsagittal plane. The patients maintained their teeth in centric occlusion with their lips relaxed.

2.3 Cephalometric tracing

The radiographs were removed from their files, randomly numbered, and listed in a key, then shuffled to avoid bias. The radiographs were traced on 60g tracing paper in a standard manner in the evening to ensure maximum darkness in the tracing room. The author was the only person who traced the radiographs, and the points on the traced radiograph were examined by an experienced orthodontist. The tracing paper was fixed to the radiograph with 3M magic sello-tape, and the radiograph was then placed on a KROY Lettering System light box and traced, using a sharp Rotring 3H lead pencil. The radiographs together with their tracings were placed on a

light viewing tablet and measured using a KONTRON MOP Videoplan digitiser (KONTRON Central Electronic GMBH, Munich, Germany) located in the Department of Orthodontics at the University of the Witwatersrand (Fig 2.1).

The variables for evaluation were selected for their relevance to changes in the vertical dimension. Ten angular measurements and six linear measurements were recorded (Figs 2.2-2.5). The angles and lines were each measured three times to two decimal places and the mean of the three measurements was the final value used as representative for that particular radiograph for the study. The only evaluator was the author. The standard deviation of each linear and angular measurement was calculated. Measurements were accepted only if the standard deviation was less than 0.99 percent.

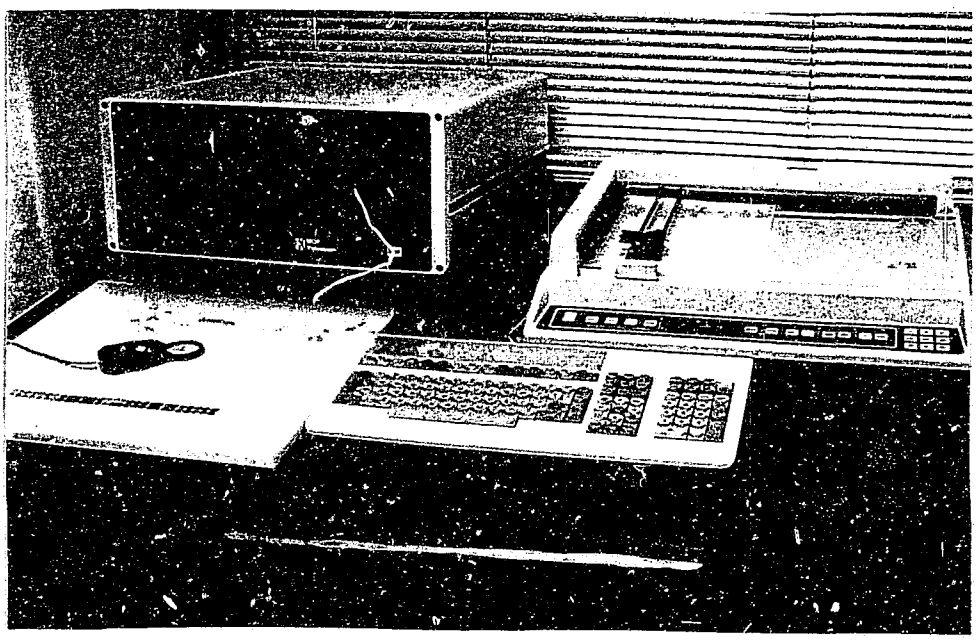

Figure 2.1-KONTRON MOP Videoplan digitiser

2.3.1 Cephalometric landmarks

Ten relevant anatomical landmarks[9,12] commonly used in cephalometric analyses were chosen for this study. These are listed below and are shown in Fig. 2.2

1. Anterior Nasal Spine (ANS) - The anterior tip of the sharp bony process extending from the maxilla at the lower nasal openings.
2. A-Point (A) - Deepest point on the concavity of the maxilla between anterior nasal spine and prosthion.
3. B-Point (B) - Deepest point on the concavity of the mandible between infradentale and pogonion.
4. Gnathion (Gn) - A point located by taking the midpoint between the most anterior (pogonion) and most inferior (menton) points of the bony chin.
5. Gonion (Go) - Located on the curvature of the mandible, formed by the intersection of the tangents of the inferior border of the mandible and the posterior border of the ramus. Bisecting the angle formed by these two lines will result in identifying point Go.
6. Menton (Me) - The most inferior point on the symphysial region of the mandible.
7. Nasion (N) - Formed by the junction of the nasal and frontal bones as seen on lateral cephalometric radiograph. This is the point on the lateral cephalometric radiograph that marks the most anterior aspect of the frontonasal suture.
8. Pogonion (Pog) - A point marking the most anterior part of the chin.
9. Posterior Nasal Spine (PNS) - The most posterior extent of the hard palate (posterior spine of the palatine bone constituting the hard palate).
10. Sella point (S) - Geometric midpoint of sella turcica (pituitary fossa).

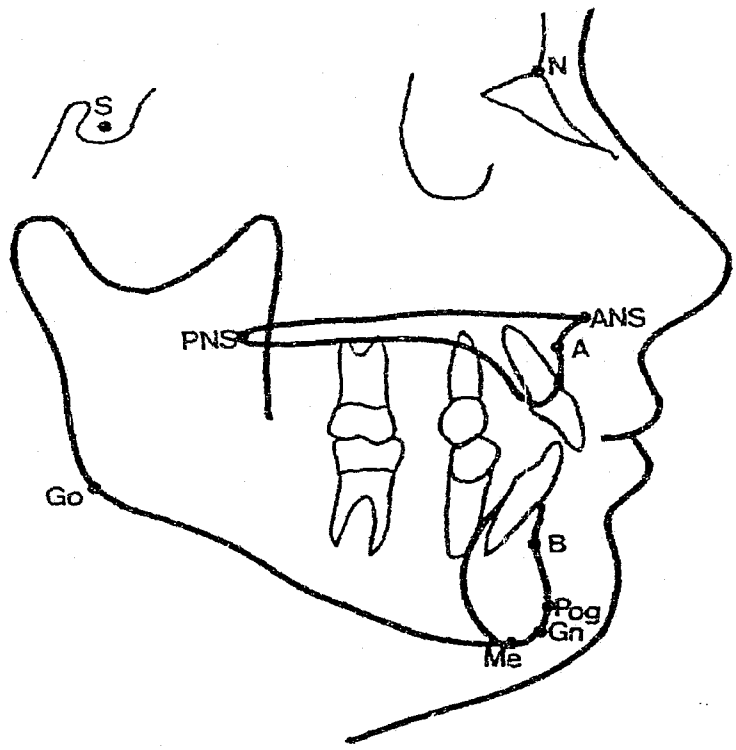

Figure 2.2 - Cephalometric reference points used in this study.

2.3.2 Cephalometric reference lines[14]

The cephalometric reference planes used in this study were (Fig. 2.3) :

1. Mandibular line (Go-Gn) - A line drawn from gonion to gnathion (as defined by Steiner[9]).
2. Occlusal line (Occ-SN) - A line is drawn through the maximal intercuspation of the cusps of the first permanent molars and the first premolars, to the midway point of the incisal overbite.
3. Palatal line (Pal-SN) - The line is drawn from the anterior nasal spine to the posterior nasal spine.
4. Sella-Nasion line (SN) - A line is drawn joining point sella to point nasion.

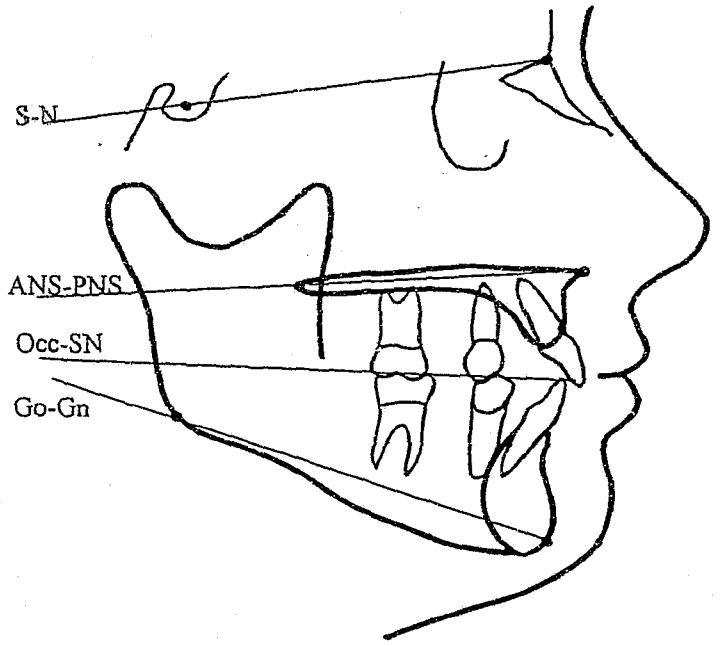

Figure 2.3 - Cephalometric reference lines used in this study.

2.4 Measuring of lateral cephalometric radiographs

2.4.1 Angular measurements (Fig. 2.4)

The 10 angular measurements were :

1. S-N-A - This is the angle formed between sella, nasion, and point A on the maxilla. This measurement relates the anterior-posterior position of the maxilla to the cranial base.
2. S-N-B - This is the angle formed between sella, nasion, and point B on the mandible. This measurement determines the anterior-posterior position of the mandible relative the cranial base.
3. A-N-B -This is the angle formed between point A, nasion, and point B. The measurement relates the apical bases to each other.
4. Mandibular plane angle (Go-Gn to SN) - The inclination of the mandibular plane, drawn from Gonion to Gnathion, is measured relative to the cranial base (S-N).
5. Occlusal plane angle (Occ-SN) - A plane through the maximal intercuspation of the occlusion is drawn, and the inclination is measured relative to the cranial base (S-N).
6. Palatal plane angle (ANS-PNS to SN) - The inclination of a plane joining the anterior nasal spine and the posterior nasal spine is measured relative to the cranial base (S-N).
7. Occlusal plane to mandibular plane (Occ-Man) - The angle between the occlusal plane and the mandibular plane.
8. Palatal plane to mandibular plane (Pal-Man) - The angle between the palatal plane and the mandibular plane.
9. Palatal plane to occlusal plane (Pal-Occ) - The angle between the palatal plane and occlusal plane.
10. Nasion-sella-gnathion (N-S-Gn) - Also known as the Y-axis angle and is formed by nasion, sella, and gnathion. This angle assists in determining the vertical position of the mandible.

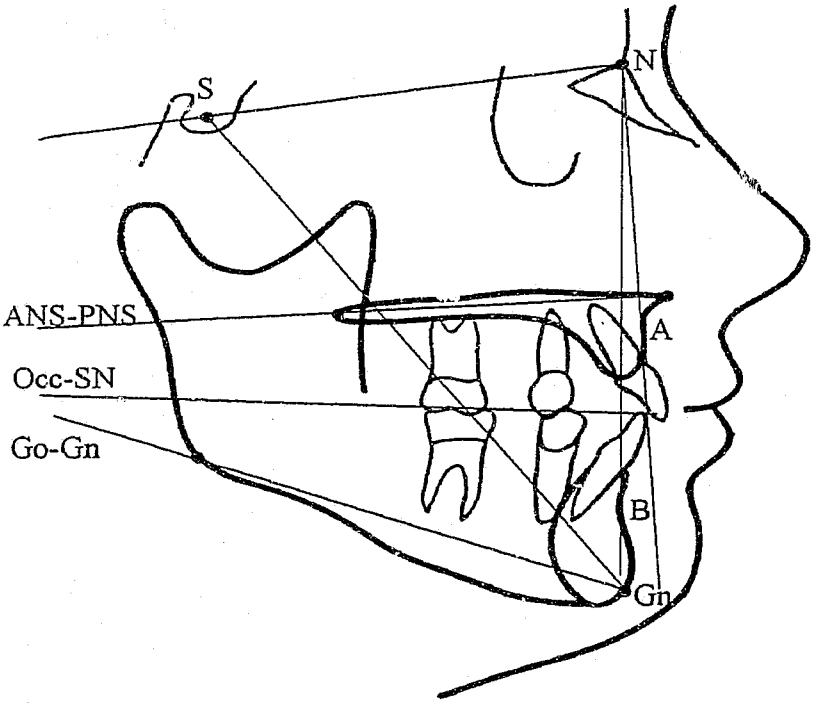

Figure 2.4 - Cephalometric construction to enable the measurement of angular relationships.

2.4.2 Linear skeletal measurements (Fig. 2.5)

The 5 linear measurements were :

1. Nasion to anterior nasal spine (N-ANS) - Distance measured in millimetres between nasion and anterior nasal spine.
2. Anterior nasal spine to menton (ANS-Me) - Distance measured in millimetres between anterior nasal spine and menton.
3. Nasion to anterior nasal spine perpendicular (Wylie and Johnson[13]) - A perpendicular is raised from line N-Me to point anterior nasal spine. Upper facial height was recorded along N-Me at the perpendicular.

4. Anterior nasal spine to menton perpendicular (Wylie and Johnson[13]) - A perpendicular is raised from line N-Me to point anterior nasal spine. Lower facial height was recorded along N-Me at the perpendicular.
5. Sella to gonion (S-Go) - A line extending from sella to gonion is drawn and this represents posterior facial height.

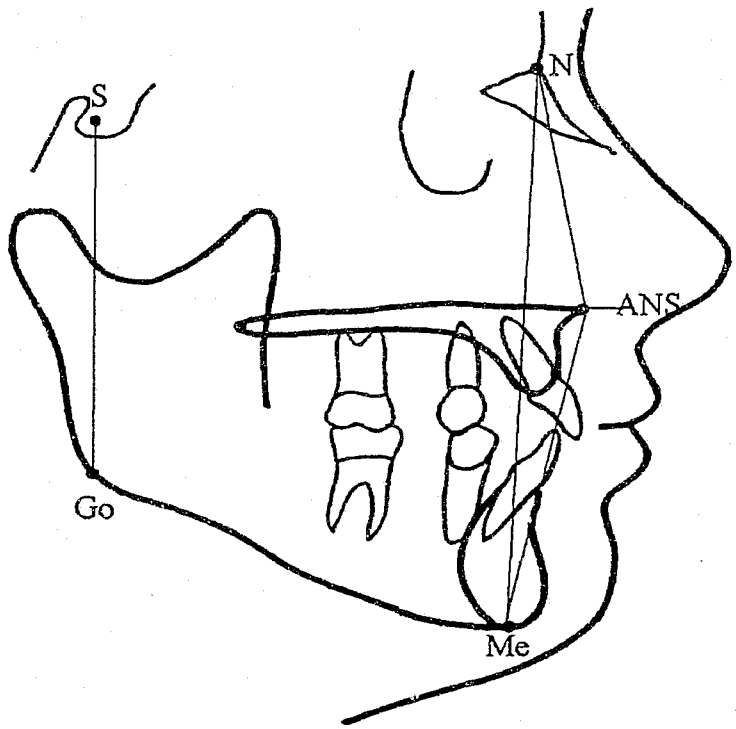

Figure 2.5 - Linear skeletal measurements used in this study.

In summary :

Previous studies assessed vertical craniofacial changes by investigating either apical base response or changes in the dentition[19,20,23]. In the current study, both the dentition and the skeletal factors are considered. The SNA, SNB, and ANB angles provide one means of classifying the experimental sample. The angular measurement GoGn-SN also classifies the sample into "high" and "low" angle sub-samples, as well as indicating any changes resulting from treatment. Changes in the cant of the occlusal plane are determined by any changes in the Occ-SN measurement. Effects of treatment on the mandibular dentition can be assessed by the Occ-Man measurement, and likewise, the maxillary dentition can be assessed by the Pal-Occ measurement. The Pal-Man measurement will give an indication of the combined maxillary and mandibular vertical dental changes between the palatal and mandibular planes. N-S-Gn is theY-axis measurement, and is an indicator of the direction of growth of the mandible. The linear measurements recording vertical dimensional change are represented by N-ANS and ANS-Me as well as Wylie's measurements. Posterior facial height changes are determined by S-Go.

2.5 Pilot study

A pilot study on five patient records was carried out before the definitive study in order to test the validity of the angular and linear measurements for this project, and to determine intra-examiner variation. The radiographs were traced in a standard manner and then digitised as described in section 2.3-2.4.2.

Error of the method :

Prior to starting the final measurements, one lateral cephalometric radiograph was randomly selected from the study sample. This radiograph was traced ten times by the same operator, and then each angle and linear variable on the tracing was measured three times in order to determine the intra-operator error. The data were evaluated statistically and the results are shown in Tables 2.2 and 2.3.

For each variable the standard deviation and percentage coefficient of variation of the repeat readings was calculated. The coefficients of variation were very small ranging between a low of 0.13% and a high of 3.80%. The results are summarised in Table 2.2 and Table 2.3. The reliability of the method was considered adequate to continue with the main study.

Table 2.2 Mean, standard deviation (sd) and coefficient of variation (cv) of angular measurements each recorded three times from each of a series of 10 repeated tracings of one radiograph.

Parameter	measure 1			measure 2			measure 3		
	mean	sd	cv (%)	mean	sd	cv (%)	mean	sd	cv (%)
SNA	81.54	0.30	0.37	80.52	0.28	0.34	80.85	0.30	0.37
SNB	76.65	0.30	0.39	77.28	0.26	0.34	77.63	0.22	0.28
ANB	4.92	0.14	2.83	3.33	0.13	3.80	3.26	0.11	3.25
GoGn/SN	33.46	0.26	0.76	33.37	0.23	0.68	32.73	0.20	0.62
Occ	19.94	0.23	1.15	18.44	0.18	0.96	17.31	0.19	1.09
Pal	7.39	0.18	2.40	7.58	0.19	2.47	7.84	0.20	2.53
Occ-Man	13.41	0.20	1.50	14.84	0.24	1.64	15.40	0.21	1.34
Pal-Man	26.01	0.20	0.76	25.74	0.20	0.77	24.85	0.24	0.98
Pal-Occ	12.53	0.23	1.87	10.88	0.19	1.70	9.40	0.24	2.54
N-S-Gn	67.62	0.33	0.48	68.06	0.30	0.44	67.76	0.28	0.41

Table 2.3 Mean, standard deviation (sd) and coefficient of variation (cv) of linear measurements each recorded three times from each of a series of 10 repeated tracings of one radiograph.

Parameter	measure 1			measure 2			measure 3		
	mean	sd	cv (%)	mean	sd	cv (%)	mean	sd	cv (%)
N-ANS	54.35	0.12	0.22	56.82	0.14	0.25	57.10	0.12	0.20
ANS-Me	65.17	0.11	0.18	69.38	0.11	0.16	70.56	0.13	0.18
N-ANS(W)	52.87	0.12	1.80	55.66	0.12	0.21	55.92	0.10	0.17
ANS-Me(W)	63.61	0.09	0.14	67.87	0.12	0.17	68.98	0.09	0.13
S-Go	71.01	0.14	0.20	76.30	0.14	0.18	77.86	0.14	0.18

2.6 Statistical analysis

The statistical analysis of the data was performed by the Institute of Biostatistics of the Medical Research Council using the statistical package stata (StataCorp, 1997 Statistical Software, Release 5.0 College Station, Tx : Stata Corporation). The critical level for statistical significance was set at $P<0.05$.

The data was pooled together and the mean value and standard deviation for each parameter was calculated. Each parameter was then evaluated noting changes from baseline, to post-treatment, to two years post-treatment. A descriptive and comparative analysis was then done to evaluate the changes that occured as a result of treatment, and what was the most likely cause of change.

CHAPTER THREE

RESULTS

The raw data for all recordings are listed in Appendix 1. The means and standard deviations for each variable in the three groups are shown in Table 3.1

3.1 Statistical evaluation-descriptive analysis

The study evaluated the changes effected in each parameter through treatment :

a) The changes for each individual from baseline, pre-treatment (Group A) to post-treatment values (Group B), were calculated by subtraction. A decrease in the angle or a decrease in the linear value of the measurement was assigned a negative (Table 3.2).

b) The changes from baseline, pre-treatment (Group A) to two years post-treatment (Group C), were calculated by subtracting the values of the two year post-treatment group from those of the baseline group for each individual. A decrease in the angle or a decrease in the linear value of the measurement was assigned a negative (Table 3.3).

The changes were then examined for statistical significance at the 5% significance level. The dangers of a type I error were kept in mind, and the results were interpreted accordingly in the cases of marginal significance. The changes were assessed using Student's paired t-test (statistical significance measured at the 5% level, through the use of 95% confidence intervals for the relevant change).

Table 3.1 Mean values and standard deviations for measurements of tracings in groups A,B, and C with a sample size of 31.

	Group A		Group B		GroupC	
	Mean	sd	Mean	sd	Mean	sd
Angular :						
SNA	81.29	0.31	80.24	0.28	80.5	0.30
SNB	76.30	0.30	76.91	0.26	77.17	0.21
ANB	5.01	0.14	3.41	0.12	3.37	0.11
GoGn-SN	33.73	0.26	33.63	0.23	32.97	0.20
Occ-SN	20.31	0.23	18.76	0.17	17.76	0.19
Pal-SN	7.53	0.18	7.73	0.19	8.06	0.20
Occ-Man	13.32	0.20	14.77	0.25	15.17	0.20
Pal-Man	26.13	0.20	25.85	0.19	24.86	0.25
Pal-Occ	12.75	0.23	11.05	0.18	9.64	0.24
N-S-Gn	67.84	0.33	68.31	0.30	68.04	0.27
Linear :						
N-ANS	54.45	0.12	56.87	0.14	57.17	0.11
ANS-Me	65.23	0.11	69.43	0.11	70.59	0.13
N-ANS(W)	52.95	0.12	55.68	0.12	55.98	0.09
ANS-Me(W)	63.64	0.09	67.88	0.12	68.98	0.09
S-Go	70.76	0.14	76.08	0.14	77.70	0.13

Table 3.2 Mean differences in parameter values between groups A and B (SE=Standard error and CI=confidence interval)

Parameter	Range of change		Mean change	SE (mean)	95%CI
	Max.decrease	Max.increase			
Angular :					
SNA	-4.86	2.90	-1.02	0.32	(-1.68;-0.36)*
SNB	-2.77	4.64	0.63	0.33	(-0.45;1.30)
ANB	-4.89	0.67	-1.60	0.24	(-2.08;-1.11)*
GoGn-SN	-9.22	4.83	-0.85	0.48	(-1.07;0.90)
Occ -SN	-9.50	7.16	-1.51	0.63	(-2.79;-0.23)*
Pal-SN	-2.89	2.76	0.19	0.29	(-0.39;0.77)
Occ-Man	-4.63	9.10	1.42	0.59	(0.23;2.62)*
Pal-Man	-9.88	3.32	-0.26	0.44	(-1.15;0.63)
Pal-Occ	-8.57	5.50	-1.65	0.55	(-2.76;-0.54)*
N-S-Gn	-5.26	5.54	0.44	0.40	(-0.38;1.25)
Linear :					
N-ANS	-1.31	6.56	2.47	0.37	(1.72;3.23)*
ANS-Me	-7.97	10.22	4.21	0.57	(3.04;5.38)*
N-ANS(W)	-1.20	7.09	2.79	0.37	(2.04;3.53)*
ANS-Me(W)	-7.80	10.35	4.26	0.57	(3.11;5.41)*
S-Go	-1.31	13.14	5.30	0.70	(3.87;6.72)*

* = Statistically significant changes ($p<0.05$)

Table 3.3 Mean differences in parameter values between groups A and C (SE=Standard error and CI=confidence interval)

Parameter	Range of change		Mean Change	SE (mean)	95%CI
	Max.decrease	Max.increase			
Angular :					
SNA	-5.93	5.53	-0.69	0.32	(-1.46;0.09)
SNB	-2.44	9.21	0.98	0.39	(0.18;1.78)*
ANB	-5.92	0.56	-1.66	0.24	(-2.15;-1.18)*
GoGn-SN	-8.04	3.84	-0.72	0.48	(-1.7;0.25)
Occ-SN	-11.45	7.52	-2.64	0.64	(-3.9;-1.3)*
Pal-SN	-5.90	4.11	0.45	0.40	(-0.36;1.27)
Occ-Man	-4.11	9.01	1.98	0.51	(0.94;3.02)*
Pal-Man	-5.34	2.69	-1.16	0.39	(-1.9;-0.36)*
Pal-Occ	-10.35	4.01	-3.13	0.47	(-4.1;-2.16)*
N-S-Gn	-7.59	4.14	0.14	0.39	(-0.66;0.93)
Linear :					
N-ANS	-5.77	7.47	2.75	0.48	(1.77;3.73)*
ANS-Me	-0.59	11.74	5.39	0.51	(4.34;6.43)*
N-ANS(W)	-4.72	7.70	3.05	0.44	(2.15;3.95)*
ANS-Me(W)	-0.76	11.13	5.38	0.51	(4.33;6.42)*
S-Go	-0.59	15.50	6.85	0.81	(5.20;8.51)*

*=Statistically significant changes ($p<0.05$)

3.2 Summary of changes over time

The results are summarized using 95% confidence intervals for the changes in Tables 3.1-3.3. Five of the angular measurements in Table 3.2 changed significantly, and all five of the linear measurements showed significant change (statistical significance measured at 5% level). In Table 3.3; six angular measurements showed significant change, as did all five linear measurements.

Angular measurements (Tables 3.1-3.3)

SNA

The mean values for this angle decreased from 81.29^0 for group A to 80.24^0 for group B, but then increased slightly to a mean of 80.50^0 for group C. The difference between the means for group A and group B was statistically significant, and the mean angle decreased by 1.02^0 (95% CI -1.68;-0.36). There was no statistically significant change between the mean data for groups A and C.

SNB

The mean values for this angle increased from 79.30^0 for group A to 76.91^0 for group B, and increased further to a mean of 77.17^0 for group C. The difference between the means for group A and group B was statistically non significant. The difference between the means for groups A and C was statistically significant (95% CI 0.18;1.78).

ANB

The mean values for this angle decreased from 5.01^0 for group A to 3.41^0 for group B, and decreased slightly further to a mean of 3.37^0 for group C. The difference between the means for groups A and B, and between groups A and C were statistically significant.

Mandibular plane angle/GoGn-SN

The mean values for this angle decreased slightly from 33.73^0 for group A to 33.63^0 for group B, and this decreased further to 32.97^0 for group C. There were no statistically significant changes between the means for groups A, B, and C.

Occlusal plane angle/Occ-SN

The mean values for this angle decreased from 20.31^0 for group A to 18.76^0 for group B, and further decreased to 17.76^0 for group C. The differences between the means for groups A and B, and groups A and C were statistically significant.

Palatal plane angle/Pal-SN

The mean values for this angle increased slightly from 7.53^0 for group A to 7.73^0 for group B, and increased further to 8.06^0 for group C. There were no statistically significant changes between the means for groups A and B, and between groups A and C.

Occlusal to mandibular plane angle/Occ-Man

The mean values for this angle increased from 13.32^0 for group A to 14.77^0 for group B, and increased further to 15.17^0 for group C. The differences between the means for groups A and B, and groups A and C were statistically significant.

Palatal to mandibular plane angle/Pal-Man

The mean values for this angle decreased from 26.13^0 for group A to 25.85^0 for group B, and decreased further to 24.86^0 for group C. The differences between the means for groups A and B were not statistically significant. The differences between the means for groups A and C were statistically significant.

Palatal to occlusal plane angle/Pal-Occ

The mean values for this angle decreased from 12.75^0 for group A to 11.05^0 for group B, and decreased further to 9.64^0 for group C. The differences between the means for groups A and B, and between groups A and C were statistically significant.

Nasion-sella-gnathion/N-S-Gn

The mean values for this angle increased slightly from 67.84^0 for group A to 68.31^0 for group B, then decreased slightly to 68.04^0 for group C. There were no statistically significant changes between groups A, B, and C.

Linear measurements (Tables 3.1-3.3)

Nasion to anterior nasal spine/N-ANS

This linear measurement increased from a mean value of 54.45 mm for group A to 56.87 mm for group B, increased further to 57.17 mm for group C. The differences between groups A and B, and groups A and C were statistically significant.

Anterior nasal spine to menton/ANS-Men

This linear measurement increased from a mean value of 65.23 mm for group A to 69.43 mm for group B, increased further to 70.59 mm for group C. The differences between groups A and B, and groups A and C were statistically significant.

Nasion to anterior nasal spine (Wylie)/N-ANS(W)

This linear measurement increased from a mean value of 52.95 mm for group A to 55.68 mm for group B, increased further to 55.98 mm for group C. The differences between groups A and B, and groups A and C were statistically significant.

Anterior nasal spine to menton (Wylie)/N-ANS(W)

This linear measurement increased from a mean value of 63.64 mm for group A to 67.88 mm for group B, increased further to 68.98 mm for group C. The differences between groups A and B, and groups A and C were statistically significant.

Sella to gonion/S-Go

This linear measurement increased from a mean value of 70.76 mm for group A to 76.08 mm for group B, increased further to 77.70 mm for group C. The differences between groups A and B, and groups A and C were statistically significant.

A summary of the statistically significant changes recorded is shown in Table 3.4.

Table 3.4 Summary of statistically significant changes as determined by Student's t-test

	Pre- to post-treatment	Post- to two years post-treatment
Angular		
SNA	Decreased	No change
SNB	No change	Increased
ANB	Decreased	Decreased
Occ-SN	Decreased	Decreased
Occ-Mand	Increased	Increased
Pal-Mand	Decreased	Decreased
Linear		
N-ANS	Increased	Increased
ANS-Me	Increased	Increased
N-ANS (Wylie)	Increased	Increased
ANS-Me (Wylie)	Increased	Increased
S-Go	Increased	Increased

3.3 Results of regression modelling (Appendix B)

After noting the changes that occurred for the different parameters, regression models were fitted to establish whether changes depended on any of the following variables :

a) The initial value of the parameter.
b) Age at the start of treatment.
c) The time elapsed (post treatment and two years post-treatment).
d) Gender.
e) Extractions.
f) Skeletal pattern.

Multiple regression analyses (general linear models) were performed to identify those factors which are the greatest determinants of change in each outcome parameter. These results may be found in Appendix 2.

The results are summarised below, and only the factors which were shown to have a statistically significant effect on the changes between groups A and B, and groups A and C will be described.

3.3.1 Angular measurements (Appendix 2)

SNA

The regression analysis showed that extraction of teeth was a significant determinant of the post-treatment reduction in angle SNA. Patients without extractions showed less of a decrease in SNA post-treatment than those patients who had extractions. The original skeletal pattern of the patients also influenced the extent of the decrease in the SNA angle. A skeletal Class II pattern was associated with a greater decrease in the SNA angle.

SNB

Angle SNB did not change significantly between groups A and B. Angle SNB increased between groups A and C. The regression analysis found that for this particular measurement none of the candidate explanatory variables were significant i.e. none exerted dominant influence.

ANB

Angle ANB showed significant changes between groups A and B, and between groups A and C. The most important determinant of the amount of change in angle ANB during treatment is identified as the original skeletal pattern. Subjects with a Class II skeletal pattern showed a greater decrease in angle ANB than did Class I patients. There is a significant decrease in angle ANB during the retention period. The size of the initial measurement of angle ANB is a significant determinant of the change between groups A and C; the larger the initial value of ANB, the larger will be the decrease in this angle. Also between groups A and C, females showed less of a decrease in angle ANB than males.

Mandibular plane angle/GoGn-SN

From group A to group B, the mandibular plane angle (GoGn-SN) showed no statistically significant change. The regression analysis however, showed that the greater the value of the initial GoGn-SN, the greater will be the decrease in the mandibular plane angle. The initial value of GoGn-SN is the most important determinant of variation in change ($P<0.05$).

There are three other factors of marginal significance :

i) Non extraction cases showed a greater decrease in the mandibular plane angle, as compared with the extraction cases.

ii) Age at the start of treatment - the older the subject at the start of treatment, the smaller will be the decrease of Go-Gn.

iii) Duration of treatment - the greater the time elapsed, the less will be the decrease.

From group A to group C, the mean mandibular plane angle (GoGn-SN) showed an insignificant decrease. The initial GoGn-SN value is the most important determinant of variation in change ($P<0.01$), and the greater the initial GoGn-SN the greater will be the decrease. The time period from the start of treatment to two years post-treatment is insignificant.

Two other factors are of marginal significance :

i) Age at the start of treatment - the older the subject at the start of treatment, the smaller will be the decrease of Go-Gn.

ii) Gender - for the mandibular plane angle females showed less of a decrease than males between groups A and C.

Occlusal plane angle/Occ-SN

The regression analysis showed that the initial value of the occlusal plane angle is the most important determinant of treatment change in this parameter. The higher the initial value of the occlusal plane angle, the greater is the change. Factors such as the time from start of treatment to the post-treatment radiograph, and Class II skeletal pattern are in the model, but are not significant. Extractions are of marginal significance, with non-extraction cases showing a larger decrease in the occlusal plane than extraction cases. The occlusal plane to SN showed a decrease between group A and group C. The initial value was of marginal significance ($P<0.065$). The greater the initial value of occlusal plane to SN, the greater will be the decrease between group

A and group C.

The other factors in the model are insignificant.

Palatal plane angle/Pal-SN

None of the variables in the regression analysis showed any statistically significant effects on this parameter.

Occlusal to mandibular plane angle/Occ-Man

The occlusal plane to the mandibular plane angle showed statistically significant increases between groups A and B, and between groups A and C. For the difference between group A and group B the regression analysis showed that the greater the initial occlusal to mandibular plane measurement, the less will be the increase post-treatment. The initial value of the occlusal to mandibular plane angle is the most important determinant of variation of change ($P<<0.05$) for this parameter.

Treatment duration or the time elapsed was also shown to have a statistically significant effect on the changes between group A and group B ($P<0.05$). The greater the time that has elapsed from the initial occlusal to mandibular plane measurement, the greater will be the increase in this value. For the difference between group A and group C, the regression analysis showed that the greater the initial occlusal to mandibular plane angle, the less will be the increase between group A and group C. The initial measurement of occlusal to mandibular plane is the most important determinant of variation in change ($P<<0.005$). Treatment duration or the time elapsed was also shown to have a statistically significant effect on the changes between groups A and C. The longer the duration between group A and group C, the larger will be the increase in the occlusal to mandibular plane angle.

Palatal to mandibular plane angle/Pal-Man

The size of the initial measurement ($P<<0.05$) was the most important determinant of change in the palatal to mandibular plane angle between groups A and B. The regression analysis revealed that the larger the value of the initial measurement, the more the palatal to mandibular plane will decrease between group A and group B. Treatment duration was also shown to have a statistically significant effect on the changes between group A and group B. The greater the amount of time

elapsed, the less will be the decrease in the palatal to mandibular plane angle.

For the change between group A and group C, gender was shown to be a statistically significant determinant, with females showing less of a decrease in the palatal to mandibular plane angle than males.

Palatal to occlusal plane angle/Pal-Occ

The palatal to occlusal plane showed a statistically significant decrease during treatment. The regression analysis showed that the most important determinants of change in the palatal to occlusal plane between group A and group B were :

i) Size of the initial measurement - the greater the initial value of the palatal to occlusal plane, the larger will be the decrease between group A and group B.

ii) Non-extraction cases - patients with extractions will show less of a decrease in the palatal to occlusal plane angle between group A and group B.

The palatal to occlusal plane showed a decrease two years post-treatment. Regression analysis revealed that gender was the only significant determinant of change when considering the palatal to occlusal plane between groups A and C. Females showed less of a decrease than males.

Nasion-sella-gnathion angle/N-S-Gn

Angle N-S-Gn showed a non significant increase post-treatment. Regression analysis showed that the size of the initial measurement of N-S-Gn was the most important determinant of change between group A and group B. The greater the initial measurement of N-S-Gn, the less will be the increase post-treatment.

None of the variables in the regression analysis showed any statistically significant effects on this parameter between groups A and C.

3.3.2 Linear measurements

Nasion to anterior nasal spine/N-ANS

Nasion to anterior nasal spine showed a significant increase between group A and group B. The regression analysis revealed two variables that affected this parameter :

i) Size of the initial measurement - the smaller the initial nasion to anterior nasal spine

measurement, the greater will be the increase between group A and group B.

ii) Gender - between groups A and B, females show less of an increase than males.

Nasion to anterior nasal spine showed a significant increase between groups A and C. The regression analysis revealed two variables that affected this parameter :

i) Size of the initial measurement - the smaller the initial nasion to anterior nasal spine measurement, the greater will be the increase between group A and group C.

ii) Gender - females show less of an increase than males between groups A and C.

Anterior nasal spine to menton/ANS-Me

Anterior nasal spine to menton showed a significant increase between group A and group B. The regression analysis showed the effect of two variables on this parameter :

i) Duration of treatment - treatment duration or the time elapsed was shown to have a statistically significant effect on the changes between groups A and B. The greater the time elapsed between group A and group B, the greater will be the increase in anterior nasal spine to menton

ii) Gender - Females showed less of an increase than males ($P<0.05$).

Anterior nasal spine to menton showed a statistically significant increase between group A and group C. Two variables affected this parameter :

i) Gender - Females showed less of an increase than males ($P<0.05$).

ii) Age at the start of treatment - The earlier treatment is started i.e. the younger the patient, the less will be the increase in anterior nasal spine to menton between group A and group C.

There are two other factors of marginal significance :

i) Skeletal pattern - Class II skeletal pattern shows less of an increase than Class I skeletal types.

ii) Duration of treatment - The greater the time elapsed between groups A and C, the greater will be the change in anterior nasal spine to menton.

Nasion to anterior nasal spine-Wylie's measurement/N-ANS (W)

Wylie's measurement of nasion to anterior nasal spine showed a significant increase between groups A and B. The regression analysis showed two variables that influenced the parameters :

i) Gender - Females showed less of an increase than males.

ii) Age at the start of treatment was of marginal significance ($0.05<P<0.10$). The younger the patient at the start of treatment the less will be the increase post-treatment.

Wylie's measurement of nasion to anterior nasal spine showed an increase between group A and group C. The regression analysis showed the effect of two variables on this parameter :

i) Gender - females showed less of an increase than males.

ii) Duration of treatment - of marginal significance, was the time elapsed between group A and group C. An increase in the time elapsed from the initial radiograph to two years post-treatment, will lead to a greater increase in the measurement of nasion to anterior nasal spine.

Anterior nasal spine to menton-Wylie's measurement/ANS-Me (W)

Wylie's anterior nasal spine to menton showed an increase between group A and group B. The regression analysis showed two variables that influenced this parameter :

i) Gender - Females showed less of an increase than males.

ii) Duration of treatment - Treatment duration or the time elapsed was shown to have a statistically significant effect on the changes between groups A and B. The greater the time elapsed between group A and group B, the greater will be the anterior nasal spine to menton measurement.

Wylie's anterior nasal spine to menton two year post-treatment measurement, showed a significant increase. There are three factors of significance that are important determinants of variation in change ($P<0.05$) :

i) Gender - Females show less of an increase than males.

ii) Age at the start of treatment - The younger the patient at the start of treatment, the less will be the increase in anterior nasal spine to menton between groups A and C.

iii) Skeletal pattern - Class II skeletal patterns show less of an increase than the Class I and Class III skeletal patterns.

Of marginal significance is the time elapsed between groups A and C. The greater the time elapsed between group A and group C, the greater will be the increase of anterior nasal spine to menton.

Sella-gonion/S-Go

Sella to gonion showed a significant increase between groups A and B. Regression analysis

showed that two variables had an affect on this parameter :

i) Gender - Females showed less of an increase than males.

ii) Size of the initial measurement - The greater the initial measurement of sella-gonion, the less will be the increase in this measurement between group A and group B.

The age of the patient at the start of treatment is of marginal significance and the younger the patient at the start of treatment, the less will be the increase in sella-gonion. Sella to gonion increased between group A and group C. Included in the regression analysis were two important variables :

i) Gender - Females showed less of an increase than males.

ii) Age of patient at the start of treatment - the younger the patient at the start of treatment, the less will be the increase in sella-gonion between groups A and C.

Of marginal significance is the Class II skeletal pattern ($0.05<p<0.1$), showing less of an increase in sella-gonion than the Class I and Class III skeletal patterns.

CHAPTER FOUR

DISCUSSION

4.1 Introduction

Change in the vertical dimension of patients treated with the Begg light wire technique has been a controversial issue for many years. The technique has been blamed for opening of the bite and increasing the vertical dimension of the face, thereby exacerbating any existing problems. The aim of the current study was to evaluate cephalometrically the vertical changes that occurred in a sample of patients treated with the Begg light wire technique, as well as to put forward possible reasons for these changes.

Changes in both linear and angular measurements in a growing patient population will undoubtedly reflect the combined effect of orthodontic treatment and growth. In a retrospective study such as this, it is not possible to control or accurately differentiate the effect of the two variables. Reference to data recorded in recognised growth studies however will help to differentiate the effect of growth from the possible effect of orthodontic treatment on specific parameters.

The Michigan[34] growth study provides a major database for contemporary analysis, and this study was carried out in Ann Arbor, at the Center for Human Growth and Development at the University of Michigan. The Michigan[34] growth study involved a group of children presenting mild and moderate malocclusions. Cephalometric radiographs were taken at regular intervals during growth of children, and the resultant data were grouped to provide a picture of the average, normal growth changes.

The influence of growth is considered only at this stage as the prime intention of this study was to investigate the total treatment experience of patients undergoing Begg therapy during a growth period. It may be instructive however, to now attempt to account for the influence of growth.

These data could then be used to account for the effect of growth changes which will have taken place in the sample of the present study. If the mean growth changes are subtracted from the mean changes recorded in this study, the remainders should reflect the influence of treatment.

Hence data was established from age-matched groups in the Michigan[34] Growth Study so that growth changes between group A and group B and between group A and group C could be accounted for.

The procedure and results are displayed in Tables 4.4 and 4.5.

Table 4.1 Mean Michigan growth values for a sample matched for age, drawn from the Michigan[34] growth study.

Parameter	Mean Group A Equivalent Mean age= 11 years	Mean Group B Equivalent Mean age=15 years	Mean Group C Equivalent Mean age=17 years
Angle			
SNA	81.30	81.00	81.60
SNB	77.50	77.60	78.70
ANB	3.15	3.40	2.90
GoGn-SN	33.75	33.20	31.95
Occ-SN	17.70	16.10	14.75
Pal-SN	7.40	7.70	7.50
Pal-Man	26.55	25.75	24.55
Pal-Occ	10.35	8.50	7.30
N-S-Gn	67.05	67.35	66.55
Linear			
N-ANS	54.30	56.75	57.70
ANS-Me	68.80	71.70	74.40
S-Go	75.65	79.75	83.65

Table 4.2 Differences as a result of growth occurring between group A and group B in the Michigan[34] growth study.

Parameter	Mean Group A Equivalent Mean age=11 years	Mean Group B Equivalent Mean age=15 years	Difference
Angle			
SNA	81.30	81.00	-0.3
SNB	77.50	77.60	0.1
ANB	3.15	3.40	0.25
GoGn-SN	33.75	33.20	-0.55
Occ-SN	77.70	16.10	-1.60
Pal-SN	7.40	7.70	0.30
Pal-Man	26.55	25.75	-0.8
Pal-Occ	10.35	8.50	-1.85
N-S-Gn	67.05	67.35	0.3
Linear			
N-ANS	54.30	56.75	2.45
ANS-Me	68.80	71.70	2.90
S-Go	75.56	79.75	4.10

Table 4.3 Differences as a result of growth occurring between group A and group C in the Michigan[34] growth study.

Parameter	Mean Group A Equivalent Mean age=11 years	Mean Group C Equivalent Mean age=17 years	Difference
Angle			
SNA	81.30	81.60	0.30
SNB	77.50	78.70	1.2
ANB	3.15	2.90	-0.25
GoGn	33.75	31.95	-1.8
Occ-SN	17.70	14.75	-2.95
Pal-SN	7.40	7.50	0.10
Pal-Man	26.55	24.55	-2.0
Pal-Occ	10.35	7.30	-3.05
N-S-Gn	67.05	66.55	-0.5
Linear			
N-ANS	54.30	57.70	3.40
ANS-Me	68.80	74.40	5.60
S-Go	75.65	83.65	8.00

Table 4.4 Differences between the changes in the present study and changes in the Michigan[34] growth study between group A and group B due to treatment.

Parameter	Difference Present study (Growth and treatment)	Difference Michigan[34] Growth Study	=Treatment effect
Angle			
SNA	-1.02	-0.30	-0.72
SNB	0.63	0.10	0.53
ANB	-1.60	0.25	-1.35
GoGn-SN	-0.85	-0.55	-0.30
Occ-SN	-1.51	-1.60	0.09
Pal-SN	0.19	0.30	0.11
Pal-Man	-0.26	-0.80	0.54
Pal-Occ	-1.65	-1.85	0.20
N-S-Gn	0.44	0.30	0.14
Linear			
N-ANS	2.47	2.45	0.02
ANS-Me	4.21	2.90	1.31
S-Go	5.30	4.10	1.2

Table 4.5 Differences between the changes in the present study and changes in the Michigan[34] growth study between group A and group C due to treatment.

Parameter	Difference Present study (Growth and treatment)	Difference Michigan[34] growth study	=Treatment result
Angle			
SNA	-0.69	0.30	-0.39
SNB	0.98	1.20	0.22
ANB	-1.66	-0.25	-1.41
GoGn-SN	-0.72	-1.80	1.08
Occ-SN	-2.64	-2.95	0.31
Pal-SN	0.45	0.10	0.35
Pal-Man	-1.16	-2.00	0.84
Pal-Occ	-3.13	-3.05	-0.08
N-S-Gn	0.14	-0.50	0.34
Linear			
N-ANS	2.75	3.40	0.65
ANS-Me	5.39	5.60	0.21
S-Go	6.85	8.00	1.15

4.2 Angular measurements

On the assumption that normal growth patterns would have been maintained over the time period covered by this study, the angular measurements selected are unlikely to have changed. The changes that may be observed should therefore be related more to the effects of orthodontic treatment rather than growth. There could be exceptions to this assumption and these will be noted as each angular measurement is discussed.

SNA

The SNA angle decreased significantly between groups A and B (Table 3.2;-1.02^0). There were no statistically significant changes however between groups A and C (Table 3.3;-0.69^0). An assessment of normal growth as represented by data from the Michigan[34] growth study (Table 4.1) shows that the SNA angle hardly changes over a comparable period of time. Consequently, the reduction in the SNA angle noted over the treatment period of this study may be considered a result of active orthodontic treatment. This result correlates with the decrease in SNA angle reported by O'Reilly[20], in a study comprising extraction cases only. Gianelly, Arena and Bernstein[29] also reported a decrease in the SNA angle, but their sample was made up of non-extraction cases only, whereas the present study evaluated both extraction and non-extraction cases. The regression analysis (Appendix 2) indicated that extraction of teeth was a significant determinant in the change of angle SNA. This is a logical finding and concurs with the findings of Gianelli, Arena and Bernstein[29] who stated that "....., we believe that up to 50% of the SNA response represents tooth movement"[29]. The presence of a Class II skeletal pattern was also shown to be a significant determinant of SNA angle change. Clearly the greater the Class II jaw relationship, the greater will be the emphasis on reduction of the Class II relationship by means of orthodontic treatment. More than half (54.84%) the cases in the present sample displayed a Class II jaw relationship. Knight[30] attributed the reduction in the SNA angle to the incisor retraction that takes place during stage I and II of the Begg technique. One could take issue with Knight's[30] point of view and point out that during stage I and II, the apices of the central incisors may become labially proclined, while during stage III, root torque moves the root apices palatally, and with remodelling, point A also moves palatally, thus contributing to a reduction in the SNA angle. However the combined retraction effects must all contribute to this favourable change.

SNB

The change between group A and C showed a significant increase in the SNB angle (Table 3.3 ;0.98^0).This finding is in agreement with the findings of Gianelly, Arena and Bernstein[29]. The regression analysis found that for this particular measurement none of the candidate explanatory variables were significant i.e. none exerted dominant influence.

Information from the Michigan[34] Growth Study indicates that the SNB angle increased 1.2^0 as a result of growth over a comparable period of time. Therefore, it would appear that orthodontic treatment had no inhibiting or stimulating effect on mandibular growth of the patients in the present study.

ANB

In the current study, angle ANB decreased significantly between groups A and B (Table 3.2;-1.6^0) and groups A and C (Table 3.3;-1.66^0). Normal growth appeared to produce a very slight reduction in the ANB angle (Table 4.2;-0.25^0). Consequently the reduction in ANB experienced by patients in the present study must be as a result of orthodontic treatment acting essentially on the SNA angle. The presence of a Class II skeletal pattern was also shown to be a significant determinant of SNA angle change. Clearly the greater the Class II skeletal relationship, the greater will be the emphasis on reduction of the Class II skeletal relationship by means of orthodontic treatment.

Mandibular plane angle/GoGn-Sn

Several reports have tried to substantiate the claim that the mandibular plane angle opens as a result of Begg orthodontic treatment[20,22,23,25,29,30]. The results of this study showed that there were no significant changes in the mandibular plane angle between groups A and B (Table 3.2;-0.85^0) and groups A and C (Table 3.3;-0.72^0). Data from the Michigan[34] growth study shows that over a period of ten years the GoGn angle also reduced slightly. The patients in the present study followed the same trend in spite of receiving orthodontic treatment using the Begg technique. The findings are in contrast to the work of Weber[22], who, citing a thesis by Phillips (1965), showed that the mandibular plane to Frankfort horizontal increased post-treatment and then decreased steadily two years post-treatment. Barton[23] also showed a significant increase in the mandibular plane during treatment, but his research did not cover an extended post-treatment stage. Venezia[24]

showed a slight decrease in the mandibular plane post-treatment.

While different studies show contrasting effects of the Begg technique on the mandibular plane angle, there is general agreement that any increase in this angle is probably due to molar extrusion. Bijlstra[19], and Swain and Ackerman[21] indicated that molar extrusion may result in an increase of the mandibular plane angle. Molar extrusion is dependent on archwire design, archwire forces and elastic forces; all variables determined by the clinician. It is reasonable to assume that with different clinicians ranging in experience from early post-graduate students to highly experienced individuals there will be variation in the appreciation and execution of the subtleties affecting molar extrusion. This may well be a major reason for the variations in the reported results of the repeated studies on the effect of the technique on the mandibular plane angle.

The regression analysis (Appendix 2) between group A and group B indicated that the mandibular plane angle was less likely to change if the patients in group A were older, treatment period extended, and had recorded a small initial value. This is in accordance with the views generally accepted in Orthodontic theory, that low mandibular plane angles and short lower anterior facial height maintain the same trend with growth. The regression analysis (Appendix 2) also indicated that extraction of teeth would result in the mandibular plane angle showing less of a decrease.

Occlusal plane angle/Occ-SN

Obvious reduction of the occlusal plane occurred throughout treatment, and the decrease was significant between groups A and B (Table 3.2;-1.5^0) and groups A and C (Table 3.3;-2.64^0). This is in contradiction to Bijlstra[19], Weber[22], Barton[23], and O'Reilly[20], who all showed an increase in the occlusal plane through treatment, followed by a gradual decrease two years post-treatment[19,20]. The decrease in the occlusal plane angle that occurred in the Michigan[34] growth study almost exactly matched the changes that occurred in the present sample of patients. This once again shows that the Begg treatment per se had no effect on molar extrusion. As in the present study, Venezia[24] showed a significant decrease in the occlusal plane to SN in the post-treatment stage. The regression analysis (Appendix 2) indicated that extraction of teeth, and the size of the initial measurement, were significant determinants in the occlusal plane to SN angle change. A small initial measurement will result in a greater decrease of the occlusal plane to SN. The occlusal plane angle will decrease less in extraction than non-extraction cases. This may be due to the fact that in non extraction cases, there is usually reduced need for the use of class II elastics and

therefore minimal extrusive effect on the molars. Bijlstra's[19] study showed that there was an increase in the occlusal plane. However, he did not state whether the sample was extraction or non-extraction. In Barton's[23] study, all the patients were treated with extractions and the results showed an increase in the occlusal plane to SN. Barton[23] stated "I can't help but feel that we must become more aware of the freeway space and its relationship to vertical development and the theories of extrusion and intrusion of teeth". In O'Reilly's[20] study, all the patients were treated with extractions, and the increase of the occlusal plane angle was attributed to molar extrusion due to intermaxillary elastics and anchor bends in the archwire.

Palatal plane angle/Pal-SN

The change between groups A and B (Table 3.2;0.19^0), and groups A and C (Table 3.3;0.45^0) showed a non-significant change in the palatal plane angle. Evaluation of the data from the Michigan[34] growth study (Table 4.1-4.3) also showed this angle to be stable. The effect of treatment is minimal as shown by the data in tables 4.4 and 4.5. The regression analysis for the changes between group A and group C for the palatal plane angle revealed that none of the candidate explanatory variables were significant contributors to change in the palatal plane angle. This finding is in agreement with Harber (1970-cited by Weber[22]), whose study showed that the palatal plane angle to the anterior cranial base did not change significantly with treatment.

Occlusal to mandibular plane angle/Occ-Man

There was a statistically significant increase in this angle between groups A and B (Table 3.2;1.42^0), and groups A and C (Table 3.3;1.98^0). For this angle to increase there needs to be some lower molar intrusion, lower incisor extrusion, upper incisor intrusion or development of the mandibular symphysis and anterior dentoalveolar structures in the vertical plane. Evaluation of other related parameters suggests that there has been no molar extrusion. In fact the mandibular plane to SN angle showed a tendency to decrease although this did not reach statistically significant levels. It could be speculated that the change in the occlusal-mandibular plane angle may be due to a combination of some lower molar intrusion, maxillary incisor intrusion and symphysial growth. There are no comparable data from the Michigan[34] growth study. A decrease in the occlusal plane to sella-nasion and a relatively constant mandibular plane will result in an increase of the occlusal plane relative to the mandibular plane. Bijlstra[19] however showed a

decrease in the occlusal to mandibular plane angle, and explained this as a natural tendency of the mandibular plane to flatten as growth proceeded. Bijlstra[19] revealed molar extrusion, thus leading to an increase in the mandibular plane angle. For the occlusal plane to SN angle to remain the same or to reduce, it is a prerequisite that there should be no lower molar extrusion and that direction of growth should remain unaltered throughout treatment. Furthermore, it should be borne in mind that cases involving extraction of second bicuspids will require uprighting of first bicuspids during Begg stage III treatment. The reciprocal effect of uprighting springs on distally tipped first bicuspids is a depressing force exerted by the hook arm of the uprighting springs on the arch wire and therefore on the molar teeth. The intrusive force on the molars can in certain cases actually create a posterior open bite.

The regression analysis indicated a statistically significant ($P<0.005$) interaction between time elapsed, as well as the initial measurements. The longer the treatment duration, the larger will be the increase in the occlusal to mandibular plane angle. The larger the initial value, the smaller will be the change in the value at the end of treatment. This interaction may be as a result of changes associated with the growing child.

Palatal to mandibular plane angle/Pal-Man

There was no significant change between group A and group B. However, the palatal to mandibular plane angle difference between group A and group C (Table 3.3; -1.16^0) decreased significantly. The Michigan[34] growth studies (Tables 4.1-4.3) also show a slight decrease in the palatal to mandibular plane angle with growth. When the influence of growth is discounted, the effect of orthodontic treatment on this parameter is negligible (Table 4.4-4.5). The analysis of variance (Appendix 2) shows that gender is a significant determinant of change, with females showing less of a decrease than males. O'Reilly's study[20] which included a sample of female subjects only, revealed that the palatal to mandibular plane decreased significantly throughout treatment; however when compared with the untreated control group the decrease was insignificant. Therefore, from this evidence it would appear that the Begg appliance used on the patients in the current study had no effect on the palatal to mandibular plane angle.

Palatal to occlusal plane angle/Pal-Occ

There was a significant decrease in the palatal to occlusal plane angle between groups A and B (Table 3.2;-1.65^0), and groups A and C (Table 3.3; -3.13^0). This correlates with O'Reilly's [20] finding, where the palatal to occlusal plane angle decreased in the retention period. This pattern follows almost exactly the changes represented in the Michigan[34] growth study (Table 4.4;-1.85^0 and Table 4.5;-3.05^0). Once again the evidence supports the contention that the orthodontic treatment per se had no significant effect on the structures related to the palatal to occlusal plane angle.

Nasion-sella-gnathion/N-S-Gn

The change between groups A and B (Table 3.2;0.44^0), and groups A and C (Table 3.3;0.14^0), showed non significant increases in the N-S-Gn angle. Evaluation of changes in the Y axis revealed in the Michigan[34] growth study showed that with normal growth there is little change in the direction of growth over a 10 year period. The results of the present study indicate that treatment with the Begg technique had no effect on the direction of growth of the patients included in the present study. The results of the regression analysis indicate that the smaller the initial measurement of N-S-Gn at the beginning of treatment, the less will be the increase in this angle post-treatment. The work of O'Reilly[20] showed that the N-S-Gn angle in the control group (24 untreated, white-female patients, between the ages of 11 and 15 years) decreased significantly from the start of treatment until the end of retention, and the experimental group (24 white-female patients, between the ages of 11 and 15 years, treated with the Begg technique) showed an increase from the beginning of treatment until the end of treatment, although this increase was not statistically significant. Gianelly, Arena and Bernstein[29] reported slight increases in mandibular prognathism measured as N-S-Gn, but the report did not state whether this increase was statistically significant.

4.3 Linear measurements

Unlike the angular measurements, the linear values will be affected by both growth and orthodontic treatment.

In a study by Gianelly, Arena and Bernstein[29] the linear measurements all showed statistically significant increases.

Nasion to anterior nasal spine/N-ANS

In the current study the N-ANS measurement increased significantly between groups A and B (Table 3.2; 2.47mm), and groups A and C (Table 3.3; 2.75mm). Changes in this parameter (upper anterior facial height) should reflect growth rather than orthodontic treatment. This is borne out by comparing the changes recorded for the matched samples from the Michigan[34] growth study and the samples evaluated in the present study (Tables 4.4 and 4.5). The differences are so mild that it is reasonable to assume that orthodontic treatment had no effect on upper anterior facial height of the sample studied.The regression analysis indicated that changes in this parameter are influenced by the size of the initial measurement as well as gender. A small initial measurement will result in an increased N-ANS measurement, perhaps indicating a catching up growth spurt. Males show a greater tendency to an increase in N-ANS measurement, an expected finding which is related not only to the greater facial dimensions of male subjects but may also be related to the slowing down on the growth curve of the female subjects. In O'Reilly's[20] study, there was a significant increase in upper facial height for the experimental group. However, there was no statistical significance between the increased upper facial height in both the experimental and control (untreated) samples. This also corroborates with the findings of the present study.

Anterior nasal spine to menton/ANS-Me

Lower facial height, expressed as anterior nasal spine to menton, showed significant increases between groups A and B (Table 3.2;4.21mm), and groups A and C (Table 3.3;5.39mm). The lower anterior facial height is probably the dimension most susceptible to treatment-induced change. Comparison of the changes that occur as a result of normal growth (Table 4.1) between groups A and B with the change that was recorded in the present study (Table 4.4) shows that treatment may have contributed on average 1.3mm to an increase in anterior lower facial height. With the passage of time this effect was negated and two years post retention there was in fact no clinically significant difference between the sample of the present study and the reference group from the Michigan[34] growth study (Table 4.5). The regression analysis (Appendix 2) indicated that an increased time period between groups A and B, and groups A and C will contribute to an increase in lower facial height, a not unexpected finding. This is due to the continued growth over an extended period of time. The regression analysis also indicated that gender played a role, with

males showing a larger increase in lower facial height. Ball and Hunt[31] showed that there was an increase in lower facial height with the use of the Begg appliance. This increase was not statistically significant when compared with the control (untreated) group. O'Reilly[20] reported an increase in the distance anterior nasal spine to menton throughout treatment. This increase was also not significant when compared with that of the control group. In a study by Arat and Iseri[32], there was an increase in total anterior facial height throughout treatment. In the study, the sample size of Begg cases was small (11), and therefore one should view the results with caution.

Nasion to anterior nasal spine(Wylie)/N-ANS(W)

Wylie and Johnson's[13] measurements for this dimension showed a significant increase between groups A and B (Table 3.2; 2.79mm), and groups A and C (Table 3.3; 3.05mm). As discussed previously the changes in upper facial height are due to growth rather than orthodontic treatment. The regression analysis indicated that gender was a significant determinant in the N-ANS. Males would be expected to show a greater increase in this dimension than females.

Anterior nasal spine to menton (Wylie)/ANS-Me (W)

As with the earlier discussion on the lower anterior facial height, Wylie and Johnson's[13] measurement of anterior nasal spine to menton also showed significant increases between groups A and B (Table 3.2; 4.26mm), and between groups A and C (Table 3.3; 5.38mm). Once again, gender played an important determinant role for change between groups A and B and groups A and C, with females showing less of an increase than males. The regression analysis (Appendix 2) also showed age of the patient to be a determinant, the younger the patient at the start of treatment, the less will be the increase in anterior nasal spine to menton between group A and group C. This may reflect the failure of the younger patients to have reached the pubertal growth spurt. The presence of a Class II skeletal pattern was also shown to be a significant determinant of ANS-Men measurement change. The greater the Class II jaw relationship, the smaller the increase in lower facial height. A study by Barton[23], which compared the treated Begg sample with a group treated with Kloehn headgear therapy, concluded that anterior facial height increases more with headgear therapy than with the Begg light wire technique. Menesez[25] found a significant increase in upper and lower facial height in patients treated with the Begg technique, and the increase in lower facial height was attributed to the significant increase in the height of

the lower molars. Contrary to Menesez's[25] study, where it was found that Class II division 1 cases were associated with a larger increase in lower facial height, this study reported that patients with a Class II skeletal pattern showed less of an increase in lower facial height than patients with a Class I skeletal pattern. Both these findings were observed during the retention period.

Sella to gonion/S-Go

Posterior facial height increased significantly between groups A and B (Table 3.2; 5.3mm), and groups A and C (Table 3.3; 6.85mm). This dimension can be influenced by both growth and appliance therapy. It is of interest to note that normal growth over a comparable period of time is greater (Table 4.3; 8.00mm) than the mean change recorded in the present study (Table 3.3; 6.85mm). Once again this suggests that the Begg technique as used on patients in the present study produced no molar extrusion and in fact may have resulted in some molar intrusion. The regression analysis (Appendix 2) indicated that gender was a significant determinant of S-Go change. As expected, females showed less of an increase in sella to gonion than males between groups A and B and also between groups A and C. The greater the initial measurement of sella-gonion, the less will be the increase post-treatment. The age of the patient was also of significance, and perhaps unexpectedly, the younger the patient at the start of treatment, the less was the increase in sella to gonion. This once again may be related to younger patients not reaching the pubertal growth spurt within the time limits of the study.

4.4 Summary

This cephalometric study of 31 cases drawn from the records of a private orthodontic practice demonstrated that treatment with the Begg light wire technique had no deleterious effect on the vertical dimension in this sample.

The angular and linear parameters selected for evaluation of the vertical dimension were measured at the start, at the finish and two years after completion of the treatment. Changes over the treatment and post treatment periods included changes resulting from orthodontic treatment as well as changes resulting from growth extending over about five years. Using data from the Michigan[34] growth study it was possible to exclude the effects of growth from the analysis of

measured changes and to evaluate the effects of treatment on its own. In the final analysis, none of the parameters selected showed any significant evidence of an increase in the vertical dimension of the face that could have been attributed to orthodontic treatment.

4.5 Conclusion

The results of this study have shown that for the selected sample, the vertical dimension was not adversely affected by orthodontic treatment using the Begg light wire technique.

The null hypothesis (Page 11; 1.5) is therefore retained.

Appendix 1 Mean and standard deviation (sd) for each individual patient in groups A, B, and C

Group A = Pre-treatment

Group B = Immediately post-treatment

Group C = Two years post-treatment

Angle SNA

	Group A		Group B		Group C	
	Mean	sd	Mean	sd	Mean	sd
	73.13	0.13	73.95	0.06	73.45	0.42
	79.68	0.10	78.8	0.15	78.85	0.04
	76.11	0.12	74.73	0.37	74.39	0.02
	85.26	0.25	87.4	0.78	85.61	0.09
	77.66	0.15	78.58	0.20	77.89	0.06
	77.94	0.05	77.2	0.41	80.08	0.57
	80.64	0.35	75.78	0.59	74.71	0.33
	85.44	0.42	81.40	0.08	81.91	0.16
	85.77	0.23	84.62	0.30	85.39	0.64
	84.01	0.27	82.54	0.20	83.39	0.11
	80.78	0.13	77.53	0.12	80.63	0.21
	77.10	0.23	76.09	0.12	76.15	0.11
	77.09	0.45	77.07	0.07	77.24	0.10
	82.77	0.25	81.01	0.20	80.84	0.32
	83.11	0.28	86.00	0.25	85.38	0.12
	82.29	0.08	79.39	0.14	79.74	0.14
	82.59	0.17	82.31	0.16	81.58	0.23
	79.52	0.15	77.71	0.10	80.45	0.11
	83.53	0.31	83.08	0.14	83.62	0.27
	77.38	0.23	78.14	0.11	76.63	0.23
	88.33	0.54	89.72	0.11	89.32	0.52
	83.29	0.57	79.06	0.14	80.21	0.21
	83.76	0.54	81.78	0.53	81.97	0.61
	83.31	0.22	83.59	0.39	83.00	0.19
	83.31	0.56	80.61	0.47	81.40	0.96
	79.24	0.20	77.77	0.26	76.64	0.22
	82.00	0.66	81.69	0.68	80.39	0.30
	82.29	0.22	79.84	0.13	80.37	0.35
	81.78	0.45	82.75	0.31	81.78	0.55
	77.24	0.53	76.41	0.63	82.77	0.49
	83.65	0.66	80.87	0.45	79.77	0.6
Mean	81.29	0.31	80.24	0.28	80.50	0.30
sd	3.39	0.18	3.69	0.20	3.56	0.22
Max	88.33	0.66	89.72	0.78	89.32	0.10
Min	73.13	0.05	73.95	0.06	73.45	0.02
Range	81.29	0.31	80.24	0.28	80.50	0.30
Median	82.29	0.25	79.84	0.20	80.45	0.23

Angle SNB

	Group A		Group B		Group C	
	Mean	sd	Mean	sd	Mean	sd
	69.53	0.04	72.56	0.14	71.55	0.05
	73.64	0.07	74.30	0.14	74.08	0.09
	75.28	0.16	76.45	0.14	76.83	0.14
	78.11	0.02	80.71	0.03	78.83	0.08
	75.03	0.03	77.65	0.07	77.69	0.18
	76.98	0.31	76.87	0.11	79.33	0.08
	74.96	0.07	73.97	0.54	72.52	0.79
	78.42	0.31	76.62	0.34	78.51	0.34
	78.83	0.23	78.97	0.66	80.17	0.13
	78.4	0.76	78.55	0.26	79.17	0.29
	77.5	0.39	76.77	0.44	77.83	0.13
	71.24	0.25	75.87	0.07	71.14	0.27
	72.74	0.13	74.21	0.09	73.92	0.20
	75.79	0.26	75.53	0.30	77.22	0.09
	78.46	0.09	83.10	0.03	82.86	0.01
	76.35	0.14	74.88	0.11	74.77	0.12
	82.09	0.15	81.32	0.09	80.84	0.04
	74.50	0.29	74.31	0.08	74.74	0.05
	80.23	0.26	80.83	0.67	81.42	0.35
	73.58	0.11	73.66	0.24	74.66	0.17
	82.37	0.62	82.74	0.22	82.14	0.16
	74.92	0.42	72.18	0.09	73.46	0.17
	77.85	0.17	77.89	0.30	79.22	0.16
	79.12	0.32	81.52	0.12	81.13	0.32
	78.33	0.19	77.47	0.47	78.11	0.10
	77.07	0.38	76.12	0.25	75.40	0.41
	75.63	0.49	75.01	0.59	74.02	0.32
	76.16	0.71	74.65	0.31	76.26	0.45
	77.83	0.36	78.67	0.52	78.31	0.03
	69.71	0.61	72.40	0.49	78.92	0.30
	77.53	0.91	78.51	0.21	77.36	0.58
Mean	79.3	0.30	76.91	0.26	77.17	0.21
sd	3.08	0.23	3.03	0.19	3.12	0.17
Max	82.37	0.91	83.10	0.67	82.86	0.79
Min	69.53	0.02	72.18	0.03	71.14	0.03
Range	79.3	0.30	76.91	0.26	77.17	0.21
Median	76.35	0.26	76.62	0.22	77.69	0.16

Angle ANB

	Group A		Group B		Group C	
	Mean	sd	Mean	sd	Mean	sd
	3.34	0.05	1.51	0.09	1.61	0.07
	6.10	0.05	4.71	0.11	4.89	0.08
	0.79	0.11	-1.61	0.09	-2.67	0.18
	7.34	0.11	7.32	0.07	6.57	0.04
	2.79	0.09	1.04	0.15	0.44	0.07
	0.56	0.10	0.52	0.07	1.17	0.05
	5.65	0.05	1.70	0.15	2.36	0.07
	7.42	0.17	4.98	0.01	3.57	0.05
	7.31	0.40	5.07	0.15	5.71	0.26
	5.45	0.19	4.02	0.06	4.06	0.13
	3.99	0.03	0.58	0.11	2.57	0.18
	5.28	0.34	0.39	0.23	4.64	0.08
	4.75	0.11	2.94	0.10	3.27	0.07
	7.08	0.15	5.56	0.12	4.09	0.21
	4.82	0.01	2.81	0.06	3.04	0.11
	5.73	0.03	4.64	0.14	5.11	0.11
	0.54	0.03	1.21	0.05	0.64	0.07
	5.31	0.19	3.60	0.04	5.43	0.04
	3.28	0.10	1.90	0.12	2.05	0.07
	3.99	0.10	4.42	0.08	2.64	0.10
	6.68	0.17	6.60	0.20	6.81	0.31
	8.44	0.11	6.85	0.11	6.80	0.07
	5.83	0.02	4.11	0.16	3.30	0.07
	3.83	0.12	2.78	0.10	2.04	0.06
	4.95	0.30	2.88	0.18	2.88	0.04
	1.90	0.12	1.25	0.12	1.22	0.08
	6.56	0.12	6.44	0.13	6.33	0.14
	6.45	0.11	6.00	0.27	4.61	0.10
	4.26	0.33	3.90	0.05	3.24	0.12
	7.07	0.17	4.37	0.08	3.92	0.22
	7.99	0.26	3.25	0.47	2.07	0.17
Mean	5.01	0.14	3.41	0.12	3.37	0.11
sd	2.15	0.10	2.20	0.09	2.12	0.07
Max	8.44	0.40	7.32	0.47	6.81	0.31
Min	0.54	0.01	-1.61	0.01	-2.67	0.04
Range	5.01	0.14	3.41	0.12	3.37	0.11
Median	5.31	0.11	3.60	0.11	3.27	0.08

Angle GoGn-SN

	Group A		Group B		Group C	
	Mean	sd	Mean	sd	Mean	sd
	33.39	0.38	32.16	0.70	34.1	0.18
	38.02	0.02	36.00	0.83	38.24	0.68
	35.82	0.19	36.15	0.16	34.11	0.22
	35.74	0.19	37.54	0.15	37.36	0.08
	37.86	0.11	32.56	0.19	31.37	0.20
	33.9	0.22	34.06	0.12	30.3	0.03
	32.67	0.22	35.29	0.20	36.51	0.18
	32.74	0.14	33.97	0.19	32.33	0.17
	31.40	0.21	31.80	0.19	31.79	0.17
	28.51	0.07	31.71	0.43	30.92	0.10
	31.33	0.64	30.28	0.21	29.07	0.05
	42.25	0.67	33.03	0.10	39.00	0.13
	33.77	0.14	32.12	0.31	31.71	0.27
	36.85	0.25	37.76	0.05	35.95	0.14
	29.00	0.31	27.00	0.10	24.67	0.19
	34.25	0.14	37.11	0.06	37.80	0.10
	27.66	0.13	27.23	0.12	28.64	0.13
	35.24	0.39	31.89	0.12	32.31	0.11
	29.03	0.13	29.57	0.20	25.24	0.12
	40.08	0.13	41.25	0.24	40.55	0.04
	28.43	0.18	27.46	0.11	29.24	0.11
	29.30	0.22	34.14	0.04	32.04	0.19
	25.36	0.35	28.90	0.09	26.54	0.85
	30.89	0.71	30.34	0.56	32.37	0.25
	35.05	0.48	37.47	0.11	33.45	0.22
	38.19	0.15	39.33	0.16	39.47	0.25
	37.86	0.19	38.33	0.32	37.93	0.20
	32.41	0.25	34.48	0.42	30.87	0.15
	27.26	0.38	25.89	0.16	26.74	0.20
	39.73	0.07	39.22	0.16	31.68	0.42
	41.53	0.25	38.41	0.41	39.86	0.26
Mean	33.73	0.26	33.63	0.23	32.97	0.21
sd	4.46	0.17	4.09	0.19	4.41	0.17
Max	42.25	0.71	41.25	0.83	40.55	0.85
Min	25.36	0.02	25.89	0.04	24.67	0.03
Range	33.73	0.26	33.62	0.23	32.97	0.21
Median	33.77	0.21	33.97	0.16	32.31	0.18

Angle Occ-SN

	Group A		Group B		Group C	
	Mean	sd	Mean	sd	Mean	sd
	26.40	1.03	16.90	0.23	19.52	0.16
	21.68	1.38	19.72	0.66	21.90	0.13
	25.32	0.15	21.28	0.07	16.67	0.23
	18.72	0.17	16.96	0.16	19.55	0.10
	21.20	0.08	16.43	0.10	15.33	0.18
	20.48	0.12	14.75	0.15	15.95	0.13
	16.63	0.06	23.79	0.17	24.14	0.22
	22.19	0.08	22.21	0.11	21.42	0.11
	18.88	0.10	18.16	0.24	14.59	0.05
	21.29	0.27	18.05	0.09	16.60	0.08
	18.97	0.45	14.35	0.07	16.29	0.11
	25.55	0.19	20.59	0.23	25.12	0.12
	23.97	0.06	22.98	0.15	22.98	0.42
	24.28	0.18	21.64	0.34	20.37	0.22
	17.73	0.16	13.01	0.11	12.35	0.16
	18.79	0.07	21.42	0.05	19.91	0.19
	13.86	0.17	15.69	0.06	13.56	0.31
	20.04	0.10	20.07	0.17	18.71	0.09
	16.13	0.22	11.34	0.19	9.42	0.29
	21.75	0.15	23.64	0.19	20.75	0.16
	18.65	0.30	13.6	0.20	16.92	0.19
	19.34	0.21	21.15	0.17	18.81	0.09
	14.25	0.33	18.09	0.19	13.52	0.25
	15.75	0.11	18.73	0.07	19.17	0.09
	22.70	0.09	23.34	0.18	19.33	0.14
	20.00	0.11	19.53	0.25	19.01	0.31
	27.03	0.15	20.76	0.21	22.63	0.35
	15.90	0.38	18.62	0.12	14.24	0.10
	16.62	0.13	15.06	0.08	12.08	0.22
	25.82	0.13	24.03	0.12	14.38	0.37
	19.59	0.16	15.76	0.24	15.47	0.34
Mean	20.31	0.23	18.76	0.17	17.76	0.19
sd	3.62	0.28	3.47	0.11	3.79	0.10
Max	27.03	1.38	24.03	0.66	25.12	0.42
Min	13.86	0.06	11.34	0.05	9.42	0.05
Range	20.31	0.23	18.76	0.17	17.76	0.19
Median	20.00	0.15	18.73	0.17	18.7	0.16

Angle Pal-SN

	Group A		Group B		Group C	
	Mean	sd	Mean	sd	Mean	sd
	12.82	0.15	10.18	0.78	11.56	0.11
	12.7	0.07	10.51	0.07	12.91	0.10
	10.62	0.34	9.88	0.06	12.28	0.09
	7.94	0.97	10.70	0.11	10.76	0.02
	9.17	0.16	6.28	0.54	6.43	0.18
	11.37	0.30	9.54	0.11	9.29	0.24
	7.71	0.12	9.89	0.06	11.01	0.05
	8.10	0.04	10.19	0.23	7.39	0.26
	7.33	0.18	4.45	0.13	6.67	0.12
	5.43	0.15	5.79	0.20	5.44	0.14
	0.29	0.09	0.74	0.13	2.06	0.15
	9.24	0.09	9.38	0.06	8.32	0.39
	10.05	0.13	11.45	0.18	14.16	0.18
	6.41	0.11	7.16	0.13	10.12	0.27
	7.34	0.26	6.78	0.18	6.62	0.34
	5.27	0.05	6.21	0.11	6.88	0.17
	2.82	0.16	4.31	0.10	4.40	0.32
	4.13	0.09	3.32	0.01	3.23	0.26
	5.26	0.18	5.71	0.16	3.43	0.22
	11.56	0.06	11.56	0.25	11.80	0.19
	3.46	0.16	2.59	0.16	3.99	0.32
	6.15	0.06	8.14	0.12	8.53	0.2
	5.12	0.19	7.38	0.13	7.24	0.76
	5.27	0.35	7.24	0.30	8.9	0.31
	9.19	0.04	10.45	0.26	10.98	0.06
	6.23	0.21	7.89	0.08	8.56	0.24
	10.16	0.16	11.89	0.19	8.96	0.12
	8.68	0.04	9.05	0.22	10.85	0.06
	2.82	0.17	1.42	0.10	4.50	0.14
	12.73	0.18	12.97	0.26	6.83	0.08
	8.08	0.40	6.66	0.35	5.90	0.13
Mean	7.53	0.18	7.73	0.19	8.06	0.20
sd	3.17	0.17	3.16	0.15	3.11	0.14
Max	12.82	0.97	12.97	0.78	14.16	0.76
Min	0.29	0.04	0.74	0.01	2.06	0.02
Range	7.53	0.18	7.73	0.19	8.06	0.2
Median	7.71	0.15	7.89	0.13	8.32	0.18

Angle Occ-Man

	Group A		Group B		Group C	
	Mean	sd	Mean	sd	Mean	sd
	5.53	0.27	14.62	0.66	14.54	0.22
	15.63	0.09	16.42	0.32	16.62	0.13
	10.12	0.06	14.85	0.39	17.59	0.07
	17.23	0.14	20.47	0.15	18.22	0.30
	16.58	0.05	16.21	0.06	15.75	0.18
	13.14	0.49	18.37	0.19	14.48	0.06
	16.14	0.30	11.50	0.44	12.03	0.22
	10.42	0.14	11.70	0.25	10.84	0.18
	12.75	0.31	13.96	0.04	16.61	0.20
	7.25	0.15	13.50	0.25	14.00	0.15
	11.77	0.13	15.98	0.13	12.82	0.12
	16.59	0.45	12.08	0.26	13.86	0.07
	9.48	0.31	8.86	0.10	8.99	0.28
	12.14	0.18	15.96	0.05	15.87	0.12
	11.26	0.17	13.63	0.60	12.35	0.27
	15.51	0.13	15.74	0.17	18.11	0.14
	13.68	0.12	11.46	0.20	15.18	0.12
	15.25	0.30	11.72	0.08	13.51	0.20
	12.81	0.11	18.17	0.40	15.65	0.19
	18.22	0.14	17.43	0.37	19.56	0.13
	10.28	0.43	13.60	0.17	11.66	0.02
	9.93	0.07	12.94	0.17	13.34	0.14
	11.22	0.20	10.65	0.36	12.48	0.22
	15.66	0.14	11.64	0.25	13.48	0.46
	11.98	0.17	14.44	0.13	14.11	0.16
	18.59	0.31	19.58	0.37	20.27	0.23
	10.64	0.17	17.5	0.20	15.64	0.31
	16.22	0.13	15.94	0.06	16.7	0.49
	10.76	0.12	10.95	0.23	14.47	0.33
	14.10	0.40	15.02	0.14	16.92	0.44
	22.14	0.15	22.99	0.49	24.57	0.05
Mean	13.32	0.20	14.77	0.25	15.17	0.20
sd	3.57	0.12	3.19	0.16	3.07	0.12
Max	22.14	0.49	22.99	0.66	24.57	0.49
Min	5.53	0.05	8.86	0.04	8.99	0.02
Range	13.32	0.20	14.77	0.25	15.17	0.20
Median	12.81	0.15	14.62	0.20	14.54	0.18

Angle Pal-Man

	Group A		Group B		Group C	
	Mean	sd	Mean	sd	Mean	sd
	20.30	0.10	21.46	0.21	21.90	1.33
	24.45	0.81	25.68	0.12	25.13	0.29
	24.74	0.07	26.41	0.15	21.93	0.72
	27.38	0.02	26.71	0.19	26.63	0.21
	28.58	0.19	26.07	0.16	24.27	0.40
	22.88	0.25	24.46	0.20	21.37	0.20
	25.27	0.24	25.46	0.24	25.45	0.25
	24.40	0.11	23.65	0.04	24.63	0.10
	24.06	0.03	27.37	0.19	25.04	0.12
	22.93	0.23	25.93	0.11	25.62	0.11
	30.80	0.28	29.39	0.13	27.04	0.1
	33.36	0.07	23.48	0.22	30.83	0.23
	23.45	0.08	20.44	0.39	18.11	0.40
	30.65	0.16	30.39	0.01	26.36	0.08
	21.26	0.23	20.47	0.17	17.77	0.11
	29.22	0.10	31.01	0.19	31.24	0.11
	24.86	0.09	22.79	0.32	24.15	0.11
	31.35	0.16	28.66	0.23	29.02	0.32
	23.37	0.19	24.07	0.12	21.82	0.04
	27.8	0.07	29.94	0.23	28.98	0.37
	25.50	0.19	24.77	0.21	24.88	0.16
	22.98	0.15	25.83	0.34	23.43	0.06
	20.37	0.50	21.38	0.27	18.37	0.34
	25.91	0.24	23.13	0.13	23.04	0.05
	25.68	0.33	27.38	0.11	22.5	0.20
	32.27	0.25	31.13	0.27	31.02	0.08
	27.26	0.25	26.20	0.10	29.19	0.20
	23.94	0.13	24.97	0.27	19.93	0.27
	24.55	0.32	24.35	0.26	22.56	0.20
	26.98	0.29	25.99	0.19	24.67	0.06
	33.5	0.09	32.37	0.30	33.84	0.44
Mean	26.13	0.20	25.85	0.19	24.86	0.25
sd	3.63	0.15	3.14	0.08	3.99	0.25
Max	33.5	0.81	32.37	0.34	33.84	1.33
Min	20.3	0.02	20.44	0.04	17.77	0.04
Range	26.13	0.20	25.85	0.19	24.86	0.25
Median	25.27	0.19	25.83	0.19	24.67	0.20

Angle Pal-Occ

	Group A		Group B		Group C	
	Mean	sd	Mean	sd	Mean	sd
	14.19	0.12	6.32	0.23	8.22	0.26
	9.29	0.39	9.28	0.07	8.87	0.02
	14.53	0.46	11.13	0.13	4.18	0.61
	10.00	0.23	6.45	0.08	8.55	0.1
	11.67	0.10	9.79	0.15	8.98	0.21
	9.73	0.33	5.49	0.14	6.52	0.12
	8.89	0.30	14.39	0.20	12.9	0.21
	14.20	0.10	12.22	0.28	13.56	0.29
	11.37	0.17	13.48	0.11	7.95	0.19
	15.90	0.11	12.16	0.07	11.45	0.26
	18.84	0.04	13.53	0.06	14.32	0.24
	16.06	0.38	11.49	0.18	16.55	0.29
	13.83	0.26	11.67	0.34	9.15	0.27
	18.15	0.11	14.66	0.05	10.32	0.18
	10.01	0.22	6.37	0.16	5.52	0.11
	13.76	0.51	15.25	0.29	13.28	0.20
	11.31	0.09	11.51	0.09	9.27	0.17
	16.02	0.10	17.06	0.22	15.24	0.31
	10.53	0.07	5.68	0.10	6.13	0.21
	9.45	0.21	12.23	0.25	8.83	0.20
	15.24	0.24	11.51	0.14	12.63	0.09
	13.16	0.22	12.91	0.14	10.13	0.08
	9.27	0.55	10.90	0.36	6.21	0.34
	10.30	0.22	11.85	0.18	9.81	0.31
	13.47	0.09	13.03	0.18	8.34	0.09
	13.62	0.19	11.73	0.24	10.79	0.38
	16.94	0.27	8.37	0.49	13.69	0.39
	7.37	0.29	8.60	0.17	3.32	0.24
	13.78	0.54	13.40	0.17	7.28	0.64
	13.02	0.17	10.88	0.22	7.59	0.23
	11.37	0.16	9.15	0.23	9.35	0.26
Mean	12.75	0.23	11.05	0.18	9.64	0.24
sd	2.91	0.14	2.92	0.10	3.22	0.14
Max	18.84	0.55	17.06	0.49	16.55	0.64
Min	7.37	0.04	5.49	0.05	3.32	0.02
Range	12.75	0.23	11.05	0.18	9.64	0.24
Median	13.16	0.22	11.51	0.17	9.15	0.23

Angle N-S-Gn

	Group A		Group B		Group C	
	Mean	sd	Mean	sd	Mean	sd
	72.69	0.14	70.75	0.02	71.11	0.15
	71.95	0.47	73.06	0.07	73.57	0.17
	66.6	0.18	68.11	0.10	66.99	0.25
	68.22	0.47	67.11	0.04	68.58	0.12
	70.14	0.22	67.41	0.70	67.95	0.18
	63.91	0.25	64.96	0.32	63.04	0.27
	68.01	0.50	69.27	0.51	69.85	0.54
	67.36	0.45	70.68	0.14	67.79	0.53
	66.71	0.18	67.03	0.41	65.21	0.38
	65.57	0.65	66.77	0.41	67.11	0.21
	65.1	0.60	66.43	0.29	65.78	0.15
	73.91	0.23	68.65	0.52	72.9	0.30
	67.72	0.22	67.2	0.15	66.97	0.16
	72.62	0.61	72.99	0.05	73.40	0.37
	63.98	0.19	59.19	0.23	60.14	0.36
	69.76	0.30	71.54	0.16	71.14	0.12
	63.72	0.32	64.45	0.06	64.80	0.02
	69.71	0.29	69.85	0.17	69.85	0.08
	62.64	0.32	63.24	0.13	61.77	0.30
	72.39	0.31	73.30	0.32	73.23	0.17
	65.34	0.60	64.21	0.42	67.0	0.47
	66.44	0.26	71.08	0.43	70 58	0.20
	62.02	0.06	63.42	0.51	63.12	0.17
	65.41	0.37	65.51	0.92	67.28	0.79
	68.81	0.19	70.20	0.50	69.28	0.48
	69.06	0.44	70.95	0.13	70.95	0.08
	65.09	0.33	70.63	0.22	68.51	0.31
	69.63	0.21	72.03	0.19	69.71	0.36
	62.44	0.38	64.58	0.32	64.82	0.23
	75.66	0.13	74.34	0.17	68.07	0.06
	70.32	0.48	68.66	0.55	68.83	0.34
Mean	67.84	0.33	68.31	0.30	68.04	0.27
sd	3.56	0.16	3.55	0.21	3.39	0.17
Max	75.66	0.65	74.34	0.92	73.57	0.79
Min	62.02	0.06	59.19	0.02	60.14	0.02
Range	67.84	0.33	68.31	0.30	68.04	0.27
Median	67.72	0.31	68.65	0.23	68.07	0.23

Linear N-ANS

	Group A		Group B		Group C	
	Mean	sd	Mean	sd	Mean	sd
	57.81	0.10	58.33	0.06	58.1	0.16
	58.02	0.18	60.56	0.05	61.24	0.06
	55.62	0.10	62.18	0.06	63.1	0.06
	54.90	0.16	54.08	0.12	55.89	0.05
	61.46	0.01	62.66	0.06	64.3	0.08
	57.27	0.15	59.03	0.15	58.77	0.10
	50.79	0.11	56.34	0.21	57.79	0.05
	50.78	0.19	56.51	0.06	54.92	0.06
	51.68	0.06	50.70	0.05	51.87	0.08
	54.12	0.17	54.21	0.11	55.05	0.14
	55.47	0.12	60.18	0.08	61.52	0.15
	51.23	0.06	55.81	0.10	51.06	0.23
	61.68	0.06	60.95	0.12	62.16	0.15
	56.24	0.004	61.02	0.12	63.24	0.06
	53.81	0.07	52.49	0.26	53.87	0.16
	54.93	0.16	56.41	0.31	56.71	0.15
	51.28	0.23	52.57	0.10	52.43	0.27
	48.42	0.22	50.93	0.37	51.37	0.06
	55.63	0.12	59.00	0.24	60.45	0.06
	60.12	0.05	61.49	0.11	61.15	0.05
	47.48	0.07	50.88	0.10	51.48	0.12
	53.14	0.11	56.06	0.21	55.1	0.06
	53.78	0.10	57.09	0.10	58.84	0.10
	54.11	0.13	56.27	0.18	56.95	0.15
	57.23	0.06	58.11	0.22	58.97	0.10
	55.12	0.21	56.09	0.01	57.72	0.10
	49.17	0.16	53.85	0.101	53.56	0.21
	55.66	0.17	59.4	0.24	60.68	0.1
	49.94	0.23	53.28	0.10	56.77	0.14
	56.37	0.11	60.59	0.06	50.6	0.10
	54.69	0.10	55.95	0.30	56.7	0.12
Mean	54.45	0.12	56.87	0.14	57.17	0.11
sd	3.55	0.06	3.48	0.09	3.96	0.06
Max	61.68	0.23	62.66	0.37	64.30	0.27
Min	47.48	0.004	50.70	0.01	50.60	0.05
Range	54.45	0.12	56.87	0.14	57.17	0.11
Median	54.90	0.11	56.41	0.11	56.95	0.10

Linear ANS-Me

	Group A		Group B		Group C	
	Mean	sd	Mean	sd	Mean	sd
	59.69	0.16	63.02	0.09	64.74	0.16
	62.74	0.06	67.22	0.09	67.35	0.11
	64.19	0.17	74.41	0.11	74.18	0.11
	66.3	0.05	67.95	0.12	68.68	0.05
	66.92	0.06	73.18	0.09	76.64	0.16
	59.95	0.18	65.28	0.17	63.96	0.047
	61.76	0.09	69.31	0.10	69.28	0.001
	67.05	0.18	75.45	0.08	74.82	0.07
	62.35	0.07	65.87	0.10	66.42	0.06
	65.52	0.27	71.96	0.07	69.78	0.11
	63.85	0.20	69.07	0.11	70.45	0.09
	72.10	0.23	64.13	0.03	72.82	0.10
	57.49	0.05	62.95	0.03	63.46	0.14
	67.97	0.05	73.26	0.10	75.91	0.14
	56.86	0.11	58.16	0.05	58.87	0.40
	71.71	0.03	77.31	0.16	77.28	0.21
	61.84	0.11	62.56	0.23	63.69	0.12
	67.77	0.04	71.74	0.16	77.08	0.06
	63.44	0.04	69.68	0.09	71.01	0.14
	75.78	0.05	79.51	0.10	79.62	0.11
	63.25	0.19	65.66	0.24	66.0	0.11
	65.59	0.21	69.32	0.16	70.21	0.04
	57.98	0.05	61.19	0.04	62.66	0.05
	64.84	0.18	71.50	0.16	71.92	0.15
	66.68	0.03	67.16	0.07	66.09	0.14
	68.43	0.20	71.29	0.19	71.19	0.11
	59.52	0.10	65.23	0.11	68.73	0.20
	66.72	0.02	70.22	0.21	71.21	0.28
	66.69	0.06	75.91	0.02	78.43	0.14
	68.79	0.12	73.16	0.09	74.92	0.21
	78.41	0.18	79.68	0.10	80.87	0.22
Mean	65.23	0.11	69.43	0.11	70.59	0.13
sd	4.99	0.07	5.34	0.06	5.52	0.08
Max	78.41	0.27	79.68	0.24	80.87	0.40
Min	56.86	0.02	58.16	0.02	58.87	0.001
Range	65.23	0.11	69.43	0.11	70.59	0.13
Median	65.52	0.10	69.32	0.10	70.45	0.11

Linear N-ANS perpendicular (Wylie)

	Group A		Group B		Group C	
	Mean	sd	Mean	sd	Mean	sd
	55.39	0.08	55.79	0.08	55.75	0.06
	54.57	0.07	57.65	0.11	57.81	0.05
	53.49	0.21	60.58	0.15	61.19	0.04
	51.83	0.11	51.04	0.16	53.24	0.06
	58.54	0.06	60.68	0.10	62.24	0.06
	56.98	0.12	59.32	0.15	59.07	0.05
	49.56	0.12	55.60	0.01	57.21	0.06
	48.97	0.07	54.72	0.10	53.70	0.06
	50.54	0.06	50.04	0.05	51.48	0.06
	53.45	0.11	53.22	0.10	54.35	0.17
	55.7	0.17	60.39	0.18	61.34	0.06
	50.22	0.16	55.79	0.12	50.40	0.20
	56.47	0.13	60.38	0.14	61.21	0.17
	55.25	0.13	60.03	0.18	62.62	0.12
	52.97	0.16	51.76	0.11	53.70	0.10
	53.55	0.10	54.43	0.07	55.49	0.20
	50.57	0.12	52.70	0.04	51.97	0.06
	48.0	0.12	51.0	0.06	50.53	0.09
	55.27	0.09	58.52	0.16	59.82	0.10
	59.1	0.11	60.66	0.11	60.34	0.05
	45.66	0.10	48.4	0.10	49.76	0.16
	50.58	0.11	54.01	0.07	52.48	0.20
	52.75	0.15	56.56	0.15	57.8	0.06
	52.86	0.21	54.98	0.03	55.39	0.06
	55.32	0.14	56.02	0.10	58.06	0.16
	54.42	0.12	55.45	0.07	57.16	0.11
	47.98	0.12	52.13	0.16	51.19	0.06
	54.58	0.11	58.08	0.13	59.6	0.09
	49.51	0.10	51.98	0.26	54.75	0.06
	54.3	0.10	58.88	0.11	49.57	0.09
	52.96	0.10	55.38	0.21	56.24	0.08
Mean	52.95	0.12	55.68	0.11	55.98	0.09
sd	3.19	0.04	3.51	0.06	3.97	0.05
Max	59.10	0.21	60.68	0.26	62.62	0.20
Min	45.66	0.06	48.40	0.01	49.57	0.04
Range	52.95	0.12	55.70	0.12	55.98	0.10
Median	53.45	0.11	55.6	0.11	55.75	0.06

Linear ANS-Me perpendicular (Wylie)

	Group A		Group B		Group C	
	Mean	sd	Mean	sd	Mean	sd
	56.95	0.05	59.50	0.06	61.32	0.14
	59.13	0.11	63.61	0.05	63.52	0.11
	61.65	0.00	72.00	0.17	72.07	0.15
	62.54	0.02	64.17	0.16	65.37	0.002
	64.25	0.09	70.38	0.06	73.81	0.05
	59.57	0.06	64.30	0.06	63.96	0.05
	60.75	0.10	68.53	0.009	68.49	0.10
	65.02	0.16	73.66	0.07	73.17	0.06
	60.51	0.06	64.89	0.006	65.29	0.10
	66.79	0.03	70.07	0.66	68.39	0.001
	63.27	0.06	69.74	0.06	70.09	0.11
	71.24	0.06	63.44	0.10	71.76	0.06
	56.32	0.08	61.95	0.15	62.03	0.04
	65.97	0.02	71.03	0.08	74.16	0.08
	55.65	0.06	57.07	0.10	57.76	0.12
	69.48	0.13	75.07	0.21	74.96	0.22
	61.13	0.09	62.01	0.30	62.97	0.15
	66.7	0.05	70.50	0.06	76.04	0.04
	62.54	0.22	69.16	0.10	69.98	0.07
	74.15	0.07	78.32	0.21	78.96	0.08
	62.03	0.005	64.03	0.10	63.96	0.06
	62.83	0.16	67.44	0.14	67.78	0.12
	56.73	0.12	60.07	0.09	61.41	0.11
	63.54	0.10	70.4	0.15	70.98	0.06
	64.37	0.04	65.07	0.05	64.26	0.12
	67.18	0.08	70.41	0.05	70.21	0.17
	57.54	0.13	63.66	0.16	65.96	0.06
	65.09	0.09	68.31	0.16	69.24	0.06
	65.94	0.16	74.26	0.10	77.07	0.01
	66.84	0.21	71.93	0.07	73.48	0.15
	77.16	0.12	79.25	0.006	80.04	0.11
Mean	63.64	0.09	67.88	0.12	68.98	0.09
sd	5.04	0.06	5.40	0.12	5.64	0.05
Max	77.16	0.22	79.25	0.66	80.04	0.22
Min	55.65	0.00	57.07	0.006	57.76	0.001
Range	63.64	0.09	67.88	0.12	68.98	0.09
Median	63.27	0.08	68.53	0.10	69.24	0.08

Linear Sella-Go (PFH)

	Group A		Group B		Group C	
	Mean	sd	Mean	sd	Mean	sd
	68.56	0.12	72.28	0.10	70.07	0.07
	66.91	0.10	74.66	0.05	71.28	0.15
	65.20	0.10	78.06	0.06	79.06	0.25
	69.6	0.06	68.62	0.06	69.97	0.06
	70.69	0.14	81.37	0.15	86.16	0.06
	68.56	0.05	73.94	0.10	75.77	0.18
	66.33	0.04	74.25	0.07	74.72	0.15
	69.04	0.79	79.36	0.18	80.0	0.18
	71.53	0.11	72.57	0.21	74.17	0.18
	74.44	0.21	74.16	0.09	76.08	0.32
	74.42	0.09	84.51	0.08	85.8	0.24
	67.79	0.15	72.36	0.15	70.22	0.15
	66.02	0.09	74.10	0.18	73.82	0.18
	75.11	0.31	78.46	0.14	86.38	0.23
	69.76	0.15	68.45	0.20	76.72	0.11
	76.29	0.25	77.95	0.10	75.69	0.10
	75.26	0.45	78.05	0.16	76.63	0.16
	68.79	0.12	77.73	0.40	78.64	0.17
	74.81	0.03	81.56	0.03	91.29	0.14
	76.22	0.12	77.93	0.22	79.9	0.10
	69.86	0.02	74.60	0.16	73.22	0.07
	74.08	0.12	76.61	0.11	78.06	0.06
	73.03	0.10	74.66	0.13	81.36	0.09
	73.57	0.06	81.33	0.27	79.17	0.12
	68.75	0.07	69.29	0.02	74.46	0.07
	68.17	0.18	72.98	0.12	72.54	0.16
	55.96	0.10	66.17	0.22	66.23	0.06
	75.84	0.08	79.29	0.06	84.85	0.09
	75.86	0.10	89.0	0.18	91.36	0.15
	71.76	0.06	76.42	0.26	78.04	0.13
	71.36	0.11	77.74	0.05	77.14	0.05
Mean	70.76	0.14	76.08	0.14	77.70	0.13
sd	4.35	0.15	4.83	0.08	6.10	0.07
Max	76.29	0.79	89.00	0.4	91.36	0.32
Min	55.96	0.02	66.17	0.02	66.23	0.05
Range	70.76	0.14	76.08	0.14	77.70	0.13
Median	70.69	0.10	76.42	0.13	76.72	0.14

Appendix 2 Analysis of variance tables

The variable names in brackets were the codes used during the analyses.

SNA post-treatment (snaz2)

Source	df	Sum of squares	Mean square	F	P
Model	2	39.08	19.542	8.74	0.0011
Residual	29	64.81	2.235		
Total	31	103 89	3.351		

Parameter estimates

Parameter	Coef	Std.Err.	t	p	95%CI
Constant	0.83	0.44	-1.88	0.071	(-1.73;0.07)
Non-extraction	1.6	0.54	2.97	0.006	(0.49;2.69)
Class II	1.58	0.53	-2.98	0.006	(-2.66;-0.49)

SNA two years post-treatment (snaz3)

Source	df	Sum of squares	Mean square	F	P
Model	2	15.56	7.78	1.77	0.1877
Residual	29	127.22	4.39		
Total	31	142.78	4.61		

Parameter estimates

Parameter	Coef	Std.Err.	t	p	95%CI
Constant	-0.56	0.62	-0.9	0.375	(-1.82;0.71)
Non-extraction	0.10	0.75	1.32	0.20	(-0.54;2.54)
Class II	-1.01	0.74	-1.36	0.186	(-2.52;0.51)

SNB post-treatment (snbz2)

Source	df	Sum of squares	Mean square	F	P
Model	3	24.89	8.30	2.80	0.06
Residual	28	82.84	2.96		
Total	31	107.72	3.47		

Parameter estimates

Parameter	Coef	Std.Err.	t	p	95%CI
Constant	12.33	7.03	1.75	0.09	(-2.07;26.74)
snbx1	-0.155	0.09	-1.72	0.096	(-0.34;0.03)
Non-extraction	1.35	0.62	2.17	0.038	(0.77;2.62)
Class II	-0.716	0.64	-1.112	0.276	(-2.03;0.602)

snbx1=size of the initial SNB measurement.

SNB post-treatment (snbz3)

Source	df	Sum of squares	Mean square	F	P
Model	3	11.66	3.89	0.78	0.514
Residual	28	139.27	4.97		
Total	31	150.93	4.87		

Parameter estimates

Parameter	Coef	Std.Err.	t	p	95%CI
Constant	14.49	10.21	1.419	0.167	(-6.43;35.41)
snbx1	-0.085	0.117	-0.722	0.476	(-0.32;0.156)
mun0	-0.046	0.04	-1.165	0.254	(-0.13;0.034)
Class II	-0.686	0.836	-0.820	0.419	(-2.40;1.03)

snbx1=size of the initial SNB measurement.

mun0=time elapsed from the initial measurement.

ANB post-treatment (anbz2)

Source	df	Sum of squares	Mean square	F	P
Model	2	13.2.	6.605	4.45	0.021
Residual	29	43.'	1.484		
Total	31	56.25	1.814		

Parameter estimates

Parameter	Coef	Std.Err.	t	p	95%CI
Constant	-1.29	0.482	-2.678	0.012	(-2.28;-0.31)
Female	0.47	0.498	0.943	0.353	(-0.54;1.49)
Class II	-1.24	0.432	-2.863	0.008	(-2.12;-0.35)

ANB two years post-treatment (anbz3)

Source	df	Sum of squares	Mean square	F	P
Model	3	13.97	4.66	3.10	0.043
Residual	28	41.99	1.50		
Total	31	55.96	1.81		

Parameter estimates

Parameter	Coef	Std.Err.	t	p	95%CI
Constant	-1.653	0.669	-2.473	0.02	(-3.02;-0.28)
anbx1	-0.211	0.104	-2.017	0.053	(-0.42;0.003)
Female	0.981	0.513	1.912	0.066	(-0.07;2.03)
Non-extraction	0.715	0.447	1.601	0.121	(-0.20;1.63)

anbx1=size of initial ANB measurement

GoGn-SN post-treatment (gognz2)

Source	df	Sum of squares	Mean square	F	P
Model	4	86.34	21.58	4.02	0.011
Residual	27	145.11	5.374		
Total	31	231.44	7.466		

Parameter estimates

Parameter	Coef	Std.Err.	t	p	95%CI
Constant	-5.43	7.914	-0.685	0.499	(-21.7;10.82)
gognx1	-0.274	0.090	-3.045	0.005	(-0.46;0.09)
mun0	0.075	0.043	1.745	0.092	(-0.013;0.16)
mun2	0.121	0.070	1.731	0.095	(-0.022;0.27)
Non-extraction	-1.651	0.843	-1.96	0.061	(-3.38;0.079)

gognx1=size of initial Go-Gn measurement.

mun0=age at the start of treatment.

mun2=time period from initial measurement to post-treatment.

Go-Gn two years post-treatment (gognz3)

Source	df	Sum of squares	Mean square	F	P
Model	4	81.34	20.33	3.75	0.014
Residual	27	146.36	5.42		
Total	31	227.69	7.34		

Parameter estimates

Parameter	Coef	Std.Err.	t	p	95%CI
Constant	-8.254	7.232	-1.141	0.264	(-23.1;6.58)
gognx1	-0.218	0.093	-2.341	0.027	(-0.41;-0.03)
mun0	0.07	0.04	1.713	0.098	(-0.014;0.15)
mun3	0.047	0.029	1.604	0.120	(-0.013;0.11)
Female	1.92	0.99	1.933	0.064	(-0.12;3.96)

gognx1=size of the initial measurement

mun0=age at the start of treatment

mun3=time period from the start of treatment to two years post-treatment.

Occlusal plane post-treatment (occz2)

Source	df	Sum of squares	Mean square	F	P
Model	4	176.7	44.17	5.54	0.002
Residual	27	215.29	7.97		
Total	31	391.99	12.64		

Parameter estimates

Parameter	Coef	Std.Err.	t	p	95%CI
Constant	-4.41	7.98	-0.553	0.585	(-20.78;11.9)
occx1	-0.40	0.132	-3.035	0.005	(-0.67;-0.13)
mun0	0.079	0.050	1.577	0.127	(-0.024;0.18)
Non-extraction	-2.86	1.03	-2.77	0.010	(-4.98;-0.74)
Class II	1.081	1.05	1.026	0.314	(-1.08;3.25)

Occlusal plane two years post-treatment (occz3)

Source	df	Sum of squares	Mean square	F	P
Model	4	100.12	25.03	2.22	0.0933
Residual	27	304.24	11.27		
Total	31	404.36	13.04		

Parameter estimates

Parameter	Coef	Std.Err.	t	p	95%CI
Constant	-13.122	9.44	-1.39	0.176	(-32.49;6.25)
occx1	-0.299	0.155	-1.927	0.065	(-0.62;0.019)
mun0	0.101	0.059	1.696	0.101	(-0.021;0.22)
Female	1.479	1.375	1.076	0.291	(-1.34;4.3)
Class II	1.424	1.254	1.136	0.266	(-1.15;3.99)

occx1=size of the initial occlusal plane to SN measurement.

mun0=age at the start of treatment.

Palatal plane post-treatment (palz2)

Source	df	Sum of squares	Mean square	F	P
Model	2	11.73	5 [illegible]	2.48	0.101
Residual	29	68.57	2. [illegible]		
Total	31	80.296	2.590		

Parameter estimates

Parameter	Coef	Std.Err.	t	p	95%CI
Constant	-5.631	4.022	-1.4	0.172	(-13.86;2.6)
palx1	-0.11	0.086	-1.269	0.215	(-0.29;0.067)
mun0	-5.631	4.022	-1.4	0.172	(-13.86;2.6)

palx1=size of the initial palatal plane to SN measurement.

mun0=age at the start of treatment.

Palatal plane two years post-treatment (palz3)

Source	df	Sum of squares	Mean square	F	P
Model	3	21.86	7.29	1.49	0.24
Residual	28	136.95	4.89		
Total	31	158.81	5.123		

Parameter estimates

Parameter	Coef	Std.Err.	t	p	95%CI
Constant	-3.95	5.8	-0.681	0.502	(-15.82;7.93)
palx1	-0.21	0.124	-1.687	0.103	(-0.46;0.044)
mun0	0.040	0.039	1.032	0.311	(-0.04;0.120)
Non-extraction	0.3	0.803	0.374	0.711	(-1.34;1.95)

palx1=size of the initial measurement of palatal plane to SN

mun0=age at the start of treatment

Occlusal to mandibular plane post-treatment (ocmz2)

Source	df	Sum of squares	Mean square	F	P
Model	2	147.29	73.64	11.04	0.0003
Residual	29	193.38	6.67		
Total	31	340.67	10.99		

Parameter estimates

Parameter	Coef	Std.Err.	t	p	95%CI
Constant	2.257	3.58	0.63	0.534	(-5.1;9.61)
ocmx1	-0.53	0.144	-3.66	0.001	(-0.82;-0.23)
mun2	0.174	0.075	2.31	0.029	(0.02;0.33)
Non-extraction	0.828	0.986	0.839	0.409	(-1.2;2.85)
Class II	-0.575	0.975	-0.59	0.56	(-2.58;1.43)

ocmx1=size of the initial occlusal to mandibular plane measurement

mun2=time elapsed from the start of treatment to post-treatment

Occlusal to mandibular plane two years post-treatment (ocmz3)

Source	df	Sum of squares	Mean square	F	P
Model	2	92.47	46.233	8.07	0.0016
Residual	29	166.14	5.73		
Total	31	258.603	8.34		

Parameter estimates

Parameter	Coef	Std.Err.	t	p	95%CI
Constant	1.499	3.09	0.485	0.631	(-4.82;7.82)
ocmx1	-0.323	0.126	-2.57	0.016	(-0.58;-0.07)
mun3	0.067	0.031	2.262	0.031	(0.007;0.13)

ocmx1=size of the initial occlusal to mandibular plane measurement

mun3=time elapsed from the start of treatment to two years post-treatment

Palatal to mandibular plane post-treatment (pamaz2)

Source	df	Sum of squares	Mean square	F	P
Model	4	87.311	21.83	5.82	0.0016
Residual	27	101.22	3.75		
Total	31	188.54	6.082		

Parameter estimates

Parameter	Coef	Std.Err.	t	p	95%CI
Constant	-1.096	6.65	-0.165	0.870	(-14.8;12.56)
pamax1	-0.382	0.097	-3.924	0.001	(-0.58;-0.18)
mun0	0.047	0.036	1.292	0.207	(-0.03;0.12)
mun2	0.129	0.058	2.205	0.036	(0.009;0.25)
Non-extraction	-1.381	0.714	-1.936	0.063	(-2.85;0.083)

pamax1=size of the initial palatal to mandibular plane measurement

mun0=age at the start of treatment

mun2=time elapsed from the initial measurement to post-treatment

Palatal to mandibular plane two years post-treatment (pamaz3)

Source	df	Sum of squares	Mean square	F	P
Model	4	48.919	12.23	3.24	0.027
Residual	27	101.83	3.772		
Total	31	150.75	4.863		

Parameter estimates

Parameter	Coef	Std.Err.	t	p	95%CI
Constant	-7.744	5.897	-1.313	0.2	(-19.84;4.36)
pamax1	-0.121	0.098	-1.225	0.231	(-0.32;0.08)
mun0	0.036	0.034	1.048	0.304	(-0.03;0.11)
mun3	0.044	0.024	1.815	0.081	(-0.01;0.09)
Female	1.948	0.815	2.389	0.024	(0.27;3.62)

pamax1=size of the initial measurement

mun0=age at the start of treatment

mun3=time elapsed from the start of treatment until two years post-treatment

Palatal to occlusal plane post-treatment (paloz2)

Source	df	Sum of squares	Mean square	F	P
Model	3	131.57	43.86	7.54	0.0008
Residual	28	162.77	5.813		
Total	31	294.34	9.495		

Parameter estimates

Parameter	Coef	Std.Err.	t	p	95%CI
Constant	8.35	3.11	2.683	0.012	(1.97;14.73)
palox1	-0.482	0.14	-3.45	0.002	(-0.77;-0.2)
mun2	-0.083	0.07	-1.21	0.237	(-0.22;0.06)
Non-extraction	-2.44	0.88	-2.786	0.009	(-4.24;-0.65)

palox1=size of the initial palatal to occlusal plane measurement

mun2=time elapsed from the initial measurement to post-treatment

Palatal to occlusal plane two years post-treatment (paloz3)

Source	df	Sum of squares	Mean square	F	P
Model	3	53.16	17.72	2.92	0.052
Residual	28	170.08	6.07		
Total	31	223.24	7.20		

Parameter estimates

Parameter	Coef	Std.Err.	t	p	95%CI
Constant	-10.08	6.76	-1.49	0.147	(-23.92;3.76)
mun0	0.06	0.04	1.40	0.172	(-0.03;0.15)
mun3	-0.05	0.03	-1.59	0.122	(-0.11;0.01)
Female	2.10	1.02	2.07	0.048	(0.01;4.19)

mun0=age at the start of treatment

mun3=time elapsed from the initial treatment to two years post-treatment

Nasion-sella-gnathion angle post-treatment (nsgz2)

Source	df	Sum of squares	Mean square	F	P
Model	3	27.88	9.29	1.98	0.139
Residual	28	131.32	4.69		
Total	31	159.20	5.14		

Parameter estimates

Parameter	Coef	Std.Err.	t	p	95%CI
Constant	16.08	7.46	2.16	0.04	(0.80;31.35)
nsgx1	-0.23	0.11	-2.11	0.04	(-0.46;-0.01)
Non-extraction	-1.12	0.80	-1.41	0.17	(-2.76;0.51)
Class II	0.97	0.79	1.24	0.227	(-0.64;2.59)

nsgx1=size of the initial measurement

Nasion-sella-gnathion two years post-treatment (nsgz3)

Source	df	Sum of squares	Mean square	F	P
Model	3	31.14	10.38	2.44	0.086
Residual	28	119.28	4.26		
Total	31	150.41	4.85		

Parameter estimates

Parameter	Coef	Std.Err.	t	p	95%CI
Constant	0.08	9.41	0.01	0.99	(-19.2;19.36)
nsgx1	-0.15	0.1	-1.45	0.157	(-0.35;0.06)
mun0	0.05	0.04	1.34	0.19	(-0.03;0.12)
mun3	0.04	0.03	1.66	0.11	(-0.01;0.09)

nsgx1=size of the initial measurement

mun0=age at the start of treatment

mun3=time elapsed from the start of treatment to two years post-treatment

Nasion to anterior nasal spine post-treatment (nansz2)

Source	df	Sum of squares	Mean square	F	P
Model	3	36.94	12.31	3.49	0.03
Residual	28	98.88	3.53		
Total	31	135.82	4.38		

Parameter estimates

Parameter	Coef	Std.Err.	t	p	95%CI
Constant	21.88	6.88	3.18	0.004	(7.80;35.96)
nansx1	-0.23	0.10	-2.38	0.024	(-0.43;-0.03)
mun0	-0.04	0.03	-1.15	0.259	(-0.11;0.03)
Female	-1.60	0.79	-2.04	0.05	(-3.21;0.01)

nansx1=size of the initial measurement

mun0=age at the start of treatment

Nasion to anterior nasal spine two years post-treatment (nansz3)

Source	df	Sum of squares	Mean square	F	P
Model	4	83.03	20.76	3.80	0.014
Residual	27	147.64	5.47		
Total	31	230.67	7.44		

Parameter estimates

Parameter	Coef	Std.Err.	t	p	95%CI
Constant	17.53	7.10	2.47	0.02	(2.96;32.09)
nansx1	-0.27	0.12	-2.24	0.03	(-0.52;-0.02)
mun3	0.04	0.03	1.43	0.17	(-0.02;0.10)
Female	-3.21	0.98	-3.26	0.003	(-5.23;-1.19)
Class II	-0.83	0.83	-1.00	0.33	(-2.54;0.87)

nansx1=size of the initial measurement

mun3=time elapsed from the initial measurement to two years post-treatment

Anterior nasal spine to menton post-treatment (ansmz2)

Source	df	Sum of squares	Mean square	F	P
Model	3	110.13	36.71	4.78	0.008
Residual	28	214.94	7.68		
Total	31	325.07	10.49		

Parameter estimates

Parameter	Coef	Std.Err.	t	p	95%CI
Constant	2.17	2.93	0.74	0.47	(-3.84;8.18)
mun2	0.15	0.08	1.92	0.07	(-0.01;0.31)
Female	-3.55	1.14	-3.13	0.004	(-5.88;-1.23)
Class II	-1.37	0.99	-1.39	0.18	(-3.39;0.65)

mun2=time elapsed from start of treatment to post-treatment

Anterior nasal spine to menton two years post-treatment (ansmz3)

Source	df	Sum of squares	Mean square	F	P
Model	4	131.83	32.96	6.91	0.0006
Residual	27	128.80	4.77		
Total	31	260.63	8.41		

Parameter estimates

Parameter	Coef	Std.Err.	t	p	95%CI
Constant	18.67	6.09	3.07	0.005	(6.18;31.17)
mun0	-0.09	0.04	-2.36	0.03	(-0.17;-0.01)
mun3	0.05	0.03	1.76	0.09	(-0.01;0.10)
Female	-3.52	0.90	-3.90	0.001	(-5.38;-1.67)
Class II	-1.50	0.78	-1.92	0.065	(-3.10;0.10)

mun0=age at the start of treatment

mun3=time elapsed from start of treatment to two years post-treatment

Nasion to anterior nasal spine perpendicular (Wiley) post-treatment (nanswz2)

Source	df	Sum of squares	Mean square	F	P
Model	3	37.98	12.66	3.74	0.022
Residual	28	94.73	3.38		
Total	31	132.71	4.28		

Parameter estimates

Parameter	Coef	Std.Err.	t	p	95%CI
Constant	19.51	6.84	2.85	0.008	(5.51;33.52)
nanswx1	-0.14	0.11	-1.26	0.218	(-0.36;0.09)
mun0	-0.06	0.03	-1.72	0.096	(-0.12;0.11)
Female	-1.90	0.77	-2.48	0.02	(-3.47;-0.33)

nanswx1=size of the initial measurement

mun0=age at the start of treatment

Nasion to anterior nasal spine perpendicular(Wiley) two years post-treatment (nansw3)

Source	df	Sum of squares	Mean square	F	P
Model	3	60.66	20.22	4.26	0.014
Residual	28	132.99	4.75		
Total	31	193.65	6.25		

Parameter estimates

Parameter	Coef	Std.Err.	t	p	95%CI
Constant	6.61	5.97	1.11	0.28	(-5.63;18.84)
mun0	-0.03	0.04	-0.72	0.477	(-0.11;0.05)
mun3	0.04	0.03	1.40	0.17	(-0.02;0.09)
Female	-2.96	0.90	-3.29	0.003	(-4.81;-1.12)

mun0=age at the start of treatment

mun3=time elapsed from the start of treatment to two years post-treatment

Anterior nasal spine to menton perpendicular (Wiley) post-treatment (ansmwz2)

Source	df	Sum of squares	Mean square	F	P
Model	3	126.7	42.23	6.23	0.0022
Residual	28	189.8	6.78		
Total	31	316.50	10.21		

Parameter estimates

Parameter	Coef	Std.Err.	t	p	95%CI
Constant	1.26	2.76	0.46	0.65	(-4.39;6.91)
mun2	0.18	0.07	2.44	0.02	(0.03;0.33)
Female	-3.73	1.07	-3.50	0.002	(-5.92;-1.54)
Class II	-1.32	0.93	-1.42	0.17	(-3.22;0.58)

mun2=time elapsed from the start of treatment to post-treatment

Anterior nasal spine to menton perpendicular (Wiley) two years post-treatment (ansmwz3)

Source	df	Sum of squares	Mean square	F	P
Model	4	144.38	36.09	8.28	0.0002
Residual	27	117.76	4.36		
Total	31	262.14	8.46		

Parameter estimates

Parameter	Coef	Std.Err.	t	p	95%CI
Constant	21.57	5.82	3.71	0.001	(9.63;33.52)
mun0	-0.11	0.04	-2.90	0.007	(-0.18;-0.03)
mun3	0.04	0.03	1.55	0.13	(-0.01;0.09)
Female	-3.43	0.86	-3.97	0.000	(-5.21;-1.66)
Class II	-1.86	0.75	-2.49	0.019	(-3.39;-0.33)

mun0=age at the start of treatment

mun3=time elapsed from the start of treatment to two years post-treatment

Sella to gonion post-treatment (sgoz2)

Source	df	Sum of squares	Mean square	F	P
Model	4	253.20	63.30	7.43	0.0004
Residual	27	230.07	8.52		
Total	31	483.27	15.59		

Parameter estimates

Parameter	Coef	Std.Err.	t	p	95%CI
Constant	44.00	10.70	4.11	0.000	(22.04;65.96)
sgox1	-0.29	0.12	-2.33	0.03	(-0.54;-0.03)
mun0	-0.10	0.05	-1.82	0.08	(-0.20;0.01)
Female	-5.06	1.20	-4.23	0.000	(-7.51;-2.61)
Class II	-1.81	1.09	-1.09	0.287	(-3.41;1.05)

sgox1=size of the initial measurement

mun0=age of patient at the start of treatment

Sella to gonion two years post-treatment (sgoz3)

Source	df	Sum of squares	Mean square	F	P
Model	4	418.69	104.67	12	0.000
Residual	27	235.45	8.72		
Total	31	654.13	21.10		

Parameter estimates

Parameter	Coef	Std.Err.	t	p	95%CI
Constant	40.62	10.83	3.75	0.001	(18.4;62.83)
sgox1	-0.13	0.13	-1.06	0.3	(-0.39;0.13)
mun0	-0.12	0.05	-2.33	0.03	(-0.23;-0.02)
Female	-7.25	1.21	-5.0	0.000	(-9.73;-4.77)
Class II	-2.01	1.1	-1.83	0.079	(-4.27;0.25)

sgox1=size of the initial measurement at the start of treatment

mun0=age of patient at the start of treatment

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