THE INTRODUCTION OF A NEW LATERAL CEPHALOMETRIC METHOD AND ITS POTENTIAL APPLICATION IN OPEN BITE DEFORMITIES.

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Declaration

STATEMENT BY CANIDATE

I, Salahuddien Mohamed Dawjee, hereby declare that the work on which this thesis is based is original (except where acknowledgements indicate otherwise) and that neither the whole work nor any part of it has been, or shall be submitted for another degree at this or any other university.

The work reported in this thesis was performed in the Department of Orthodontics, University of Limpopo, Medunsa Campus, Republic of South Africa.

All opinions or statements expressed in this thesis do not necessarily reflect that of the University of Limpopo, the supervisors of the thesis or the external examiners.

Signature:

Date:

SM Dawjee

Dedication

To my parents Cassim and Mariam Dawjee
May God be pleased with us all?
Verily His contentment is the Greatest.

Acknowledgement

My sincere gratitude and appreciation is extended to:

1. God Almighty – The Creator and Sustainer of the universe. Nothing happens without His permission.
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Keywords

South Africa
South African Blacks
Malocclusion
Open bite
Anterior open bite
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Cephalometric methods
Cephalometric analysis
Facial dimensions
Vertical facial dimensions

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List of abbreviations

AOB	anterior open bite
MRC	Medical Research Council
NHANES	National Health and Nutrition Estimates Survey
TMJ	temporomandibular joint
MRI	magnetic resonance imaging
CAT	computer aided tomography
FH	Frankfort horizontal
DI	discrepancy index
ABO	American Board of Orthodontics
MP	mandibular plane
PP	palatal plane
OP	occlusal plane
PFH	posterior facial height
AFH	anterior facial height
UFH	upper facial height
LFH	lower facial height
ANS	anterior nasal spine
UAFH	upper anterior facial height
LAFH	lower anterior facial height
ODI	overbite depth indicator
Mx	maxilla
Md	mandible
Go	gonion
Gn	gnathion
APDI	anteroposterior dysplasia indicator
CF	combination factor
MOHC	Medunsa Oral Health Centre
S	sella
N	nasion

Po	porion
PNS	posterior nasal spine
OCP	occlusal contact point
REPC	Research Ethics and Publication Committee
BDS	Bachelor of Dental Surgery
MEDUNSA	Medical University of Southern Africa
MEAW	multilooped edgewise archwire technique
SAS	Skeletal Anchorage System
MAS	Micro-screw Anchorage System
PAS	posterior airway space
DO	distraction osteogenesis
PL	poly lactide
3D	three-dimensional
CBCT	cone beam computerised tomography
ROC	receiver operating characteristic
SD	standard deviation

Summary

Open bite deformity is a dentofacial anomaly characterised by a space between the upper and lower teeth when the jaws are brought together. When the posterior teeth are in contact and there is separation between the upper and lower incisal edges, the condition is referred to as an anterior open bite (AOB). Anterior open bite occurs more commonly among the Black African race groups, and unless recognised and intercepted early in life, treatment of the condition can become complicated, extended and expensive.

Some of the aetiological factors cited in the development of the condition include, an unfavourable growth pattern, finger sucking habits, enlarged tonsillar lymphoid tissue, abnormal tongue and orofacial muscular activity and hereditary factors.

Morphologically AOB can involve only the dentoalveolar regions of the craniofacial anatomy, in which case the AOB is said to be a dental AOB; it may be the result of a disproportion between the jaws and is then referred to as a skeletal AOB, or it may be a mixture of the two. The aetiology and structural components of AOB would largely determine the mode of treatment, which can be orthodontic treatment, orthognathic surgery or a combination of the two.

Previous studies into the prevalence of AOB in South Africa have reported it to be as high as 27%. Since a major percentage of the patients seen at the School of Dentistry of the University of Limpopo are of the South African Black race group it became relevant to investigate the prevalence of AOB at this institution and to develop a fresh assessment method with standardised values for this population sample.

A retrospective study was therefore undertaken among patients visiting the School of Dentistry of the University of Limpopo to determine the prevalence of AOB over a 15-year time period from 1992 to 2006. All

patients with an AOB were documented with regard to age, gender, severity and aetiology. The criteria for determining open bite was a measure of at least 1 mm vertical separation between the incisal edges of the upper and lower incisors when the posterior teeth are in occlusion, as determined from the lateral cephalograms and confirmed by the study models.

A review of the literature pertaining to craniofacial growth, the aetiology, pathogenesis, clinical presentation and treatment of AOB is also presented as well as investigative techniques for the assessment of AOB. A revised lateral cephalometric assessment method proposed as the Dawjee Analysis was designed and developed and is introduced. It consists of 12 measurements of which nine have never been previously mentioned in the literature and are being defined and described for the first time in this proposed analysis. These parameters are measured against existing and tested anatomical landmarks and planes, combined with the introduction of one new landmark and seven new measuring planes that have not been cited or described in other established analyses. These landmarks, planes and measurement parameters of the analysis are presented and its utility is described. A case study of a patient with AOB is included with an assessment of pre-treatment and post-treatment changes using this analysis.

In order to establish standardised values for this population sample, the proposed Dawjee analysis was applied to a control group consisting of 50 adult male and 50 adult female subjects whose cephalometric analysis conformed to the standardised values for this race group.

The analysis was also applied to an AOB sample from the retrospective study consisting of 46 male and 59 female cephalograms. Based on the amount of incisor separation this group was divided into mild, moderate and severe AOB. All subjects in both the AOB and control samples were in their permanent dentition stage, having their first permanent molars in a Class I relation.

In testing the validity of the proposed Dawjee Analysis, 20 cephalograms from the control group and 20 from the AOB group were also evaluated using other established cephalometric methods and the results thereof were compared to the findings of the proposed Dawjee Analysis

From the 15-year retrospective investigation this study found the prevalence of AOB to be 9.67% with the male to female ratio of 46:54. The condition appears to be more common before the age of 13 years than after 13 years with a ratio of 68:32. The aetiology of the AOB in order of rank was found to be thumb or finger sucking, hereditary, nasal obstruction and unknown causes. Over the 15-year period the number of AOB patients attending the Orthodontic Department, School of Dentistry of the University of Limpopo, decreased from 16% to 8%. While this could be due to the realization that the principal cause (thumb or finger sucking) carries a social stigma, a concerted effort must be made to educate communities so that this detrimental habit can be minimised and eradicated.

Standardised values for the proposed Dawjee Analysis are presented and potential flaws are outlined. When comparisons are drawn between the control and AOB group it was found that the latter differs from the control sample in 8 of the 12 of the parameters, namely:

1. Incisor separation
2. Anterior cranial base inclination
3. Posterior maxillary position
4. Posterior mandibular position
5. Interalveolar angle
6. Point B position
7. Apex of the maxillary triangle
8. Apex of the mandibular triangle

The null hypothesis, which states there are no difference in the cephalometric values of the proposed Dawjee Analysis between AOB subjects and a control group for this population sample, was therefore rejected.

These morphological differences were supported by the findings of other established analysis that were tested on the AOB and control groups. The difference of the proposed Dawjee Analysis from other cephalometric methods lies in its capability to identify and separate the skeletal from the dental components of an AOB for this study sample.

Diagnosis involves a comparison to population standards and the aim of cephalometrics is to describe the standardised morphology of a population. To this end standardised values for the proposed Dawjee Analysis in a South African Black population sample have been determined which focuses on identifying the morphological basis of an AOB.

Chapter 1

Introduction

The face is the most distinguishing feature of a person and plays a unique role in all social interactions as well as in the establishment of the self-image. No other part of the human body laughs, cries, sings, speaks, sneers or flirts. It is the face that is photographed, it is the facial features that we remember or describe, it is the face that we use to express ourselves to others, and it is the face that most reveals all our emotions. No region of our anatomy more powerfully conveys our feelings nor elicits more profound reactions when disease or genetic disorders disfigure it than the face (Helms *et al.*, 2005). It is no wonder that we often judge others and ourselves by facial appearances and that we wish to improve undesirable facial traits. Variations of facial features or perceptions of such variations are the two most important reasons people seek orthodontic treatment.

The first people interested in measurements of the head and face were the artists and philosophers and not, as one might think, the anatomists or anthropologists (Krogman and Sassouni, 1957). The Greeks wrote extensively about facial beauty, which seemed easy to define since beauty to them was a matter of balance and proportion. Plato devised the 'golden proportion', a way of subdividing an object so that proportionally the smaller part is to the greater, the same as the greater is to the whole (Shorey, 1933). According to this formula, perfectly beautiful faces had to be proportioned.

Artists came to concur with the Greeks who believed that the beautiful face was one that had perfect symmetry. According to Moyers, however, Francis Bacon held a different view and found symmetric faces boring. He claimed that "there is no excellent beauty which hath not strangeness in proportion" (Moyers, 1984a).

In our quest for perfection, humans will persist in their search for a magic mathematical formula of facial beauty. Ricketts explored the divine proportion as formulated from the Fibonacci series in relation to the dentofacial complex and found that a number of golden relationships exist in the face. He highlighted their potential value in orthodontic treatment planning as well as for orthognathic surgery (Ricketts, 1982b).

One could speculate that the first real cephalometrists were the 16th century artists Albert Dürer and Leonardo da Vinci both of whom left sketches showing the planes and angles of the face to depict, not beauty but variability (Peck and Peck, 1995).

Modern and more scientific head measurements have attempted to reduce morphology, beauty and growth to rigid numbers. With the invention of the cephalostat, longitudinal studies of the same individual were possible and a more precise mathematical analysis was adopted. Prior to this, the anthropologists' callipers permitted only external measurements with a high degree of error (Athanasiou, 1995).

In 1931 both Broadbent and Hofrath singularly and independently developed the cephalostat for the same purpose, namely, to study growth and its associate variabilities. Ten years later Downs developed the first so called cephalometric analysis. He studied the relationship between idealism and measurements in a small series of faces with 'ideal occlusions' from both genders and subjects with different ages (Downs, 1952). The simplicity of the concept that has persisted for almost 2500 years entered and engaged the science of technology.

Cephalometrics have helped orthodontists understand that they do not have all the answers (Hixon, 1972). In orthodontics, nothing manifests normal variability among people more evidently than cephalometrics. It conveys the unpredictability in the way people grow and the inability to accurately predict this variability for any single human being.

A cephalogram freezes a craniofacial event and like a photograph describes certain tissue relationships that exists at any one moment in time. A cephalometric analysis is not only a method of defining craniofacial morphology and diagnosing deformity but also helps identify anatomical variation and growth prediction.

Growth can be defined in different ways. Some biologists describe it as all the expected natural changes that take place between conception and death. To others, growth is a size change alone and should be carefully separated from maturation, differentiation and translation (Moyers, 1984a). Growth of the craniofacial complex is important since the head and face is the site of so many functions – respiration, food ingestion, speech, vision, olfaction, hearing, mastication, facial expression and the brain itself. While certain craniofacial functions are in place in the neonate – breathing, sucking, crying, vision, hearing and smell – their natural maturation and all other orofacial behavioural development are dependant on normal craniofacial growth. No other site of the human body has such a concentration of essential functions. Multiple clinical fields are therefore interested and contribute to craniofacial biology.

In craniofacial development, variabilities become clinically important at different levels of deviation from the norm depending on the age, sex, self-image, socio-economic status and even the cultural background of the patient and family. In many diagnoses it is sufficient to think simply in terms of abnormal versus normal or the presence or absence of an abnormality, and therefore presumes knowledge of the normal. To the orthodontist it would mean normal craniofacial growth and morphology, but to the patient it may mean ‘normal’ facial attractiveness. The latter requires a different diagnostic approach by the orthodontist than is usual in medicine and dentistry, because facial aesthetics, self-image and ethics based on the patient’s cultural perceptions have nothing to do with the science of craniofacial biology.

In orthodontics, diagnosis always involves comparison to population standards, as well as to ideals and/or to the clinician's past experience. It is essential therefore that determining deviations from the normal, predicting the future development, and planning treatment must all be based on knowledge of craniofacial growth and variability, and the potential for their alteration. Such variability from the norm, with a potential for alteration and treatment that is of common and continued interest to orthodontist, is the dentofacial anomaly of anterior open bite (AOB).

Anterior open bite may be defined as: that condition where the upper incisor crowns fail to overlap the incisal third of the lower incisor crowns when the teeth are brought into full occlusion. Within the limits of this definition, the degree or severity of malocclusion may vary from a mild AOB to a severe and handicapping malocclusion (Mizrahi, 1978).

According to Tsang *et al,* the term 'open bite' can be traced back to 1842 when it was first used by Caravelli to define a distinct type of occlusion (Tsang *et al.*, 1997). Many classifications have since been proposed but none of them have been universally accepted. Some researchers have classified open bite according to location (anterior or lateral) and pattern (Thoma, 1943), while others have classified it on aetiology, as in developmental or acquired (Shira, 1961). Later, open bite was considered from a treatment point of view and divided into skeletal and non skeletal or dental types (Mizrahi, 1978). Worms and co-workers went on to further classify AOB by severity and extent of involvement into pseudo, true and compound types (Worms *et al.*, 1971). Kim defines it as a lack of coincidence and failure to meet at the anterior region between the mandibular and maxillary occlusal planes (Kim, 1974). Richardson uses both aetiological and skeletal considerations in his classification (Richardson, 1981). Thus, while there is no universal classification, the term AOB is unanimously accepted to mean a vertical gap between the upper and lower incisors when the posterior teeth are in occlusion (Mizrahi, 1978; Subtelny and Sakuda, 1964; Swineheart, 1942).

In this thesis the terms open bite and anterior open bite imply one and the same and will be defined by the acronym AOB. Posterior open bite is different from all of the former terms and if mentioned in the course of this work will be specifically referred to as posterior open bite.

Although multi-factorial in its origin, AOB can be broadly described as being either dental or skeletal in origin. Precise differentiation is essential in formulating the appropriate treatment plan as dental open bites may close spontaneously in the growing patient and are generally amenable to orthodontic treatment; skeletal open bites however, frequently worsen with growth and usually require a combination of orthodontics and orthognathic surgery. Cases have also been cited where skeletal open bites have been successfully treated via neuromuscular intervention, e.g. posterior bite plane therapy in combination with maxillary expansion (Dahan and Lelong, 2003). Furthermore, the ability to retain treated AOBs is limited and the incidence of post-treatment relapse is high, making these malocclusions a challenge to treat successfully and avert relapse (Burford and Noar, 2003).

The successful management of AOBs whether skeletal or dental is largely dependant on identifying and eliminating the aetiological factors. Equally important is the isolation of morphological components that contribute to the development of these AOBs and in this regard, the lateral cephalogram and the cephalometric analyses are of paramount importance in directing the clinician in formulating the best treatment plan.

Chapter 2

Literature review

Prevalence

One of the earliest investigations into the prevalence of AOB was undertaken by Korkhaus who reported the open bite frequency in 643 six-year-old children to be 4.2%, which decreased to 2.5% in 568 fourteen-year-old children (Korkhaus, 1928).

In the United States the prevalence of AOB appears to be highest among the Black race groups and the size of the AOB is variable. Orthodontic surveys of the adolescent and adult population have shown that the incidence of AOB is three to four times higher in African American Blacks than in Whites (Beane *et al.*, 2003). There is little in the literature to explain why African American Blacks have a higher incidence of open bites than Whites and why their open bites are more severe

On a global scale, studies on the prevalence of AOB confirm a higher incidence of AOB in races of African origin as compared to those of European decent (Table 1).

Table 1. Distribution of anterior open bite in age group samples of different countries

Country	Age group of sample	Distribution
Kenya	Undefined	24% (Hassanali and Pokhariyal, 1993)
Tanzania	12 to 15 years and 3 to 16 years	6-19% (Mugonzibwa et al., 2004; Rwakatema et al., 2006)
Nigeria	5 to 34 years	5,2% (Onyeaso et al., 2002)
Kuwait	13.2 years	3,5% (Behbehani et al., 2005)
Japan	14 to 18 years	2,4-2,9% (Kitai et al., 1990)
Italy	11 to 14 years	1,1% (Ciuffolo et al., 2005)

Even within the Black races, the incidence is variable. A Kenyan study found AOB was the highest amongst the Kalenjin ethnic group (24%), with sizes ranging between 0.4 mm and 11.5 mm. In the total sample, anterior open bite occurred in 16.5%, with a mean of 2.69 mm and a range between 0.4-11.5 mm. The mean values for anterior open bite was also found to decrease with age (Hassanali and Pokhariyal, 1993).

The National Health and Nutrition Estimates Survey III (NHANES III) undertaken in the United States of America during the period 1989-1994 listed among other dental problems, the distribution of AOB as follows (Tables 2 & 3):

Table 2. Age distribution of anterior open bite according to NHANES III (Proffit and Fields, 2000)

AOB in mm	Severity	8-11 years	12-17 years	18-50 years
Larger than 4	extreme	0.3 %	0.2 %	0.1 %
Between 3 to 4	severe	0.6 %	0.5 %	0.5 %
Between 0 to 2	moderate	2.7 %	2.8 %	2.7 %

Table 3. Percentage race distribution of anterior open bite according to NHANES III (Proffit and Fields, 2000)

AOB in mm	White group	Black group	Hispanic group
Larger than 4	0.1 %	0.7 %	0
Between 3 to 4	0.4 %	1.3 %	0
Between 0 to 2	2.4 %	4.6 %	2.1 %

While no specific aetiological factors could be identified, a study of Black primary school children from lower socio-economic suburbs in South Africa showed that 27.8% of these children had well circumscribed anterior open bites (de Muelenaere and Wiltshire, 1995) A different study undertaken in England found that in 1,500 11-year-old children, 2.7% of the sample had tongue thrust and an AOB. Of these, half had some or other associated malocclusion (Tully, 1969).

One possible explanation for the age related open bite is incomplete eruption of the incisors. While the exact cause of the open bite at this age is open to speculation, the important fact is that these studies show that many mixed dentition open bites correct themselves spontaneously (Speidel *et al.*, 1972).

Although the percentage of adult patients who seek orthodontic treatment for malocclusion has increased in recent years, the majority of treatment is still directed toward pre-adolescent and adolescent patients who are experiencing growth changes in their occlusions and facial skeleton (Bishara, 2000).

Aetiology and pathogenesis

Malocclusion due to vertical excess results from the interplay of many different aetiological factors, particularly during the growth period. These factors include growth of the maxilla and mandible, function of the lips and tongue and dentoalveolar development with eruption of the teeth. Variations in the rate of growth in both the maxillary sutures and the mandibular condyles can further influence the development of vertical malocclusion (Nielsen, 1991).

Craniofacial growth

The clinician who studies craniofacial growth does so not only for the intellectual excitement of the field, but also for the hope of clinical application. Craniofacial growth is the theory we study; orthodontics is the practice (Moyers, 1984a).

The diagnosis of a growing child is different from that of an adult. The fully grown skull is not simply a larger version of the infant form and the adult skull differs not only in size but also in shape from that of the child (Thilander, 1995). The child presents to the orthodontist with an unusual challenge to make an educated guess regarding the potential for favourable growth. Even minor changes in the growth pattern may facilitate treatment so that a poor prognosis can become a favourable one. Apparently growth makes the difference (Nahoum, 1975).

In the newborn, the upper and lower face heights are approximately 40% of their adult size. The gonial angle is so obtuse that an occlusal plane drawn through the gum pads passes through the condyle. By three years of age the cranium is almost 90% of adult size, whereas the face is only 65%. Although the midface grows in three dimensions, vertical growth appears to dominate. Maxillary growth follows, predicated by the principle of posterior growth and anterior displacement (Ranly, 2000).

Aetiological factors that cause a disturbance in the framework of normal craniofacial development achieve their undesirable effect within the equation presented by Dockrell in 1952 which states that: a cause acts for a certain period on a particular tissue to produce a result, favourable or unfavourable (Moyers, 1984b).

Genetic factors are obviously of prime importance in the development and expression of AOB. We resemble members of our own species and our own race. A Korean child adopted as a baby by an English couple will breathe English air, eat English food and speak English. His function will be wholly English, yet his face will be Korean (Mills, 1983).

The role of genetics as a determinant of AOB must therefore never be underestimated or ignored, as vertical skeletal dysplasias are inherited in much the same manner as horizontal skeletal dysplasias. The vertical dysplasias can be associated with either Class I, II or III skeletal relationships (Sassouni, 1969). As early as 1941, Brodie stated that the morphogenetic pattern, once established, does not change (Brodie, 1953). Divergent patterns of facial growth were found in subjects with AOB (Nanda, 1988) and in spite of treatment, some open bite patients continue to have insufficient vertical growth of the posterior face as the other components continue their normal growth (Nemeth and Isaacson, 1974).

An estimation of heritability can provide an indication of the relative importance of genetic factors. According to Hartsfield (2002), Lynch and Walsh have demonstrated that a trait with a heritability of 1 is said to be expressed without any environmental influence, whereas a trait with a heritability of 0.5 would have half its variability (from individual to individual) influenced by environmental factors and half by genotypic factors (Hartsfield, 2002). In a study of 79 sets of twins who had not undergone orthodontic treatment, the heritability for upper to lower anterior face height was found to be 0.71 while the heritability of anterior to posterior face height was found to be 0.66. Variables with a lower genetic determination are therefore more open to the influence of the environment of which treatment may be a component (Savoye *et al.*, 1998). However genetic factors that influence a trait may also influence its response to intervention (Smith and Balit, 1977).

Another study undertaken in Japan found the presence of Pro561Thr variant in the growth hormone receptor gene, known as the GHR P516IT allele, to be associated with decreased growth of mandibular height and can be a genetic marker for it. However, it is not clear if the effect of this allele is directly on the mandible and/or on the surrounding tissue matrix (Yamaguchi *et al.*, 2001).

As there are 1.4 million sites of variation in the human genome sequence and the genome varies from one individual to another, it would be pragmatic to understand nature and how it is influenced by the environment so that when faced with a problem the most effective treatment plan can be devised (Chakravarti, 2001).

On a morphologic level the vertical relationship of the jaws is befittingly described by the terms 'hyperdivergent and hypodivergent', which were introduced by Schudy in order to describe facial growth patterns. In his study of vertical growth patterns, Schudy mentions six anatomical components that participate in determining the vertical dimensions of the face (Schudy, 1964; Schudy, 1968). These are:

1. The mandibular condyles. Excessive upward and backward growth of the condyles will displace the chin down and back causing a long face and AOB. This type of condylar growth will be associated with obtuse gonial angles.
2. Vertical growth of the maxillary body. Through occlusal contact with the mandible, the latter is displaced downward, increasing anterior facial height.
3. Downward growth of the upper first molar. This increases the interjaw space and contributes to vertical facial dimension. Downward growth of the upper first molar is greater than the upper central incisor by a ratio of 2:1, and contributes to 70% of the interdental vertical height.
4. Upward growth of the mandibular first molars. They play a minor role and contribute only 30% to the interdental vertical height.

5. Maxillary incisors. These contribute the least to the vertical dimension when compared to the other five factors.

6. Mandibular incisors. The mandibular incisors are considered to be natures ‘great compensators’ in establishing functional and morphological harmony. They readily over erupt and procline to mask AOB and anteroposterior deficiencies.

There appears to be conflicting evidence when considering the morphologic basis of AOB. While Schudy (1968) categorically claims that the growth of the maxilla or lack of it, is the primary cause of vertical dysplasias, Bjork and Skieller (1983) have shown, with implant studies in untreated subjects, that the mandibular growth pattern is the primary aetiological factor with the maxilla’s role being secondary (Vallie, 1992).

Using metallic implants and cephalometrics, Bjork and co-workers gave a detailed account of midfacial growth. According to their findings, the maxilla is lowered by displacement approximately 43%, whereas the alveolar apposition contributes the remaining 57%. The nasal floor drops 61%, indicating that drift have added to the inferior movement caused by displacement. The orbital floor is lowered only 25% of the total, indicating that superior drift has counteracted some of the inferior displacement. The combination of drift and displacement doubles the vertical size of the maxilla between infancy and adulthood (Bjork and Skieller, 1977).

Support for the work of Bjork and co-workers can be found in a study by Isaacson *et al* who compared skeletal and dental relations in high angle, average and low angle cases. Their study demonstrated that while upper anterior face height on average is almost identical in all three groups, the lower anterior face height differs significantly (Isaacson *et al.*, 1971). This study also shows that there is a contribution to AOB posteriorly in the dentoalveolar development of the maxilla, and it is this clinically treatable factor that Schudy alludes to when he states that the maxilla is the cause of vertical dysplasias (Schudy, 1968).

Beals and Joganic systematically divided the craniofacial skeleton into two major regions, each of which has characteristic growth patterns (Beals and Joganic, 2004). The anterior region consists of the anterior cranial fossa, palate, maxillary arch, and body of the mandible while the posterior region comprises the middle cranial fossa, pharyngeal region and ramus of the mandible. Uncoordinated growth between these two regions can cause disharmony and disproportion in the vertical facial dimension.

The anterior cranial fossa matures as early as seven years (Ford, 1958) and acts as a template for the formation of the nasomaxillary complex while the posterior cranial region acts as a template for the pharyngeal space. Thus, the development of the skull base as a template for the face has a major effect on its spatial relationships, which in turn have an important effect on the functions of the face. Abnormal growth and development of this region can significantly affect the anteroposterior and mesiodistal dimensions of the airway causing functional compromises and morphological changes (Moss and Salentijn, 1969).

Early maturation of the cranial base relative to the rest of the head is useful and important for diagnostic cephalometrics. The determination of the relationships of the maxilla and the mandible to the cranial base and to each other is predicated on the stability of some anatomic plane of reference (Ranly, 2000). The angle of flexure between the anterior and posterior regions of the cranial base impacts on the vertical relationship between the two jaws (Klocke *et al.*, 2002b). As an individual matures, the midface continues to advance downward and forward beyond the age when true anterior cranial base ceases growth.

Maxillary growth and its contribution to anterior vertical dimension is also subjected to the influence of the nasal septum which is part of the primitive nasal capsule (Scott, 1954). Latham described a septo-premaxillary ligament which he claims to be the link between these two structures, transmitting the force from the growing septum as tension to the maxilla (Latham, 1970).

According to Thilander, bone growth is controlled by growth areas and not by active growth centres. The transformation of cartilage, sutural deposition, and periosteal remodelling are the basic phenomena involved in growth mechanisms. This results in three-dimensional changes in the size and shape of the nasomaxillary complex. The growth rate also varies at different times during the development of the child and continues to a much later age than what had previously been believed (Thilander, 1995).

The growth of the body of the mandible lags behind maxillary growth just as maxillary growth lags behind growth of the anterior cranial fossa. The mandible is held in a sling of muscular tissue and is connected distally to the cranium by the temporomandibular joint (TMJ) and mesially by the developing dentition. It is explicable therefore, that these two attachments function in tandem around the cranium and that any abnormality of either the TMJ or the developing occlusion will influence mandibular growth, masticatory function and facial appearance. The mandible like the maxilla is derived from the first branchial arch and is formed through a process of intramembraneous ossification, and similar to the nasomaxillary complex, the mandible grows downward and forward mainly as a result of primary and secondary displacement of the whole bone. Deposition occurs on the posterior margin of the ramus, with simultaneous resorption along its anterior contours. The only direct connection the mandible has with the rest of the head is through the articulation of the condyles with the glenoid fossa and the occlusion of teeth (Ranly, 2000).

Although an imaginary occlusal plane of the gum pads passes through the condyle, the plane of the articulated primary teeth passes below it. When viewed in a lateral cephalogram, the shape change of the average mandible is ongoing to adulthood. The posterior border of the ramus becomes more vertical and the lower border of the mandible becomes more horizontal. As a result, the gonial angle decreases with growth. The change in shape of the mandible is a result of the way this bone grows downward and forward and is a prime example of posterior growth-anterior displacement. The pace of mandibular forward growth exceeds that of the maxilla in most people so that the severe retrognathia of infancy is, for the most part overcome. Although the ANB difference between the maxilla and mandible may approach 15° at birth, by adulthood, the average mandibular deficit has been reduced to only 2° (Ranly, 2000).

Ramus height has also been speculated as a cause of AOB (Diamond, 1944; Wylie, 1946) and it has been shown that adult subjects with Class II and Class III AOBs have a short mandibular ramus (Ellis and McNamara, 1984; Ellis *et al.*, 1985).

On a logarithmic spiral the position of the foramin ovale was shown to be lower on this spiral in AOB subjects, reminiscent of a downward and divergent mandibular growth pattern. AOB was found to be a condition associated with specific special and developmental abnormalities of the oral functioning space acting as a capsular matrix (Moss and Salentijn, 1971).
Clinicians should however be vigilant of an observed deformation of the orofacial skeleton and its aetiological factors, as in AOB they are distinctly different (Moss and Salentijn, 1971). The periosteal matrix is responsible for the changes in shape of the units which make up the facial skeleton such as the effect of the temporalis on the coronoid process while the capsular matrix is responsible for the translation of parts e.g. enlargement of the oral cavity will cause displacement of adjacent structures.

Vertical growth of the mandible is essential to maintain facial proportion and harmony. Not only does the mandible need to keep pace with descent of the maxilla, but it must also maintain the interocclusal vertical dimension, which has been shown to be one of nature's norms. There is still further growth needed inferiorly to accommodate the teeth and alveolar processes. In the infant skull, the occlusal plane of the maxilla lies above the mastoid and the mandibular plane lies parallel to it. In the adult, the occlusal plane of the maxilla has dropped to the level of the mastoid, which, in turn, has descended, whereas the mandibular plane lies significantly below it (Figure 1). Significant changes in the position of gonion and the gonial angle between infancy and adulthood are also portrayed.

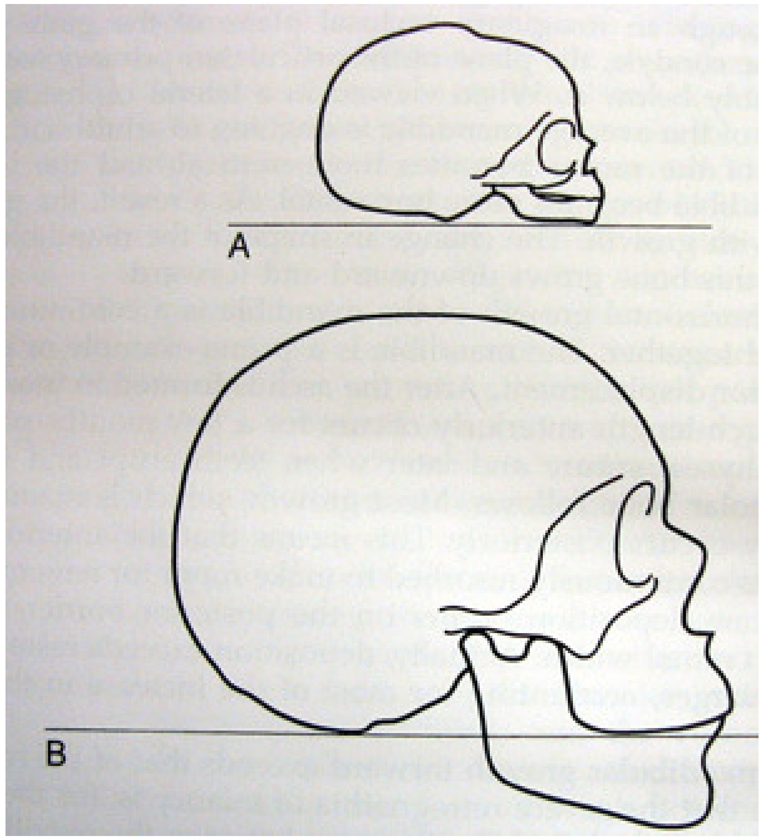

Figure 1. Downward and backward mandibular growth from infancy to adulthood (Ranly, 2000)

As the mandible is attached to the cranium by way of the bio-mechanically active TMJ it is expected that with mandibular growth and occlusal development, rotation of the mandible will occur. The mechanism underlying the rotation of the jaws is obscure. It was previously believed that the condylar cartilage was the cause of mandibular displacement on the premise that the condyles govern the growth of the entire mandible (push theory). However, it has subsequently been found that the condyles only function locally and is not a type of control centre with direct control over the growth fields. According to growth theories mandibular displacement is the primary process and results from enlargement of the soft tissues. The type of mandibular rotation is determined by those structures that start the displacement of the mandible, and the direction of condylar growth is a secondary phenomenon to adapt for the space in the temporomandibular region (pull theory) (Enlow, 1990). Therefore any longstanding change in mandibular position will alter condylar morphology and alter the three dimensional position of the mandible.

This adaptive ability of the condyle is linked to the fact that the mandible is formed from secondary cartilage and exhibits histological, biochemical, anatomic and functional differences from primary cartilages. There is little extracellular matrix and a plethora of hypertrophic cells. In contrast to other cartilages, no cell division occurs in the chondroblasts of the condyle. Cells to replenish the conversion process are derived from a perichondrium-like tissue, which also serves as the articular surface. Mesenchymal cells of this fibrous covering undergo mitosis, then differentiate into chondroblasts (Ranly, 2000). The behaviour of the condylar cartilage imparts two special properties not seen in other cartilages. First, the condyle never loses its potential to grow. From birth to about 20 years of age, the fibrocartilagenous cap gradually diminishes as the proliferative capacity slows, until, when growth ceases, there is a thin inactive zone of cartilage covered by fibrous perichondrium. This maturation stage differs from most cartilage growth zones, where bone completely replaces the cartilage. As a result the sleeping zone can be reawakened by growth hormone, as seen in acromegalics, whereas mature growth plates cannot. Second, the perichondrium is greatly influenced by mechanical forces, and new cartilage is formed, at least in part, in response to function.

Craniofacial biologists and clinicians are therefore in agreement that the condyle is a growth site and not a growth centre. While a growth centre is cartilaginous tissue that can expand interstitially with sufficient force to separate adjacent structures, a growth site is incapable of tissue separating growth and simply adds new tissue in response to other forces (Ranly, 2000). Rushton pointed out that the cartilage of long bones grew by division of the chondrocytes whereas the condyle grew by apposition of new cells at the upper surface (Rushton, 1948). This adaptive capacity of the condylar cartilage has an important bearing on the causation and management of open bite deformities.

While condylar remodelling is the product of several factors, it is important to understand how the direction of condylar growth can influence mandibular position in the vertical plane. At birth the obtuse shape of the mandible and rudimentary nature of the condyles are essential for suckling activities. With the eruption of teeth, the rami become more upright and the gonial angles become more acute (Figure 1). It has been demonstrated with metallic implants and serial cephalograms that the condyles grow in a variety of directions. When the condyles grow mostly in a posterior direction the mandible is thrust forward and the distance from condyle to chin point increases in length. In these individuals the gonial angle remains obtuse, and lower anterior face height is increased contributing to the likelihood of an AOB. When the condyles grow upward and forward, the mandible grows with the centre of rotation in the incisal area. The result is an acute gonial angle and a short effective length between the condyle and the chin resulting in a closed or deepbite (Bjork and Skieller, 1983).

Any condition afflicting the condyle will alter the symmetry, anteroposterior and vertical orientation of the mandible. In cases of ankylosis, the mandible fails to reach its normal length, while in unilateral ankylosis the unaffected side continues to grow (Engelsma *et al.*, 1980). Flores-Mir (2006) also investigated the association of the TMJ disc status and craniofacial growth using a retrospective study. They found that TMJ disc abnormality was associated with reduced forward growth of the maxillary and mandibular bodies and that TMJ disc abnormality was also associated with reduced downward growth of the mandibular ramus. This could result in a short ramus height (Klocke *et al.*, 2002a) and contribute to the development of AOB (Flores-Mir *et al.*, 2006). TMJ degeneration associated with displaced disks might be a cause leading to the development of acquired anterior open bite (Chen *et al.*, 2005).

AOB was also investigated in women with internal derangement of the TMJ where it was found that cephalometric characteristics, such as a decrease in posterior facial height, decrease in ramus height, and backward rotation and retruded position of the mandible, are associated with internal TMJ derangement (Byun *et al.*, 2005). Radiological evidence of condylar erosion has also been found in three patients with AOB and associated facial arthromyalgia (Stewart and Harris, 1996).

At a molecular level, research in the field of craniofacial development is focused on finding a balance between tissues (e.g., facial epithelia, neuroectoderm, and neural crest) and molecules (e.g., bone morphogenetic proteins and fibroblast growth factors) that play a role in sculpting the face. Neither the tissues nor molecular signals are able to act in isolation. In fact, molecular cues are constantly reciprocating signals between the epithelia and the neural crest in order to pattern and mould facial structures. Recently, it has been proposed that this cross talk is often mediated and organised by discrete centres within the tissues that are able to act as a self-contained unit of developmental potential (e.g., the rhombomere and perhaps the ectomere). Whatever the molecules are, and however these tissues interpret them, it seems that there is a remarkably conserved mechanism for setting up the initial organisation of the facial prominences between species. Brugmann *et al* refers to it as the ‘bauplan’ and regardless of species, all vertebrates appear to have the same basic blueprint (Brugmann *et al.*, 2006).

Having a sound understanding of the principles of craniofacial growth will empower orthodontists, dentists and paediatricians to readily identify facial growth problems in the anteroposterior, vertical, and transverse dimensions through a simple method of clinical evaluation. These problems, if untreated, can result in aesthetic and functional concerns and must be managed by various means within restricted time frames. Because facial growth is the result of the interaction of genetic and environmental factors (some of which are functional), growth modification may be a possibility. Some problems may be camouflaged or treated by combined surgical and orthodontic means.

Continued growth in early adulthood may enhance or detract from treatment results obtained in childhood or adolescence (Vig and Fields, 2000).

The above review on craniofacial growth brings to light some interesting aspects that can be employed by the clinician in the management of AOB. Genetics forms the blueprint of an individual's mould and while the hereditary potential of the anterior face is 70% and that of the posterior face is 60%, it is not known how variable these factors are to epigenetic influences. While the anterior cranial base matures early and sets a reliable reference for cephalometric analysis, other aspects of the facial skeleton such as the TMJ and glenoid fossa, the gonial angle, the mandibular ramus, the alveoli and the upper and lower molars are amenable to external influences and until growth is not fully complete the clinician should utilise these components to resolve an AOB.

Habits and the neuromuscular system

Abnormal form will elicit abnormal function, which can manifest itself as a compensatory function of the tongue and lips. An oral seal is required to swallow comfortably and efficiently. The patient with a backward-rotating growth pattern, an overbite of zero or less and lips barely adequate to cover the teeth comfortably, exhibits a morphologic configuration which requires extreme activity of the tongue and mentalis muscle to effect the necessary circumoral seal during swallowing (Speidel *et al.*, 1972).

It is therefore common and expected that all open bite patients demonstrate tongue thrusting during swallowing. This is necessary to create an oral seal during deglutition (Nahoum, 1975). Skeletal open bite subjects revealed tongue tips ahead of, and above the lower incisor teeth with the mandible in the rest position. Tongue posture at rest in skeletal open bite subjects appeared to be related to incisor position (Lowe *et al.*, 1985).

An interesting finding in some patients with a skeletal open bite who are pernicious tongue thrusters is a lack of the gag reflex (Whitman, 1951). In tests of stereognosis these patients were unable to identify different shaped objects with the tongue and some of these subjects could not execute alternate repetitive movements with the tongue (Bloomer, 1967). Tongue thrusting is a factor in AOB and is sometimes associated with tactile hypesthesia and disorders of oral neuromotor activity (Nahoum, 1975).

Two types of tongue thrust associated with swallowing in patients with AOB have been described:

1. Primary (endogenous) tongue thrust
2. Secondary (adaptive) tongue thrust.

Nearly all tongue thrust falls into the second category whereby the tongue is thrust forward on swallowing as an adaptive response to the presence of an AOB to prevent food/liquid/saliva escaping from the front of the mouth. Endogenous tongue thrust is often associated with excessive circumoral muscular contraction on swallowing and treatment of an AOB in patients with an endogenous tongue thrust should be cautiously approached as relapse will almost certainly occur (Subtelny, 1965).

It has been found that anterior tongue thrust is more likely to enhance rather than cause AOB (Speidel *et al.*, 1972). Several authors have shown that the balance between the lingual and buccal/labial forces on the teeth is not equal – tongue pressure exceeds that of the lips (Proffit and Fields, 2000). Tongue pressure is however not regarded as the more important factor (Neff and Kydd, 1966), instead , the resting position of the tongue was considered more important in AOB aetiology than the actual swallowing activity (Proffit and Mason, 1975).

There is also evidence, which suggests that the tongue readily accommodates to its environment. An informal evaluation of postsurgical results in over 100 cases has revealed that there has been no marked flaring or spacing of teeth in any of the cases where the tongue was crowded into a smaller postsurgical environment (Speidel *et al.*, 1972).

A neurosensory rationale to the development of open bites has also been suggested by Rubin and Weisman (1971) who found that when teeth were extracted in monkeys, the tongue movement was at first a means of soothing the surgical wound but became habitual after a period of time, and as this occurred during the development of the animal, it became an important environmental factor in the production of an open bite deformity (Rubin and Weisman, 1971).

Rudolph (1997) makes an interesting observation about the sensitivity of anterior teeth and tongue position as factors in the aetiology of AOB. He suggests that mouth breathing as a result of nasal obstruction causes evaporation of the saliva, which would lower the temperature over the incisors, and if these teeth were sensitive to begin with, they would experience more pain. To circumvent this, the tongue repositions itself over these sensitive teeth and if held in this position constantly, it would cause an AOB (Rudolph, 1997).

Nearly all patients can be taught to swallow without tongue thrusting on a voluntary or conscious level. Deglutition however, has involuntary and reflex components, which are initiated on a subconscious level. Swallowing occurs 1200 to 1500 times per day, and the patient is not aware of this activity (Barrer, 1974; Kydd and Neff, 1964; Neff and Kydd, 1966). There is also limited evidence that myofunctional therapy can benefit skeletal AOB (Barrer, 1974; Tully, 1969).

Aberrant tongue function and speech also improved in the absence of tongue or speech therapy during the postoperative period following orthognathic surgery. Periodic clinical and cephalometric evaluation demonstrated generally good stability of treatment results for the period of study (Rubin and Weisman, 1971).

Thumb or finger sucking is another serious habit in the development of AOB. The incidence of digit sucking is around 30% at 1 year of age reducing to 12% at 9 years and 2% by 12 years and the most persistent suckers were found to be females (Brenchley, 1991).

Thumb or finger sucking in a child up to the age of four or five years can be disregarded and does not result in a permanent form of malocclusion. However, persistent thumb sucking extending into the mixed (Figure 2) and permanent dentition may cause permanent changes resulting in AOB and requiring active treatment (Fletcher, 1975; Klein, 1971; Popovich and Thompson, 1973).

Figure 2. Anterior open bite in the mixed dentition

Some children actively suck their thumb (Figure 3) or fingers, while others just allow their thumb to rest passively in the mouth. Some may actively bite their fingers (Figure 4). Variations in the intensity and continuity of the habit will result in AOB of varying severity (Figure 5). As it is a socially unacceptable habit, the incidence of thumb sucking decreases with age and as a consequence so too, does tongue thrusting and AOB.

Figure 3. Abrasion of thumb caused by sucking

Figure 4. Finger biting habit

Figure 5. Anterior open bite in an adult as a result of finger biting

Cephalometric analyses of patients who sucked their thumbs showed an increased incidence of skeletal Class II jaw relationships. This is related to the action of the thumb which encourages the forward movement of the maxilla while restraining the mandible (Mizrahi, 1978).

Children who are unable to breathe through their noses are forced to lower their mandibles in order to achieve oral respiration. This permits the upper alveolar process to develop downwards causing a further lowering of the mandible and gradually producing a typical backward rotation thereof (Linder-Aronson, 1970).

An enlarged tongue and tonsils can contribute to tongue thrusting (Subtelny and Sakuda, 1964). Subjects with sleep apnoea demonstrated several alterations in craniofacial form that may reduce the upper airway dimensions and subsequently impair upper airway stability (Lowe *et al.*, 1986). Sleep apnoea subjects showed a posteriorly positioned maxilla and mandible, a steep occlusal plane, over erupted maxillary and mandibular teeth, proclined incisors, a steep mandibular plane, a large gonial angle, high upper and lower facial heights, and an anterior open bite in association with a long tongue and a posteriorly placed pharyngeal wall (Lowe *et al.*, 1986).

The efficacy of masticatory occlusion in AOB subjects has been reported to be less than that found in normal occlusion (Hixon, 1972). In an electromyographic assessment of increased and decreased facial heights, it was found that individuals with increased facial heights had weaker masticatory muscle activity (Moss, 1980). Electromyographic techniques have also been used to demonstrate that masticatory forces are greater in cases exhibiting forward rotation of the mandible than those showing backward rotation (Moller, 1966). Low electromyographic activity threshold values for the genioglossus muscle were correlated with negative overbites, under erupted maxillary and mandibular incisors and low total face heights. Low threshold values for the masseter muscle were also associated with low overbite measurements (Lowe, 1980).

Unusual generalised muscle weakness associated with scoliosis and AOB have also been reported (Proffit *et al.*, 1968). The decrease in tonic muscle activity that occurs in these muscular dystrophies can cause the mandible to rotate down and back away from the facial skeleton (Proffit and Fields, 2000). AOB may also be related to tongue positioning associated with abnormal posture of the head.

According to Mills (1983), Kreiborg conducted a longitudinal study of a child suffering from progressive muscular dystrophy. Using suitably placed implants and lateral cephalograms, it was found that the mandible rotated downward and backward as the muscles became weaker. As the teeth and alveolar process developed to fill the space posteriorly, an open bite developed and progressively worsened (Mills, 1983).

The literature is replete on the pathophysiology and clinical effects of abnormal orofacial muscle patterns and clinicians have at their disposal mechanical appliances to combat detrimental habits. Attention should also be given to the root causes of endogenous habits as these are often more difficult to manage and susceptible to relapse. In these cases clinicians should not hesitate to enlist the intervention, assistance and collaboration of a clinical psychologist in treating an AOB patient.

Dentoalveolar factors

The lips and tongue are among the earliest muscles to develop in utero (Scott, 1954) and correspondingly start to contract early since they are the first muscles to be used by the newly born infant. Consequently the alveolar processes grow under the influence of these muscles from the earliest stages. The alveolar process and teeth continue to develop vertically until they meet their antagonists. In individuals with a high mandibular plane angle, the incisor alveolar process will overdevelop to a considerable extent, but not indefinitely, and if the distance which it is required to span is too great, an open bite will develop (Mills, 1983).

The development of the alveolar processes is largely an in-filling mechanism and is much more subject to its immediate environment. According to Moss the various spaces within the head are not simply what are left over when the bones and soft tissue have formed. Their development is a closely coordinated growth pattern that has evolved phylogenetically to fulfil functional demands (Moss, 1968).

Vertical growth of the alveolar process is rapid during tooth eruption and exceeds the lowering of the roof of the palate threefold. Transversal growth occurs by separation of the two maxillary bodies at the median suture, i.e. lateral displacement, and bone resorption on the lateral walls of the nasal cavity. During tooth eruption the alveolar process increases in transversal dimension due to the buccal eruption path of the premolars and molars (Thilander, 1995).

Studies on occlusion show that the amount of overbite in the permanent dentition is not related to the amount of overbite in the deciduous dentition

(Moorrees, 1959). Also, the anterior space between the gum pads bears no relationship to the future development of open bite (Sillman, 1940).

Among the aetiological factors involved in the development of AOB the most frequently implicated cause is the overeruption of the upper molars. Many clinicians have described the importance of reducing the vertical dimension of the upper posterior segments or at least prevent extrusion of the posterior molars during treatment (Dellinger, 1986; Frost *et al.*, 1980; Iscan *et al.*, 1992; Kuhn, 1968; Schudy, 1968).

Increase in the posterior vertical dimension can also be due to mesial tipping of the molars in premolar extraction cases. As the molars tip mesially about their centre of rotation, the distal cusps elevate above the occlusal plane and come into premature contact with the molars of the opposing arch. While high pull headgear can restrict the extrusion of the upper molars, and limit the severity of AOB, it does not prevent extrusion of the mandibular molars (Proffit and Fields, 2000).

From an orthodontic perspective special attention should be paid to the dentoalveolar units in AOB patients as the anterior region is vulnerable to external influences and compensatory remodelling. A clinical method to assess dentoalveolar excess or deficiency is to observe the amount of incisor display with the lips in repose. Increased incisor display and a gummy smile are indicative of dentoalveolar compensation while a decrease incisor visibility can be the result of ongoing intermittent interferences inhibiting the eruption of these teeth.

Other causes

In a study of children at special schools, it was found that a higher incidence of AOB exists in mentally retarded and mongoloid children (Gershater, 1972). Localised AOB may also be associated with cleft lip and palate, acromegaly or trauma to the facial skeleton such as condylar fractures or Le Fort fractures of the maxilla (Burford and Noar, 2003).

Poor mechanics during fixed appliance treatment may cause extrusion of the molar teeth or 'hanging' palatal cusps, which open the bite. Failing to prevent overeruption of second molars when bite planes or functional appliances are used may also give rise to an AOB.

Clinical presentation

Diagnosis is the basis for determining clinical action, usually in the face of incomplete evidence since the examining officer can never know everything about the patient. All orthodontic diagnoses contain an element of prediction. The orthodontist analysing craniofacial morphology must not only decide whether malocclusion is present or not, but also whether any presently observed variation in morphology may develop into future problems (Moyers, 1984a).

The clinical picture of AOB will largely depend on, or vary with the changes brought about by the interplay of aetiological factors on the orofacial complex. Patients with AOB have a so called 'long face syndrome' with a more posteriorly directed growth pattern of the mandibular condyle. The direction of mandibular growth as expressed at the chin is mostly vertical. The malocclusion most commonly noted in this type of patient is an anterior open bite often in combination with Class I or II malocclusion, although AOB in Class III's have been observed (Figure 6). The associated dental eruption pattern of the posterior teeth is generally vertical and in some instances the anterior teeth may even become more retroclined with time (Nielsen, 1991).

Figure 6. Anterior open bite in a Class III patient

The patient with an AOB of skeletal origin may present with a straight, concave or convex profile. Increased lower facial height is obvious. From the frontal view the face appears long and thin. At rest, the lips are incompetent and the patient may make a conscious effort to hold the lips together with evidence of lip strain. Antegonial notching is present with a steep Frankfort mandibular plane (Beane *et al.*, 2003; Burford and Noar, 2003; Lopez-Gavito *et al.*, 1985; Tsang *et al.*, 1998).

One of the inevitable characteristics of ageing is diminished incisor display. In the adult patient, the amount of upper incisor display decreases with age whereas the lower incisor display increases. In general, males show less upper incisor (1.91 mm) whereas females show more upper incisor (3.40 mm) at rest and Whites exhibit more upper incisor than do Blacks at rest (Graber and Vanarsdall, 2000). In AOB patients, particularly those with a dental AOB, the upper and lower incisal edges bow away from each other resulting in less incisal display at rest.

Generally in AOB cases of skeletal origin, the upper lip is short and there is greater visibility of the upper teeth and gums when the patient is smiling, however, in cases of AOB of dento-alveolar origin, there may be less visibility of incisors as a result of intrusion caused by the placement of a foreign object between the incisors.

Intraorally there may be collapse in the coronal plane of the upper arch characterised by a narrow maxilla, a steep palate, posterior cross bite and flaring of the upper incisors. While the upper incisors may be spaced, the lower incisors are usually retroclined and crowded. Generalized dental crowding may also be present and occlusal contact limited to the buccal teeth distal to the first premolars depending on the severity of the AOB. The further distal in the dental arch the occlusal contact occur, the worse the AOB will be, since the first and second permanent molars act as a fulcrum (Nahoum, 1975; Nahoum, 1977) and 1mm of bite opening in the posterior region will create a 3mm bite opening anteriorly (Kuhn, 1968).

The shape of the maxillary arch will show characteristic features related to the aetiology. If the AOB is due to a foreign body habitually being placed between the incisor teeth, then the open bite will be localised to the particular teeth involved. The incisors will fail to erupt to the same occlusal level of the other teeth in the arch. When the malocclusion is a result of a thumb sucking habit then the upper incisor teeth may be proclined resulting in a V-shaped upper arch. Due to the increased buccal pressure exerted on the molar teeth by the cheeks during sucking, there is a narrowing of the arch in the molar region. The mandibular teeth are slightly depressed and lingually inclined (Moyers, 1984c).

In occlusion, the anterior open bite has a characteristic appearance. The opposing molars and premolars are in contact, the canines may or may not be in contact and the lateral and central incisors are in a definite open bite.
The mouth has the appearance of a ‘fish mouth’ (Mizrahi, 1978). On swallowing there is characteristic anterior tongue thrust with the tongue coming forward into the incisal opening to form a seal with the lower lip.

Teeth also facilitate but are not essential in the articulation of a few labio-dental and linguo-dental phones. As with masticatory efficiency, the space between the upper and lower incisors in AOB subjects, mostly affects the sibilants ‘S’ ‘Z’ and ‘F’ (Hixon, 1972). When comparing children with AOB and normal occlusion it was found that the former differed in their articulatory ability and that the compensatory adjustments in speech articulation observed in adults with AOB had not occurred in the 10- to 15-year-old children who were studied (Heihgton, 1967).

The gingiva may be inflamed and hypertrophic due to mouth breathing while the tongue can have scalloped borders and appear large. True macroglossia is rare (Graber and Vanarsdall, 2000).

A photometric study of young adults revealed some interesting facts and raised a pertinent question about facial proportions and head posture. Persons who were asymmetric compensated for their appearance by changing head posture relative to the ground, so that in the frontal plane, the interpupillary axis and the occlusal plane were parallel to the ground (Ferrario *et al.*, 1993).While this compensatory posture can mask asymmetrical discrepancies the question arises as to how individuals carry head position to compensate for disproportions of the face in the vertical dimension?

Treatment

The aim of orthodontic treatment is to achieve the best possible outcome in the shortest possible time with the least biological, social and financial cost. In order to realize this objective, the timing of treatment is of essence, and the clinician must therefore appreciate and understand craniofacial growth so that the treatment plan and the mechanics can be optimised in method and duration.

From the patient's perspective, good orthodontics is that which produces the desired result at the lowest possible cost in the least amount of time. Their understanding is usually based on aesthetics and self-image, cost, and time and not on dental relationships or cephalometric values.

The final treatment outcome must be aesthetically pleasing, functionally efficient and stable. Treatment of patients with AOB is difficult and prone to relapse due to habit recurrence or poor retention compliance (English and Olfert, 2005). Treatment planning requires a thorough history of the AOB and good clinical judgement based on a sound knowledge of craniofacial growth and the aetiology of AOB. It should attempt to correct dental and skeletal dysplasias. Unfortunately, some of the causes of these malformations such as genetic, growth, neuromuscular and habitual factors are difficult to manage and eliminate and the feasibility of treating all open bites is sometimes questionable (Subtelny and Sakuda, 1964).

Approximately one third of malocclusions in the deciduous dentition develop into good occlusions in adulthood (Sanin *et al.*, 1970). In a sample of AOB subjects studied from 7-9 years old to 10 -12 years old it was found that 80% of AOBs auto-correct (Worms *et al.*, 1971). In contrast, a slight decrease in overbite was also found from 12 to 18 years of age (Bergersen, 1988). In another sample of 14 subjects with AOB at five years, it was found that 13 subjects developed a positive overbite at age 12 (Klocke *et al.*, 2002a). The mandibular plane angle relative to the cranium also tends to close spontaneously from the mixed dentition period to maturity in the absence of treatment (Baumrind *et al.*, 1992).

Since the vast majority of these patients are children in the transitional dentition stage (Figure 7), it is conceivable that the rate of eruption of the anterior teeth had slowed down temporarily. Eruption does not occur at a constant rate and may take place in spurts. Consequently, these subjects may be referred to as having “transitional” or “pseudo” open bites (Nahoum, 1975).

Figure 7. Resolution of a "pseudo or transitional" open bite

Four treatment modalities (Mizrahi, 1978) are suggested namely:

1. Myofunctional therapy.
2. Orthodontic mechanotherapy.
3. Orthognathic surgery.
4. Combination therapy involving two or more of the above.

Myofunctional Therapy

Functional appliances were first introduced into North America in the mid 1950s by Dr. Egil Harvold who was brought to North America by Dr. Robert Moyers (Woodside, 1998). There are eight elements that can be influenced by functional appliances namely:

1. Dentoalveolar changes
2. Restriction of forward growth of the midface
3. Stimulation of mandibular growth
4. Redirection of condylar growth
5. Deflection of ramal growth
6. Deflection of mandibular growth
7. Induction of bone remodelling
8. Adaptive changes in the glenoid fossa location

Postnatal craniofacial development is determined by both exogenous and endogenous factors that may result in morphological and functional muscle changes. Functional appliances attempt to treat skeletal malocclusions through targeted exercise and to prevent an undesirable development of the dentition and the craniofacial structures. However, the success of the treatment and the stability of the outcome are not always predictable. Animal experimental studies have succeeded in simulating functional jaw orthopaedics and have demonstrated muscle remodelling processes at the genetic level (Gedrange and Harzer, 2004). Functional appliances have also been employed to treat open bites on the theory that the open bite malocclusion was caused not only by a skeletal discrepancy, but also involved faulty postural activity of the orofacial musculature (Frankel and Frankel, 1983).

Orthodontic treatment using myofunctional therapy is still directed toward pre-adolescent and adolescent patients, in spite of the fact that the percentage of adult patients has increased in recent years. This form of treatment has a greater chance of success with younger patients as they are undergoing significant growth changes in their occlusions, facial skeletons, and profiles. Several components that can be dealt with in the prediction of craniofacial changes include the direction, the magnitude, the timing, the rate of change, and the effects of treatment. Orthodontists, in general, are well informed regarding the effects of orthodontic treatment on the patient, but are not yet able to accurately predict the direction, timing, and magnitude of the facial changes that occur with growth in any single individual (Bishara, 2000).

The growth rate varies at different times during the development of the child. The processes of facial growth and changes in the dental arches continue to a much later age than had previously been realized (Thilander, 1995). Maturity indicators can enable the clinician to identify optimal timing for the treatment of dentoskeletal disharmonies in all three planes of space (Baccetti *et al.*, 2005; Fishman, 1987). In a Cochrane database of systematic reviews it was confirmed that skeletal maturity as determined by hand-wrist radiographic analysis was well related to overall facial growth velocity. It was also found that maxillary and mandibular growth velocities were related to skeletal maturity, but their relationship was less compliant than that of overall facial growth (Flores-Mir *et al.*, 2006).

Treatment of a dental AOB is mainly directed at the control, management and elimination of the aetiological factor. In young children, the open bite usually closes when the thumb sucking habit is stopped. In older patients it may be necessary to actively close the open bite by using fixed appliances with anterior vertical elastics.

Using a palatal crib on either a fixed (Figure 8) or removable appliance (Figure 9), the thumb sucking or tongue thrusting habit can be brought under control (Graber, 1963; Klein, 1971; Parker, 1971; Subtelny and Sakuda, 1964). The design of the appliance is not as important as the actual purpose, which is to provide the mechanical means to physically prevent the thumb from taking up a comfortable position in the mouth. Huang *et al* (1990) used a fixed intraoral appliance with spurs that are directed downward and backward and found it to increase the overbite in both growing and non growing subjects with a zero percent relapse in non growing individuals and 17,4 percent relapse in growing patients (Huang *et al.*, 1990; Justus, 2001).

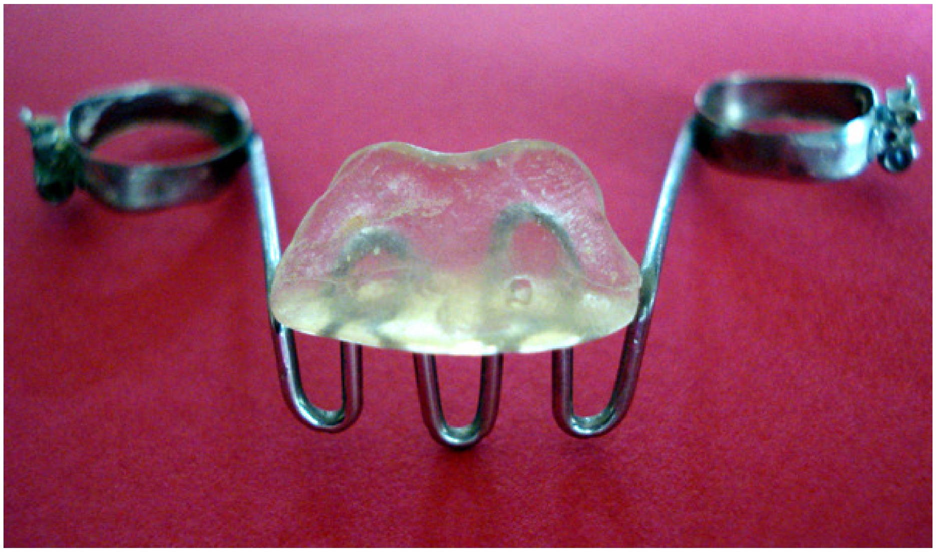

Figure 8. A fixed tongue crib

Figure 9. A removable tongue crib

It is not always easy to determine whether the thumb sucking habit is empty or meaningful. A safe and diagnostic approach would be to provide a removable palatal crib. An empty habit should cease within two to three months with this appliance. A child who wants to continue with the habit in spite of all dissuasion efforts will remove the appliance and continue the habit. These patients require psychological counselling (Mizrahi, 1978).

Willingness and cooperation on the patients' behalf is a prerequisite for the success of any treatment. In patients with an 'empty' habit, the appliance will serve as a reminder and will help the child to break the habit. If the habit is 'meaningful', a more psychologically orientated treatment approach should be adopted (Klein, 1971).

There are numerous functional appliances that have been used to treat AOB. Chin cap therapy has been used to treat a skeletal AOB with some success (Graber and Vanarsdall, 2000). A modified Thurow appliance consisting of the usual occlusal splint covering primary molars and permanent molars or premolars but excluding the incisors, to which has been added an expansion screw and a high pull headgear has also been used as a functional appliance for treating AOB (Stuani and Stuani, 2005).

The Bluegrass appliance (Figure 10) is a fixed device that has been used with considerable success in overcoming the habit of thumb-sucking and relocating tongue position at rest (Greenleaf and Mink, 2003; Haskell and Mink, 1991). The use of a palatal crib with a high-pull chin cup therapy has also been advocated (Torres *et al.*, 2006).

Figure 10. A modification of the Bluegrass appliance (www.gcortho.com/habit.htm)

Appliances described in this section initiate closure of the open bite as a result of an elimination of a thumb sucking habit or a retraining of the tongue function.

Clenching exercises is another way of controlling vertical dimension and can assist in the closure of open bite malocclusions (English and Olfert, 2005). Patients with AOB have been found to exhibit weakness of the masticatory muscles (Proffit *et al.*, 1968) while patients with a deepbite show significantly higher masticatory muscle activity (Kayukawa, 1992). Based on this it has been suggested that orthodontic treatment should include some type of dynamic myofunctional therapy in addition to the correction of static structural abnormalities (Kayukawa, 1992).

Orthodontic Mechanotherapy

There are a number of recommended orthodontic techniques for the treatment of the patient with an open bite. Most of these procedures are designed to intrude posterior teeth or at least prevent molar eruption or extrusion (Schudy, 1968) in an attempt to reduce or control anterior facial height.

More specifically, mechanics should be directed at preventing extrusion of upper posterior teeth, preventing eruption of lower molars, maintaining or creating a curve of Spee, avoiding both Class II and III elastics as they cause posterior molar extrusion, extracting the more posterior teeth if needed, and avoiding anterior vertical elastics as the incisor teeth are often already over erupted (Beane, 1999). Any form of mechanotherapy, which would depress the upper molars and encourage the upward and forward rotation of the mandible should also be considered. The most common methods of orthodontically correcting an AOB involve high pull headgear, lingual arches and posterior bite blocks.

Forward movement of the terminal molars allows the mandible to hinge upward and forward. It has been postulated that 1 mm of intrusive molar movement of the terminal molars results in approximately 3 mm of bite closure by mandibular counter clockwise rotation (Kuhn, 1968).

Levelling of the posterior teeth must be avoided and maintenance or creation of the curve of Spee is desirable. Banding of second molars should be avoided because they tend to extrude when engaged to the archwire. If second molars must be banded, they should be banded or bonded with the molar tubes in the occlusal third of the clinical crown, or the archwire should be stepped gingivally to avoid extrusion of the terminal molar on the appliance (Beane, 1999; Burford and Noar, 2003; Mizrahi, 1978).

A multilooped edgewise archwire technique (MEAW) has also been proposed for the treatment of AOB (Kim, 1987). This technique uses a combination of multilooped .016 x .022 inch stainless steel archwires and heavy anterior elastics to achieve molar intrusion and simultaneous incisor extrusion. The upper archwire of this appliance has an accentuated curve of Spee while the lower archwire has a reverse curve, which would worsen the open bite by intruding of the incisors and extruding the second premolar and molar teeth. This effect is countered by the use of strong anterior elastics producing a force of 50 gram when the jaw is closed and 150 gram with moderate opening. Patient compliance with this appliance is paramount in order to prevent aggravation and deterioration of the AOB.

Instead of using the MEAW, which requires advanced wire bending skills, a reverse curve of Spee in the upper archwire and an accentuated curve in the lower may be bent in elastic NiTi wires to extrude the upper and lower anterior segments. Palatal and lingual arches are incorporated into the appliance to control the molars.

Apart from the use of archwires and vertical elastics (Rinchuse, 1994), magnets have also been used for the treatment of AOB (Darendeliler *et al.*, 1995). These exert a repulsive force in the molar and premolar area and limit eruption or cause intrusion of these teeth. Vertical intraoral elastics in the incisor region should be used with caution, as dentoalveolar height is finite. A patient with a skeletal AOB should not be treated by elongation of the anterior teeth if these teeth are usually already in supraversion.

There are numerous reports in the literature concerning dentoalveolar characteristics of open bite malocclusion and many authors report that upper and lower anterior teeth have already over erupted in skeletal open bite cases (Nahoum, 1977; Straub, 1979; Wylie, 1946). Extruding the over erupted anterior teeth by using anterior vertical elastics to achieve bite closure would therefore seem an invalid approach to achieve stable results (Epker and Fish, 1977; Subtelny and Sakuda, 1964).

Retraction of incisors also results in a degree of extrusive movement as the crown is rotated around the centre of rotation of the tooth (Sarver and Weissman, 1995). This also has a 'drawbridge' effect (Figure 11) and encourages AOB closure (Beane, 1999). The presence of bimaxillary protrusion in an open bite patient presents the ideal opportunity to improve and correct the open bite by reducing the angulation of the anterior teeth. Extraction of the first premolars and retraction of the procumbent maxillary and mandibular incisors will produce a ‘drawbridge’ effect by elongating the incisors and closing the bite (Beane *et al.*, 2003; Beane, 1999). As such, extraction therapy may well be considered in the treatment of many of these patients.

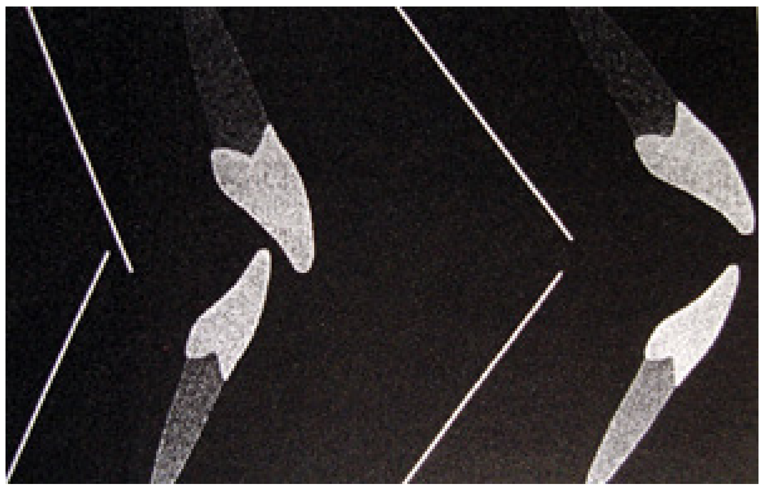

Figure 11. The drawbridge effect caused by retraction of upper and lower incisors (Beane, 1999)

Extractions and orthodontic treatment in the permanent dentition is an effective method of managing AOB. De Freitas *et al* compared the long-term stability of AOB treatment with extractions to a control group with normal occlusion and found that 74.2% of the sample had a "clinically stable" open bite correction. The primary factors that contributed to the nonsignificant decrease of the overbite were the normal vertical development of the maxillary and mandibular incisors, the smaller vertical development of the mandibular molars, and the consequent smaller increase in lower anterior face height, as compared with the control group in the long-term. They also found that there was no statistically significant decrease of the obtained anterior overbite at the end of the post-treatment period (de Freitas *et al.*, 2004). Bite closure has also been reported in patients who have had their second molars extracted (Richardson and Richardson, 1993).

If extractions are indicated as a means of relieving crowding, then the extractions should be limited to the distal regions of the dental arch (Richardson and Richardson, 1993). Any attempt to gain space by distal movement of molars is contraindicated. This type of tooth movement will aggravate the AOB due to its approximation to the hinge axis of the mandible.

Orthognathic Surgery

Surgical correction of skeletal AOB offers the advantage of direct elimination of the skeletal defect rather than indirect dental compensation (McNeill, 1973). Combined surgical and orthodontic treatment circumvents many of the limitations of individually applied treatment modes. However, its success is dependant on careful conjoint diagnosis and treatment planning. In addition to direct examination and study cast evaluation, comparative cephalometric analysis is essential. Cephalometric prediction techniques have been described and are regularly employed in the surgical management of AOB cases (McNeill *et al.*, 1972).

There are a number of operative surgical procedures to correct a skeletal open bite (Bell, 1971). The age of the patient however has an important bearing on the treatment planning. In AOB subjects there is a progressive downward and backward rotation of the mandible with continuing growth. In the surgical management of skeletal AOB it becomes essential that facial growth be completed before orthognathic surgery is undertaken (Bjork and Skieller, 1983; Sinclair and Allen, 1983). Surgical planning should not only focus on the AOB, instead, the surgical planning should encompass horizontal and vertical changes before and after surgery (Bailey *et al.*, 2002). Surgical techniques for both Class I (Figure 12) and Class II (Figure 13) AOBs have been described and integrated in the surgical protocol (Reyneke, 1988). An essential component of a number of surgical protocols encompasses a reduction in posterior dentoalveolar height encouraging autorotation of the mandible and a decrease in lower anterior facial height.

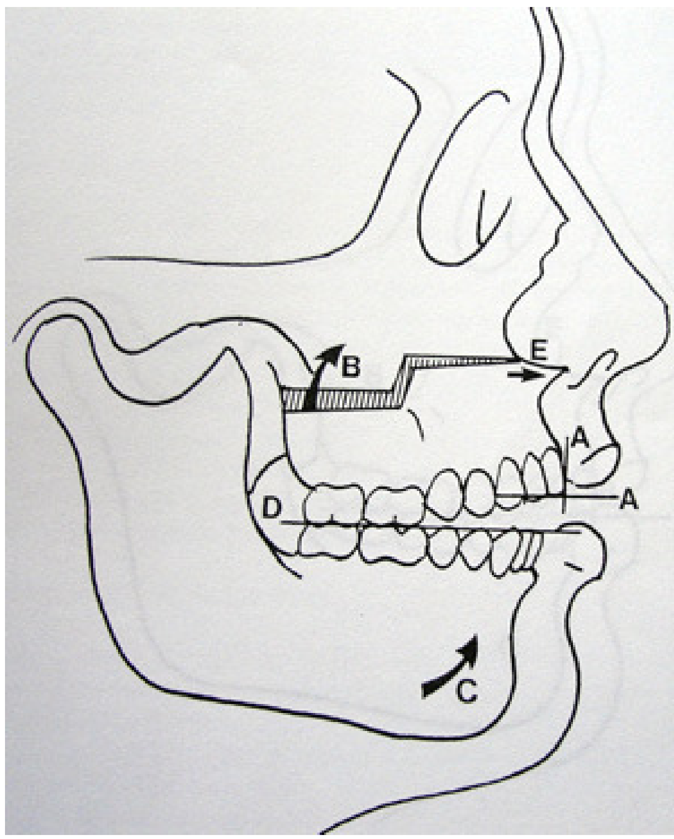

Figure 12. Surgical plan for a Class I open bite (Reyneke, 1988)

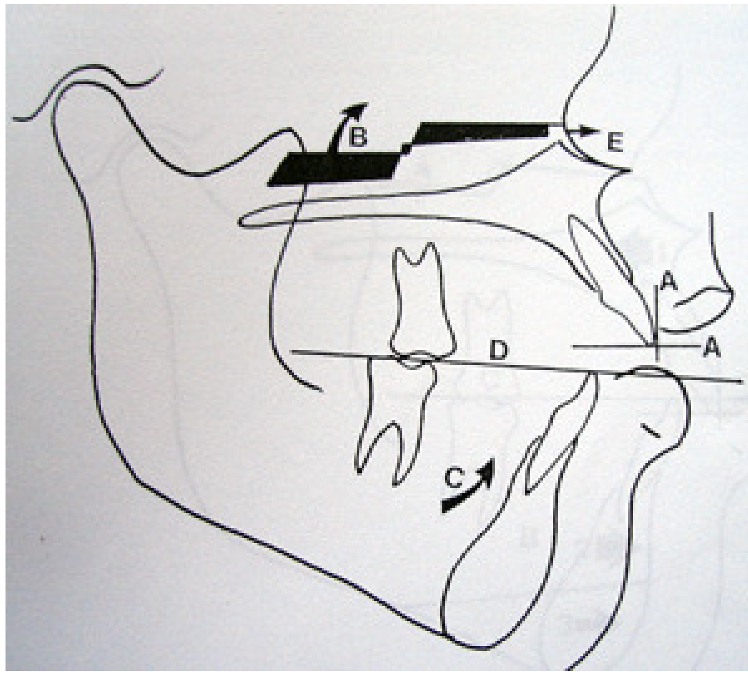

Figure 13. Surgical plan for a Class II open bite (Reyneke, 1988)

The inverted L ramus osteotomy is another surgical technique that has been used for the correction of an open bite deformity and a study of 20 patients who underwent this procedure demonstrate more stability in both the horizontal and vertical dimensions than previously reported ramus procedures (Dattilo *et al.*, 1985).

Segmental subapical osteotomies (Dimitroulis, 1994) are surgical resections of either the mandible or maxilla beyond the root apices, that are also employed in the orthognathic management of AOB. Anterior segmental subapical osteotomies may be accompanied by extraction of first premolars and the most common surgical techniques used are the Wunderer (Kim *et al.*, 2002) and Kole (Kloosterman, 1985) procedures. Segmental osteotomies can often be done in conjunction with a Le Fort I osteotomy without jeopardising the healing capacity of the bone (Angelillo and Dolan, 1982).

Orthodontic preparation in theses cases, as with most orthognathic patients, is vital to ensure that the segments are at their correct levels to enable bite closure without creating steps in the occlusal plane. Presurgical orthodontic treatment must also ensure that the roots are adequately diverted to accommodate unimpeded and uncomplicated osseous cuts in non-extraction cases.

When comparing the stability of various surgical procedures in Japanese subjects with a skeletal class III open bite it was found that clockwise rotation of the palatal plane, which moves the anterior maxillary structures down, is an effective way to produce a reasonably stable correction of the anterior open bite. In contrast, superior repositioning of the maxilla that significantly rotates the mandible in the closing direction should be applied with caution (Moldez *et al.*, 2000).

Some innovative contributions to the surgical correction of AOB include distraction osteogenesis and the use of biodegradable plates. Distraction osteogenesis (DO) is a technique that leads to osseous generation and osteosynthesis by means of slow traction applied to the bone and the soft tissues. Distraction can be both unilateral and bilateral and can correct deficiencies on one, two or three different levels. In a case reported by Gualini (2007) bite closure was achieved through distraction osteogenesis using a horizontal osteotomy in combination with a Quad Helix appliance (Gualini, 2007). It has been found that healing of osteotomy sites has also improved through the use of biodegradable PL (Poly Lactic) plates and screws to stabilize bone segments and eliminate the need for subsequent surgical intervention to remove irritating titanium plates and screws (Bell and Kindsfater, 2006).

Although not common, macroglossia has been cited as a causative factor in AOB. In such cases the best approach may be to do a partial glossectomy (Wolford and Cottrell, 1996). It has been shown that the resting tongue pressure after a partial glossectomy is less than before the surgery (Frohlich *et al.*, 1993). The removal of molars and partial glossectomy has also been recommended and these procedures are being added to various types of maxillary and mandibular osteotomy (Speidel *et al.*, 1972).

Combination Therapy

Implants offer the possibility of achieving a source of stationary anchorage for the treatment of open bite cases (Kuroda *et al.*, 2007). Osseointergrated implants and titanium miniplates have been used with intrusion mechanics in open bite malocclusions to prevent extrusion and actively intrude posterior teeth.

A TAD (temporary anchorage device) is a titanium-alloy miniscrew having a length of 6-12mm and a thickness of 1.2-2mm that is temporarily fixed to bone to enhance anchorage. The screws are self-tapping and can be inserted directly into bone through the gingiva using only topical anaesthetic. They set up stationary anchorage by gripping the cortical bone and can be loaded immediately after placement (Hermann and Cope, 2005).

These implants are usually referred to as orthodontic temporary anchorage devices (TADs) and provide a minimally invasive treatment alternative that reduces patient compliance for molar intrusion (Prosterman *et al.*, 1995; Sugawara *et al.*, 2004). TAD supported molar intrusion may be accomplished without the need for full arch brackets and wires. Molars can be intruded up to 8 mm in 7.5 months without loss of tooth vitality, adverse periodontal response or radiographically evident root resorption (Kravitz *et al.*, 2007).

Molar intrusion forces should however be kept light and continuous to minimize the risk of root resorption. Force ranges that have been described vary from 50 to 200g (Park *et al.*, 2003; Umemori *et al.*, 1999). Transpalatal arches are used in combination with TADs to prevent buccal tipping of the intruding molars. These are placed 3-5mm away from the palate to allow the resting tongue pressure to assist with intrusion. As an alternative to the use of a transpalatal arch, miniscrews can be placed on the palatal and buccal regions and an intrusive force applied to the palatal and buccal attachments on the molars.

In contrast to the Microscrew Anchorage System (MAS) (Park *et al.*, 2003) described above, the Skeletal Anchorage System (SAS) (Sugawara, 2005; Umemori *et al.*, 1999) is an alternate form of fixed anchorage. It consists of titanium anchor plates and monocortical screws that are temporarily implanted in either maxilla or the mandible as absolute orthodontic anchors. This system differs from TADs in that it requires the preparation of a surgical flap with exposure of cortical bone and attachment of the plate to the bone. This anchorage system has also been effectively used for molar intrusion.

Adult patients with AOB have also been successfully treated using posterior occlusal bite blocks with high pull headgear and archwire mechanics. This method essentially aided in reducing the lower anterior facial height through molar intrusion and upward and forward rotation of the mandible (Galletto *et al.*, 1990).

Relapse

The rate of relapse for AOB will vary depending on the treatment modality employed. Using orthodontic treatment only, the relapse was found to be 35% (Lopez-Gavito *et al.*, 1985), while surgical impaction of the maxilla by way of a Le Forte I osteotomy was found to have a relapse of 42.9% (Denison *et al.*, 1989). Although correction of an open bite cannot always be perfectly maintained, there are many patients who will derive considerable benefit from treatment with only orthodontic appliances. Prudent selection of patients and adherence to sound orthodontic principles can produce very acceptable and at times, outstanding treatment results (Beane, 1999).

Relapse of AOB has been attributed to:

1. Unfavourable mandibular growth;
2. Soft tissue factors such as tongue posture;
3. Resumption of a digit sucking habit;
4. Inappropriate orthodontic tooth movement such as extrusion of the incisors when their eruption had not previously been impeded (Galletto *et al.*, 1990; Nielsen, 1991);
5. Relapse following orthognathic surgery can occur when the mandibular condyles are not seated properly in the glenoid fossae because of inadequate maxillary bone resection during maxillary impaction (Booth *et al.*, 2007).

The first requirement to enhance stability is to eliminate the cause of the open bite. If tongue posture and aberrant function is the cause of the open bite, it is possible they may have a significant role in the post-treatment relapse observed in patients with open bite. Placement of a tongue crib may improve stability in patients with pre-treatment open bites.

Prolonged retention with fixed upper and lower retainers is advisable and necessary in most cases of open bite treatment. Retention should ideally be continued until the patient ceases to grow, although compliance may be a problem. Post-treatment sugarless gum chewing can help strengthen the masticatory muscle complex, prevent molar eruption and maintain AOB closure (English and Olfert, 2005).

In open bite patients, a dentoalveolar compensatory mechanism results in a stable overbite at the end of treatment by enlarging symphysial height through a moderate increase in symphysial volume. In addition, retrusion of the maxillary incisors contributes to overbite reduction. However, through active treatment causing a stretching and elongation of the alveolar bone, an excessive increase in vertical height of the symphysis relative to lower face height may relapse after active treatment (Beckmann and Segner, 2002).

Janson and co-workers established that open bite treatment with extractions has greater stability than open bite treatment without extractions. Treatment in the non-extraction group consisted of expanding the maxilla using either a hyrax or Haas type expander. (Janson *et al.*, 2003). They found that 61.9% of their sample had a clinically stable open bite correction as compared to the 74.2% found in a parallel study by de Freitas *et al* (2004). When comparing the stability of non-extraction treatment with the extraction of four first premolars in AOB patients it was found that extraction treatment had a greater stability of the overbite than non-extraction treatment (Janson *et al.*, 2006).

The treatment outcome of AOB will also have a better prognosis if it is a 'dental malocclusion' rather than a 'dentoskeletal' malocclusion (Sassouni and Nanda, 1964). As a rule, the more the skeletal elements contribute to the aetiology of the malocclusion, the poorer the prognosis for orthodontic treatment alone (Mizrahi, 1978). Huang (2002) also found that while orthodontic therapy appears to have a slightly lower treatment success rate than surgical treatment, they have a better long term stability than surgical therapy, in that fewer subjects achieve a positive incisor overlap with orthodontic therapy alone, but almost all that do, maintain it (Huang, 2002).

The difficulty in determining the most ideal form of retention to treated AOBs and the tendency of anterior teeth to return to their original pre-treatment vertical relationship is well recognised and undoubtedly one of the factors responsible for the orthodontists continued interest in this field. Added to this is the surge of economic empowerment of previously disadvantaged race groups in the South African context, which has prompted a greater percentage of people, affected by the malady of AOB to afford and seek specialist treatment.

Chapter 3

Cephalometrics and its application to anterior open bite deformities

The cephalometric radiograph

Assessments of the dentofacial dimensions have been around for a number of years in the specialty of orthodontics and dentistry. However, anthropologists and anatomists who recorded the various dimensions of ancient dry skulls were the first to initiate the scientific approach to the scrutiny of the human craniofacial patterns.

The measurements of the dry skulls from osteology based landmarks called craniometry were then applied to living subjects so that longitudinal growth studies could be undertaken. This technique of the measurement of the head of a living subject from bony landmarks located by palpation or pressing through the supra adjacent tissue, is called anthropometry. It could never be very accurate as long as measurements were taken through the skin and soft tissue coverage (Athanasiou, 1995).

The discovery of X-rays by Roentgen in 1895 revolutionized medical science in that it provided a method of producing radiographic images of the human body. When applied to the skull it allowed the radiographic image of the head to be assessed in two dimensions thereby making it possible to study craniofacial growth and development more accurately. The measurement of the head from the shadows of the bony and soft tissue landmarks on the radiographic image became known as roentgenographic cephalometry. Pacini introduced a lateral head film by using a teleroentgenographic technique (Pacini, 1922). This method however had its flaws in that images were unclear and distorted.

The need for a standardised technique to measure the living head as accurately as the anthropologists survey a dry skull aided in the design of the roentgenographic craniostat. In 1931, Broadbent in the USA and Hofrath in Germany simultaneously presented a standardised cephalometric technique using a high-powered X-ray machine and a head holder called a cephalostat or cephalometer. Broadbent's modification of the T. Wingate Todd's head spanner was the scientific instrument that brought about a change in the way we interpret living craniofacial tissues (Hixon, 1972).

Studies with this instrument demonstrated that skull pictures could repeatedly be taken identical with those previously made in relation to predetermined points, thus it became the forerunner of the design for the head holder. This early model could only register and permit the production of profile roentgenograms. It therefore became necessary to redesign the machine (Figure 14) to produce a complementary pair of roentgenograms, one in the sagittal plane and one in the frontal plane which, although two dimensional, would best render scientific interpretation of the three dimensional face (Broadbent, 1937).

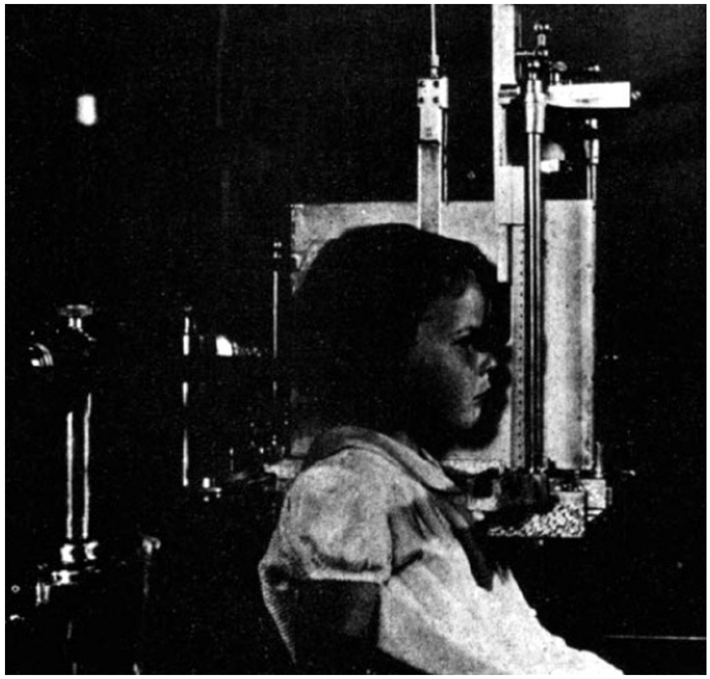

Figure 14. Broadbent's redesign of the craniostat (Broadbent, 1937)

In 1968 Bjork designed an X-ray research unit, which allowed for the position of the patients head to be monitored on a television screen. This enabled images to be recorded on video tape and enhanced the study of overbites (Bjork, 1968; Skieller, 1967). In 1988, a multi projection cephalometer was developed for research (Solow and Kreiborg, 1988). It improved control of head position and rendered more accurate digital exposure control as opposed to the traditional and less refined analogue approach.

The introduction of rare earth screen technology enabled the production of high-quality panoramic and cephalometric radiographs with sizable reductions in patient radiation dosage. Other variables such as collimation, shielding, quality control and meticulous darkroom procedures also reduced patient risk and improved image quality (Taylor *et al.*, 1988).

Magnetic resonance imaging (MRI) and computer aided tomography (CAT) scans have also been explored in the analysis of the dentofacial complex.

Three dimensional craniofacial imaging techniques have become increasingly popular and have opened new possibilities for orthodontic assessment, treatment and follow-up (Swennen and Schutyser, 2006). However, due to its cost and high dosage of radiation, it is not very popular (Proffit and Fields, 2000). Scientific support and evidence for these techniques over the conventional cephalogram are still awaited.

The maxillofacial region, extending from the base of the skull to the hyoid bone, is one of the most anatomically complex regions of the body. This area contains elements and organs belonging to a number of different systems that can be affected by a variety of local and systemic pathological processes. Diagnostic imaging has assumed a central role in the evaluation of this region (DelBalso and Hall, 1993). While the cephalogram is at best a two dimensional abstraction of a viable three dimensional face at one single moment in time (Hixon, 1972), it has enabled the profession of orthodontics to view and scientifically analyse the skull in the lateral view, enabling relationships between the teeth, bone, soft tissue and empty spaces to be scrutinized both horizontally and vertically in two dimensions. The cephalogram is an important diagnostic tool used in orthodontia. It enables clinicians to do morphological analysis, growth analysis and treatment analysis and has become a vital part of the practice of orthodontics, to the extent that one cannot do without it (Jacobsen, 1995).

The importance of a lateral cephalogram is demonstrated in a study conducted by Atchison *et al* to determine the amount of diagnostic and treatment planning information gained by orthodontists when pre-treatment radiographs are added to a set of orthodontic records. In one study it was required of 39 orthodontists to evaluate six test cases and formulate a diagnosis and treatment plan. Information was collected about the participants' certainty with their diagnoses and treatment plans, the impact of the radiographs, the number and type of radiographs that were selected, as well as the difficulty of each case. There were 741 radiographs ordered, of which 192 produced changes to the diagnostic process. The lateral cephalometric radiograph was the most productive. Panoramic and full-mouth series were useful, but provided largely duplicative information (Atchison *et al.*, 1991).

Cephalometric analysis is a method for dealing with variations in craniofacial morphology and growth. Its primary objective is comparison.
In practice, these comparisons are made for one of five reasons, namely:

1. Description.

   Cephalometrics is a description and not a prescription. It describes morphology or growth and aids in the specification, localisation and understanding of abnormalities by comparison to a standard, an ideal or oneself.

2. Diagnosis.

   The diagnostic purpose of cephalometrics is to classify precisely the nature of the problem. Cephalometric diagnosis leads to the assignment of facial types and classes.

3. Prediction.

   Description, diagnosis and prediction are practically and conceptually quite different. To make a cephalometric prediction is to observe certain quantities, assume they will behave in a determinate way and extrapolate the consequences. The clinician would like to predict future form, including growth, in the absence of treatment and then estimate the effects of particular treatments on that prediction. Despite many enthusiastic articles, certain commercial ventures and expansive use of the term growth prediction, we are not able to accurately predict several aspects of craniofacial growth.

4. Planning Treatment

   Where the clinician is able to describe, diagnose and predict craniofacial morphology, a clearer plan of orthodontic treatment would be derived. Clinicians use the cephalogram to define expected changes due to growth and treatment and to plan appropriate biomechanics. Planning orthodontic treatment is applied prediction.

5. Evaluation of Treatment Results

> Successive radiographs are used to discern the progress of treatment and to plan any changes in treatment that may seem necessary. Evaluation of treatment results is recurrent description and diagnosis.

A cephalometric analysis is therefore a collection of tested landmarks (Tng *et al.*, 1994), planes, angles and measurements intended to compress much of the information from the cephalogram into a usable form for treatment planning and assessment. It provides information about sizes and shapes of craniofacial components and their positions and orientations. The unit of analysis should be a single patient over time – all cephalometric analysis should be intrinsically longitudinal.

In practical use, a cephalometric analysis helps the clinician visualise three important aspects of craniofacial morphology:

1. What the face is now – current morphology
2. What it was or will be – past growth or expected growth
3. What the clinician wishes it to be – idealised or corrected morphology

The first step to dentofacial analysis is the clinical examination. This initial step is very vital in our overall appraisal of the patient. It is the patient after all, who is going to be treated, and not the cephalogram or the study models etc, as these are merely adjuncts to help the orthodontist come to a diagnosis and appropriate treatment plan.

Dentofacial appraisal

There are various methods used for the appraisal of the dentofacial complex. Some are still in use while others have become unfashionable and have been replaced by technologically advanced procedures.

Artistic appraisal

This is the oldest approach of representing the dentofacial features of a person. Artistic drawings of persons were kept as ideal guides for facial beauty, balance and equilibrium, in contrast to ugliness or disharmony. Artistic appraisals are usually time linked: they change and evolve with the times, for example, ideals of the Greeks, the Europeans of the Renaissance period, or the romantics of the 19^{th} century and our present day realisms are not the same. What was considered beautiful then, may not be beautiful now. Our perceptions are shaped by the current day events and happenings. Artistic appraisal is also national, cultural and race linked. The many factors that constitute a civilization reflect this endless variety of ideals that are ever changing. Thus, subjectivity is always a factor in artistic appraisal. The artistic appraisal may seem unscientific to the contemporary eye, but for that day and age it was the best representation of a person's face (Krogman and Sassouni, 1957). The use of artistic appraisal and appointing a person to do the difficult, expensive and burdensome task of drawing a patient's face has been done away with, thanks to the advent of photography.

Craniometry

Craniometry is the measurement of the human skull as used in anthropology. It is probable that the need for freedom from the subjective appraisal of one's face led to the need for a scientific basis of craniofacial evaluation and thus craniometry was used because of its high degree of accuracy and standardisation (Krogman and Sassouni, 1957). The great majority of landmarks, measurements, planes and structures used in roentgenographic cephalometry have a craniometric predecessor. Craniometry was originally used in anthropology to study dry skulls of Neanderthal and Cro-Magnon people whose skulls were found in European caves in the 18^{th} and 19^{th} centuries. From this method it has been possible to piece together knowledge on the ancient civilizations and to get some knowledge of the growth pattern by comparing one skull with another. The advantage of craniometry is that accurate measurements can be made on the dry skull, but all the data for growth is cross-sectional and craniometry cannot provide accurate data if growth is to be studied. The same individual can only be measured once (Proffit and Fields, 2000).

Anthropometry

The measurement of skeletal dimensions on living individuals is referred to as anthropometry. The various landmarks used in craniometry are repeated in living individuals simply by using soft tissue points over these bony landmarks. For example, it is possible to measure the cranium by using a point at the bridge of the nose to a point of greatest convexity of the rear of the skull. Results of craniometry and anthropometry will be different because of the soft tissue coverings in anthropometry (Proffit and Fields, 2000). The advantage of this method over craniometry is that one can follow growth of an individual over a long term period by making measurements directly on the subject at different times (Farkas, 1994).

Cephalometry

These are measurements of the living head using radiation. With this method it is possible to do accurate assessments of the cranium in two dimensions. This method depends on precisely orientating the head to take a radiograph and it combines the advantage of anthropometry and craniometry in such a way that the measurements of the bone can be made directly since the bony landmarks are visible through the soft tissue covering. In this way the same individual can be followed over time and measurements can be made on the same person. The disadvantages are that it produces a two-dimensional image of a three-dimensional structure and even with precise positioning of the head, not all measurements are possible. This can be overcome by taking radiographs from two different angles and then using triangulation to calculate the oblique differences (Proffit and Fields, 2000).

From the cephalometric image, various points and planes are established on which to superimpose serial tracings of follow up cephalometric radiographs. Broadbent (1937) was able to determine changes in the living head that could be attributed to developmental growth or to orthodontic treatment (Figure 15).

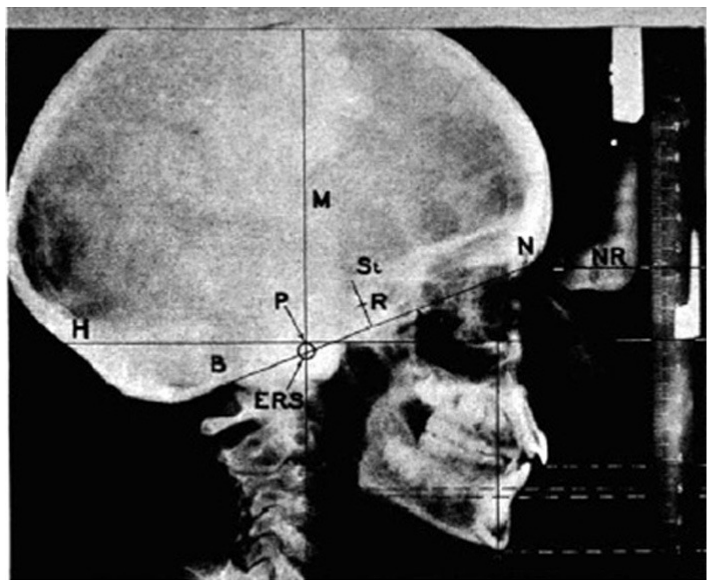

Figure 15. Broadbent's cephalometric analysis (Broadbent, 1937)

Broadbent’s method of studying growth patterns was also adopted and used by Brodie in a study of growth of the human head from 3 months to 8 years of life (Brodie, 1953). The cephalometric technique introduced by Broadbent broadened the knowledge base on growth and gave a good perspective on changes related to growth with and without orthodontic change. It was not until Wylie and Downs made comprehensive applications of cephalometrics to orthodontic diagnosis by doing analyses of the cephalograms that many others followed suit and designed various other analyses (Downs, 1948; Wylie, 1947).

With the advent of the computer age, and with computers becoming an important and frequently used component of clinical practice, the digitisation of radiographs evolved. Digitisation of cephalometric radiographs started in the late 1970's and 1980's (Cohen *et al.*, 1984; Ricketts, 1982a). This process initiated the development of computer software programs to do tracings, visual treatment objectives and surgical planning. Although at the onset, this technique was technically challenging, it has improved much over the years and clinicians are better able to identify landmarks on the computer (Graber and Vanarsdall, 2000). Hellman (1935) compiled three dimensional norms of the head and face of children at different levels of dental age or eruptive age which represent certain periods of developmental stages of the dentition (Hellman, 1935).

Photography

Since its invention, photography has been used as a tool in orthodontics. Initially photography was used for mere illustration, and later as a diagnostic tool (Krogman and Sassouni, 1957). For diagnostic purposes, there has been a move towards accuracy and standardisation. The problem however, is to accurately orientate the head in both profile and frontal views in such a way so as to minimize the amount of distortion and magnification and to produce images that can be repeated. Facial analyses have been developed from photographs early in the 1900's (Dreyfus, 1938) and with technology and digital records, analyses can now be done on the computer (Proffit and Fields, 2000).

With the introduction of cephalometry, photography was not discarded, but in many cases it was used as an adjunct or even in combination with radiographs (Graber, 1946; Margolis, 1943). Stereoscopic photography permits consideration of the face in its total volume. Photogrammetry (which is the reversal of the photographic process by converting or mapping flat two-dimensional images back into three-dimensional form) or surface and volume measurements have also been applied to facial evaluation (Bjorn *et al.*, 1954). Contourmetry was developed by Lange and Herzberg, where profiles contours were assessed (Krogman and Sassouni, 1957). This offered a method to evaluate the facial proportions. The Sassouni and Krogman's physiograph is a set up which consists of a slide projector oriented at right angles with the camera, which photographically measures the face in three dimensions (Krogman and Sassouni, 1957).

In keeping with technological progress, a combination of digital imaging and conventional radiographic techniques have been used to obtain a life-size composite image of the facial soft tissue profile, the skull and the teeth, anatomically superimposed on each other. This system overcomes major problems associated with assessment of facial deformity such as magnification, the exposure of photographs and radiographs from different positions, radiographs with over exposed soft tissue profiles, lengthy procedures in photographic studios and, in addition, enables a degree of partial automation in the management of patients (Lundstrom *et al.*, 1995).

A new non-radiographic imaging technique formed from standardised lateral head digital photography and a standardised digital photograph of the study models can also be employed for the diagnosis and treatment planning without the use of a lateral cephalogram (Moate *et al.*, 2007). When comparing this system with the use of lateral cephalograms in the diagnosis and treatment planning of orthodontic patients, it was found that the nonradiographic method varied in its reliability to measure soft tissues and was less reliable in measuring hard tissues. Neither points A or B can be reliably detected on the study models (Moate *et al.*, 2007).

Sagittal and vertical dental and skeletal intermaxillary malrelationships were only partly reflected in the face (Bittner and Pancherz, 1990). It was found that when the measurements from the facial photographs were compared with those from the lateral head films, moderate to high correlations were found between skeletal and soft tissue readings

While the accuracy of photographs in comparison to lateral cephalograms is questionable, the former still has an important contribution to make in orthodontics. For instance, a standardised photometric study of young adults found that male faces were, on average, wider and longer than the female faces, in both frontal and lateral views, with greater differences in the mouth and chin regions and with both sexes being generally symmetrical (Ferrario *et al.*, 1993).

Facial and dental casts

This was another method of keeping records of a patient's face in three dimensions. Van Loon kept very accurate records of the face (Van Loon, 1915) and face casts formed the precursor of the gnathostatic method of orientating the teeth on the dental casts, to the Frankfort horizontal (FH) and to the extra oral structures (Simon, 1924). There are various other ways of orientating the dental casts. Sassouni orientated the dental casts according to the mandibular plane for the mandibular model and the palatal plane for the maxillary model (Sassouni, 1955).

Laminagraphy

Brader introduced laminagraphy to orthodontics (Brader, 1948). It consists of a radiographic method whereby the tissue and structures above and below the plane of interest are blurred out by reciprocal movement of the x-ray tube and the film holder to show a specific area more clearly. Laminagraphy has been largely done away with in orthodontics and is used mainly for research purposes and less for clinical diagnosis (Ricketts, 1950).

Pantomography

In 1953 Koski and Poatero applied a panoramic x-ray technique to craniofacial growth appraisal (Krogman and Sassouni, 1957). The radiographic plate used, is flexible enough to be placed around a cylinder, which rotates at a certain height in a plane around the face, to record the arches of the mandible and maxilla together with alveolar bone, teeth and contiguous structures. The x-ray tube also moves around the patient in a direction opposite to the film.

Panoramic radiographs provide limited information on the vertical dimensions of craniofacial structures and clinicians should be cautious when predicting skeletal cephalometric parameters from panoramic radiographs because of their lower predictability (Akcam *et al.*, 2003).

Computer aided tomography (CAT) scans and magnetic resonance imaging (MRI)

The computer age also initiated the invention of CAT scanners. Computer aided tomography is a method of imaging anatomic information from a cross sectional plane of the body. Each image is generated by a computer synthesis of x-ray transmission data obtained in many different directions of a given plane (Rothman, 1998). These thin sections or slices of radiographic imagery are computerised and converted into an electronic image. CAT scans are used extensively in dentistry particularly in the field of implantology and have been used in orthodontic cases where it is crucial to have a three dimensional view of the cranium (Rothman, 1998).

Magnetic resonance imaging is a diagnostic radiological modality using nuclear magnetic resonance technology in which the magnetic nuclei, especially the protons of a patient, are aligned in strong uniform magnetic field. They absorb energy from tuned radiofrequency pulses and emit radiofrequency signals as their excitation decays. These signals which vary in intensity according to the nuclear abundance and molecular chemical environment, are converted into sets of tomographic images by using field gradients in the magnetic field which permits three dimensional localisation of the point sources of the signals (Allison, 2000).

While CAT scans can enable a more accurate diagnosis of dentofacial problems, they produce more ionising radiation than is required to produce conventional radiographs. This factor should be taken into account when considering a CAT scan as an alternative to a survey with conventional radiographs. Although CAT scans offer many advantages over conventional radiography, the high radiation dose to patients and the elevated cost of this procedure should be considered (Ngan *et al.*, 2003).

The future: three dimensional imaging

While conventional radiographs such as the orthopantomograph and lateral cephalogram have a place in craniofacial diagnosis particularly with respect to their low cost and radiation exposure, these two dimensional projection images and techniques are slowly being eroded and replaced by the more efficient and diagnostic but expensive three dimensional (3D) imaging methods. The latter can provide detailed information for the diagnosis and treatment planning of craniofacial malformations and also assist in preoperative treatment simulations that facilitate consultation communications empowering patients to make informed choices about their treatment (Kragskov *et al.*, 1996).

Papadopoulos and associates proposes the following requirements for an ideal 3D imaging method (Papadopoulos *et al.*, 2002):

1. It should be simple and easy to use;

2. The patient should not be exposed to any hazard;
3. It should be fast;
4. The form of the data must be easily handled;
5. It should help visualise and simulate the planned treatment procedure and
6. It should not be of high cost.

Three-dimensional imaging can broadly be divided into:

- Simple techniques such as 3D cephalometric radiography, laser scanning and automated infrared Photogrammetry;
- Advanced techniques which entail 3D ultrasound, 3D magnetic resonance imaging (MRI) and computed axial tomography (CT);
- Computer aided manufacturing procedures, namely stereolithographic biomodelling and
- Combinations of the above

3D cephalometric radiography

This procedure requires a cephalostat, an x-ray source and a personal computer with the applicable software. The 3D information is produced by combining and integrating the data received from the digitisation of a posteroanterior and a lateral cephalometric radiograph by using predefined cephalometric norms (Grayson *et al.*, 1988). Eight landmarks are digitised in the median sagittal plane from the lateral cephalogram and combined with similar landmarks of the frontal plane from the posteroanterior cephalogram. Rotating the images and pairing the landmarks between the two cephalometric images allows for the data to be processed. In this way, the two dimensions received from the lateral cephalogram and the posteroanterior one, provides a third dimension producing an electronic version of the method initially recommended by Broadbent (Broadbent, 1937).

Some drawbacks of this procedure include, the need for two cephalograms causing increased radiation exposure, greater operator expertise and a greater margin of error in the evaluation of cephalometric landmarks (Kusnoto *et al.*, 1999).

Laser scanning

Initially employed by anthropologists, this method uses low power non-hazardous surface laser scanners to assess facial volume. The scanner consists of two sources of fanned laser beams and functions as a system for acquiring the surface coordinates of the facial form. The beams are projected vertically onto the scanned surface from an oblique angle and observed from the front with a simple video camera. A computer processes the acquired image and registers the coordinates. By connecting the registered points to their neighbours, small triangular elements (facets) are generated. In this way the scanned surface represented by facets can be manipulated by computational procedures (Arridge *et al.*, 1985; Ferrario *et al.*, 1995).
Laser scanning is a relatively simple and low-cost technique that is mainly used for clinical purposes. It provides the clinician with data that enables more precise treatment outcome prediction, prognosis, treatment planning and the evaluation of treatment results (O'Grady and Antonyshyn, 1999).

Automated infrared photogrammetry

While this technique may be useful in the production of three dimensional images in anthropometry (Ferrario *et al.*, 1995), its application to orthodontics is limited, as the procedure require that the patient be immobile for a long time and readings may not be trustworthy. The technique involves making in situ markings of a predefined number of landmarks by means of special ink visible under infrared light and recording the image with infrared digital cameras. The framework is completed with the addition of scanned photographic images enabling the formation of the 3D image of the head.

3D ultrasound

Three dimensional ultrasound is mainly used for foetal visualisation and diagnosis in obstetrics (Blaas *et al.*, 2000), but has also been applied to diagnosis and treatment planning in maxillofacial surgery and investigations of the TMJ (Gateno *et al.*, 1993). It can also facilitate the immediate diagnosis of craniofacial malformations of the foetus, thus providing the opportunity for in situ treatment planning.

3D ultrasound uses high frequency sound waves that are emitted from a special probe, a transducer, which is placed in contact with the area of interest. Repetitive arrays of ultrasound beams scan the area in thin slices and are reflected back to the same transducer. Special software is used to convert the data into 3D images and the procedure is not time consuming.

3D MRI

This is one of the most valuable imaging techniques. The device consists of a large cylindrically shaped electromagnet, equipped with coils along with transmitters and receivers of radio waves. The patient is placed inside the electromagnet, which generates a powerful magnetic field around the patient that causes polarisation of hydrogen atoms within the tissues. Subsequent depolarisation of the tissues causes the emission of radiation similar to radio waves, which are recorded by the receivers and subsequently processed by the computer software to produce MR images. Because of their low hydrogen concentration, visibility of bone tissues are limited and its use in orthodontics is therefore restricted (Pavlicek *et al.*, 1983).

MRI however allows a thorough examination of the soft tissues and the TMJ especially in cases of TMJ disturbance. It is also useful in examining tongue morphology, volume and function (Karacay *et al.*, 2006).

An MRI procedure is non-invasive and safe because x-rays are not used. It cannot be used in patients with metallic implants due to interferences with the magnetic field and the high cost, militates its use in routine clinical examination.

3D CT

This technique derives from the CT scan, which with proper enhancement from computer software produces high quality 3D images. A CT scan of the head and neck is performed in thin (1-1.5mm thickness) contiguous slices. The images are processed and assembled by the computer resulting in onscreen 3D visualization of the scanned structures. In orthodontics 3D CT images are useful in TMJ evaluation and locating impacted teeth particularly canines (Papadopoulos *et al.*, 2002). Because the radiation used in this technique does not react with metal, it can be used on patients with metallic implants, bone plates and screws. The main disadvantages of CT scans are the high radiation exposure (Ngan *et al.*, 2003), cost and possible psychological stress in claustrophobic patients undergoing the procedure.

A recently introduced conebeam computed tomography (CBCT) scanning system has made major contributions to dentofacial imaging (Hatcher and Aboudara, 2004; Howerton and Mora, 2007; Vannier, 2003). Its main advantages over conventional CT scans are (Swennen and Schutyser, 2006):

1. Reduced radiation exposure;
2. Natural soft tissue shape because of the vertical scanning procedure;
3. Reduced artefacts at the level of occlusion;
4. Increased patient access because of in-office scanning, reduced equipment space and manpower requirements.

With CBCT technology all necessary radiographic records for orthodontic diagnosis and treatment planning can be captured in less than one minute (Kau *et al.*, 2005).

Stereolithographic biomodelling

This technique was initially developed in the engineering sciences to manufacture prototype models and has been extended to the fabrication of human skull models for treatment planning in maxillofacial surgery (Whitman and Connaughton, 1999). For its application the study area is initially scanned by means of MRI or conventional CT. A computer with a special manufacturing software package guides a special device to manufacture a study model. Stereolithographic biomodelling is mainly used for clinical purposes in maxillofacial surgery such as the evaluation of craniofacial abnormalities (Kragskov *et al.*, 1996), surgical planning (Zeilhofer *et al.*, 1997) and the reconstruction of cranial bone defects (Fallahi *et al.*, 1999). Disadvantages of this technique lie with MRI and CT imaging and the cost of model fabrication equipment.

Combination of 3D imaging techniques

These include laser scanning and 3D CT (Moss *et al.*, 1988), laser scanning and 3D cephalometric radiography (Nanda *et al.*, 1996), 3D CT and colour portrait photography (Xia *et al.*, 2000) and 3D CT and stereolithographic biomodelling (Papadopoulos *et al.*, 2002).

Open bite analysis using the lateral cephalogram

Open bite malformations can be assessed on the cephalogram whether they are 'pseudo or transitional open bites', dental or skeletal in nature (Nahoum, 1975). Identification of the type of open bite is important in directing the treatment plan, which may be orthodontics, surgery or combination therapy (Mizrahi, 1978). The malformation of AOB has been included in the American Board of Orthodontics (ABO) discrepancy index (DI) which is made up of various clinical entities that are measurable and have generally accepted norms (Cangialosi *et al.*, 2004). Cephalometric characteristics that have been ascribed to a patient with an AOB or an AOB tendency include: large anterior dentoalveolar height in both jaws, increased total and lower anterior facial height, a disproportionate ratio of upper-to-lower anterior face height, decreased posterior face height and an increased gonial angle, a high mandibular plane angle, a low posterior-to-anterior face height ratio and a short ramus (Klocke *et al.*, 2002a).

There are many analyses and techniques that may be used for the cephalometric assessment of AOB. A brief introduction to some of the more relevant ones is described.

The Downs' analysis

The Downs' analysis was introduced in 1950's and became the cornerstone of cephalometric analysis worldwide. While the facial plane (a line from nasion to pogonion) is effectively used to describe horizontal jaw relations, this analysis also determined for the first time, standards to measure vertical facial proportions (Downs, 1952).

It essentially uses the Y-axis (Figure 16) that is a line from the midpoint of sella turcica to gnathion, and the angle that this axis forms with the Frankfort plane. The mean for this angle is 59.4°. Measurements greater than this indicate a downward and backward rotation of the mandible with vertical growth of the face.

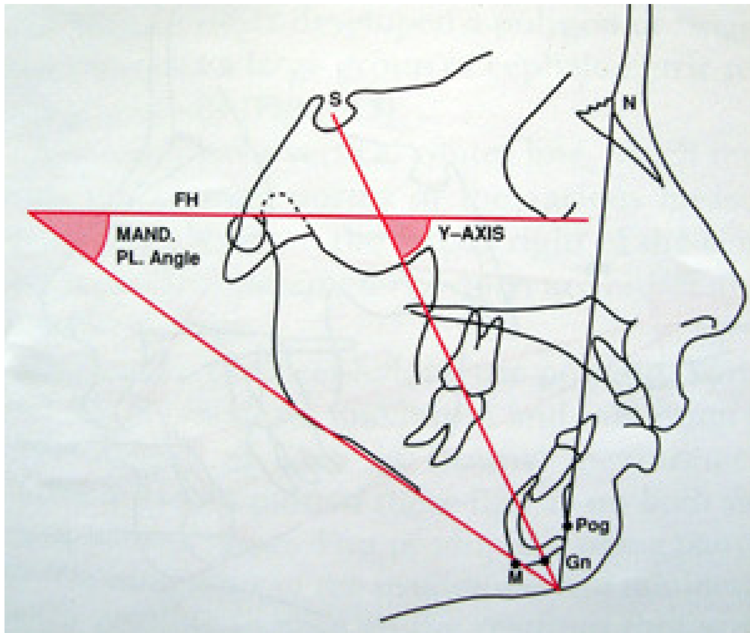

Figure 16. Down's parameters for vertical facial measurement (Jacobsen, 1995)

The mandibular plane, which is a line tangential to the gonial angle and the lowest point of the symphysis, also gives an indication of facial patterns. This plane was also measured against the Frankfort plane (Figure 16) with a mean standardised normal value of 21.9°. Larger angles imply a downward and backward cant of the mandible with frontal facial elongation.

The Sassouni analysis

The Sassouni (Figure 17) analysis essentially plots various horizontal planes on the lateral cephalogram and a measure of the degree of posterior convergence or anterior divergence of these planes indicates whether facial patterns are hyperdivergent or hypodivergent (Sassouni, 1955; Sassouni and Nanda, 1964).

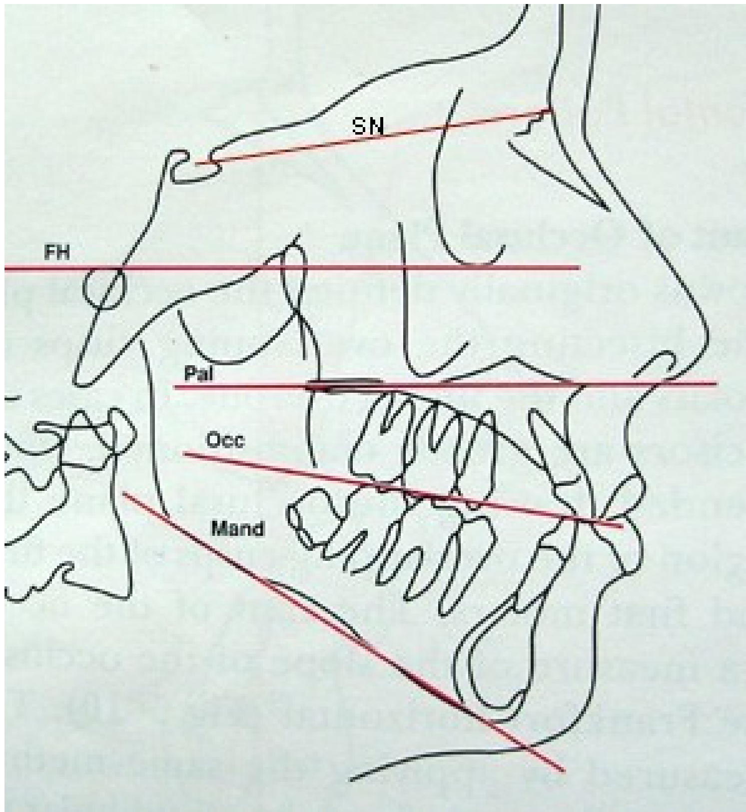

Figure 17. Horizontal reference lines used in the Sassouni analysis (Jacobsen, 1995)

The relationship of sella–nasion (SN), Frankfort horizontal, palatal, occlusal and mandibular planes (MP) to each other, are diagnostic characteristics of hypo or hyperdivergent faces (Schudy, 1964). In the hyperdivergent face, these planes all have a steep relationship to each other in contrast to the more parallel relationship of these planes in the hypodivergent or skeletal deepbite type of face (Schudy, 1964). The steep mandibular occlusal plane is an important indicator of AOB severity in contrast to the maxillary occlusal plane (Tsang *et al.*, 1997).

Anticlockwise rotation of the palatal plane, in addition to the absolute heights of the dentoalveolar segments correlated positively with the severity of AOB. The gonial angle is larger (128° in the AOB group compared to 117° in the control group) and the mandibular occlusal plane steeper (15° in the AOB group compared to 8° in the control group) (Nahoum *et al.*, 1972; Tsang *et al.*, 1997).

While the cranial base (depicted by SN) in North American Blacks was found to be shorter and steeper than in North American Whites (Beane *et al.*, 2003; D'Aloisio and Pangrazio-Kulbersh, 1992), growth studies have also found that increased angulation of the cranial base is associated with increased vertical dimension (Enlow *et al.*, 1982).

In evaluating the sella nasion:mandibular plane SN:MP angle, Bishara and Augspurger, defined high angle cases as those with values greater than 34.8° (Bishara and Augspurger, 1975), while, Isaacson and co-workers used a value of greater than 38° (Isaacson *et al.*, 1971) to define high angle cases. Average values for the palatal plane:mandibular plane (PP:MP) angle in a control group were found to be 20.7° (Nahoum, 1975) and 25.6° by Kim (Kim, 1974).

Schudy was the first person to use the occlusal plane:mandibular plane (OP:MP) angle to identify vertical differences among patients (Schudy, 1963). He found the average value for the control group to be 16°, which is a value confirmed by Kim (1974).

In a study conducted by Isaacson and co-workers (1971) on subjects whose SN:MP angle exceeded the mean of 31.7° (Riedel, 1952) by plus or minus one standard deviation, the two extreme growth patterns were evaluated. This study showed that vertical anterior facial increases exceeded vertical condylar increases in one group as manifested by backward rotating mandibles with larger SN:MP angles. Conversely in the second group the vertical condylar growth was greater than vertical anterior facial increase and manifested as forward rotating mandibles with a small SN:MP angle (Isaacson *et al.*, 1971).

Patients with severe vertical discrepancies have a clockwise rotation of the mandible (Iwasaki *et al.*, 2002). Nahoum suggests that two occlusal planes should be described namely, a maxillary occlusal plane from the intersection of the molar cusps to the incisal edge of the upper incisor and a mandibular occlusal plane from the molar cusps to the incisal edge of the lower incisor. In skeletal open bite, both the palatal plane and the maxillary occlusal plane are tipped upwards anteriorly while the mandibular occlusal plane is canted downwards (Nahoum, 1977).

A modification of the Sassouni analysis (Figure 18), includes measurements of the anterior and posterior upper and lower dental heights as well as the upper first molar position in relation to the cranium (Tsang *et al.*, 1997).

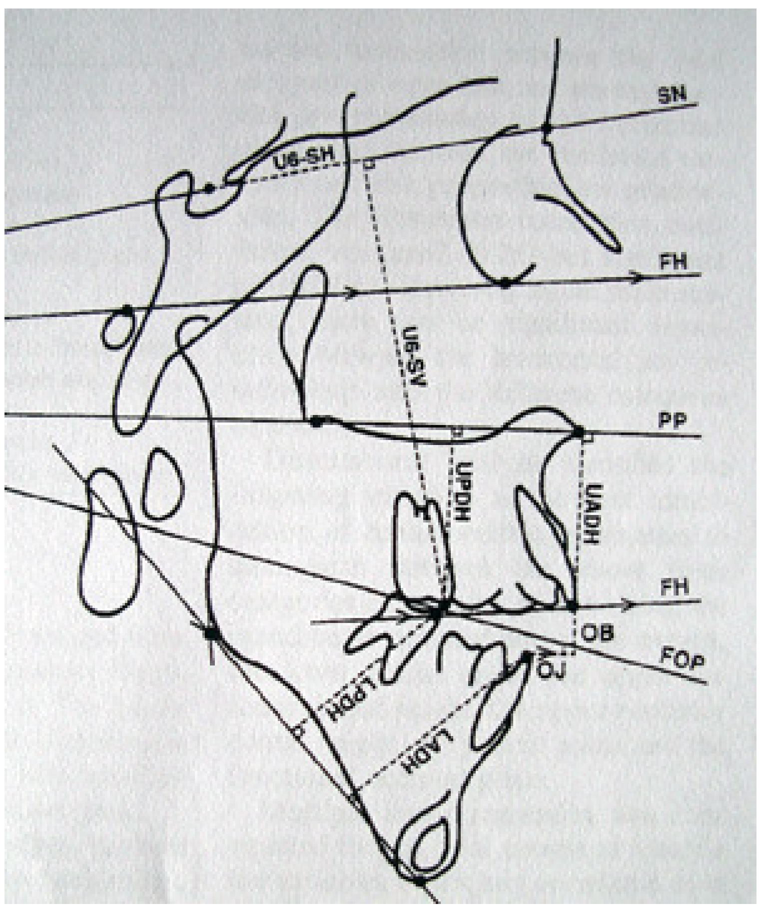

Figure 18. Divergence of the Sassouni planes in an anterior open bite case (Tsang et al., 1997)

Using the above analysis on a Chinese population it was found that AOB subjects have a shorter anterior cranial base length (70mm in the AOB group as compared to 72mm in the control group), upward and forward rotation of the maxilla, increased gonial and mandibular plane angles, increased upper posterior dental height and an increased lower anterior facial height (Tsang *et al.*, 1998). In the maxilla there is no increase in height from the cusp tips of the molars to the palatal plane (Mizrahi, 1978), but there may be a decrease in the vertical height measured from the incisal edge of the upper incisor to the palatal plane.

Another important finding in AOB patients is that in backward rotating high SN:MP angle cases, the mean anterior dental height as measured from the anterior nasal spine to the incisal edge of the central incisor is markedly longer. This leaves the already longer anterior teeth in a position of open bite which is diametrically opposed to the clinical hypothesis which states that that open bite is a result of failure of vertical growth (Isaacson *et al.*, 1971).

Facial proportions

The posterior facial height (PFH) to anterior facial height (AFH) ratio was established by Jarabak and co-workers who defined hypodivergent growers as patients having a PFH to AFH ratio of 64% or greater. Hyperdivergent growers were classified as having a PFH to AFH ratio of 58% or less (Jarabak and Fizzell, 1972; Siriwat and Jarabak, 1985).

Nahoum has extensively evaluated the upper facial height (UFH) to lower facial height (LFH) as an indication to open bite tendency (Nahoum *et al.*, 1972; Nahoum, 1975; Nahoum, 1977). He reported that patients with "good faces" had an UFH to LFH ratio of 0.810. Open bite patients had an average UFH to LFH ratio of 0.686 and deepbite patients exhibited UFH to LFH ratios of 0.900 and above. The division of the upper and lower face was determined by a perpendicular through anterior nasal spine (ANS) from the nasion-menton line. Upper facial height was measured as nasion to the ANS perpendicular and lower facial height from ANS perpendicular to menton (Figure 19). Other observations included an obtuse gonial angle with a steep and notched mandibular plane, a downwardly canted mandibular plane and an anteriorly and upwardly tipped maxillary occlusal plane (Nahoum, 1975). Nahoum (1975) also found that in subjects with skeletal open bites, the total face height was longer and that the palatal plane was tipped upward anteriorly causing the upper anterior face height to be shorter and the lower face height longer.

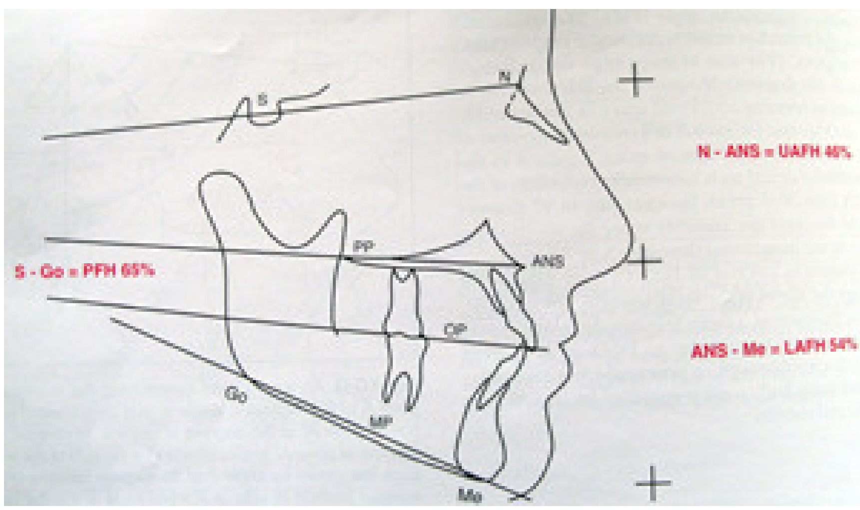

Figure 19. A cephalometric analysis illustrating facial proportions (Jacobsen, 1995)

In the average normal Caucasian face, the occlusal plane is approximately 14° to the SN line and the mandibular plane approximately 32° (Jacobsen, 1995). In South African Blacks, corresponding values were found to be 16° and 32° respectively (Naidoo and Miles, 1997). Jacobsen goes on to explain that the proportion of the upper anterior facial height (UAFH) measured from N to ANS, and lower anterior facial height (LAFH) measured from ANS to (menton) Me, to the total anterior facial measured from N to Me are approximately 46% and 54% respectively. The posterior facial height (PFH), S to Go is approximately 65% of the total anterior facial height (N-Me)

(Figure 19). Some variations in the proportions N-ANS, ANS-Me and S-Go will occur when the linear measurements are made from projected points perpendicular to a vertical line anterior to the soft tissue profile compared with when the distances are measured directly between the landmarks N to ANS, ANS to Me, and S to Go. If, in an individual, sella is low relative to nasion (a low sella position) and the upper and lower facial heights still correspond with the norms of 46% and 54%, respectively, then the palatal, occlusal and mandibular plane angles relative to the SN line will be larger than the norm values (Jacobsen, 1995). In other words, these anatomical planes will converge posteriorly and diverge anteriorly (Sassouni, 1969).

In a similar study conducted by Beane *et al* (2003), cephalometric comparisons of Black subjects in the USA with and without an open bite were used to identify skeletal and dental differences between the two groups. Statistically significant differences were found in the vertical skeletal dimensions and incisor proclination. The open bite group had a significantly longer anterior lower facial height and total facial height. The mandibular plane was rotated down relative to the cranial base (31.27° in the control group, as compared to 34.88° in the AOB group) and the palatal plane was tilted up anteriorly relative to the Frankfort plane (-0.79° in the control group as compared to –1.54° in the AOB group). The gonial angle was also greater in the open bite sample (131.73° in the control as group as compared to 134.88° in the AOB group). No significant differences were found in the skeletal anteroposterior dimensions or dental vertical development. The vertical skeletal pattern and the greater degree of dental proclination differentiated Black subjects in the USA with an anterior open bite from those without. Subjects with AOB had longer faces than those of the control group indicated by the difference in both lower and total anterior facial heights. Because the mean difference in upper facial height was found to be less than 0.5 mm, it has been proposed that lower facial height may be the important contributing factor in causing an increased anterior facial height (Beane *et al.*, 2003).

In a study of Southern African population groups comparisons were drawn between Black (Sotho-Tswana ethnic group) and White subjects of the same region using the Steiner analysis. It was found that, in relation to their propensity for AOB, South African Blacks have a shorter anterior cranial base, a shorter maxillary length, bimaxillary dentoalveolar protrusion, a decreased ramal height and an increased lower facial height (Barter *et al.*, 1995). The findings from this study conclude that cephalometric analysis carried out on other racial groups cannot be used with confidence for the Sotho-Tswana patients.

In a study undertaken by Droel and Isaacson (1972) to determine the relationship between the glenoid fossa and vertical facial proportions (Figure 20) it was found that in subjects with a high mandibular plane angle the mean value for the vertical sella-fossa relationship was 15.22 +/- 2.74mm while the group with a low mandibular plane angle had a mean value of 19.35 +/- 2.08mm (Droel and Isaacson, 1972). They concluded that backward rotating growth patterns had a more superiorly placed glenoid fossa, which effectively shortens an already deficient mandibular ramus.

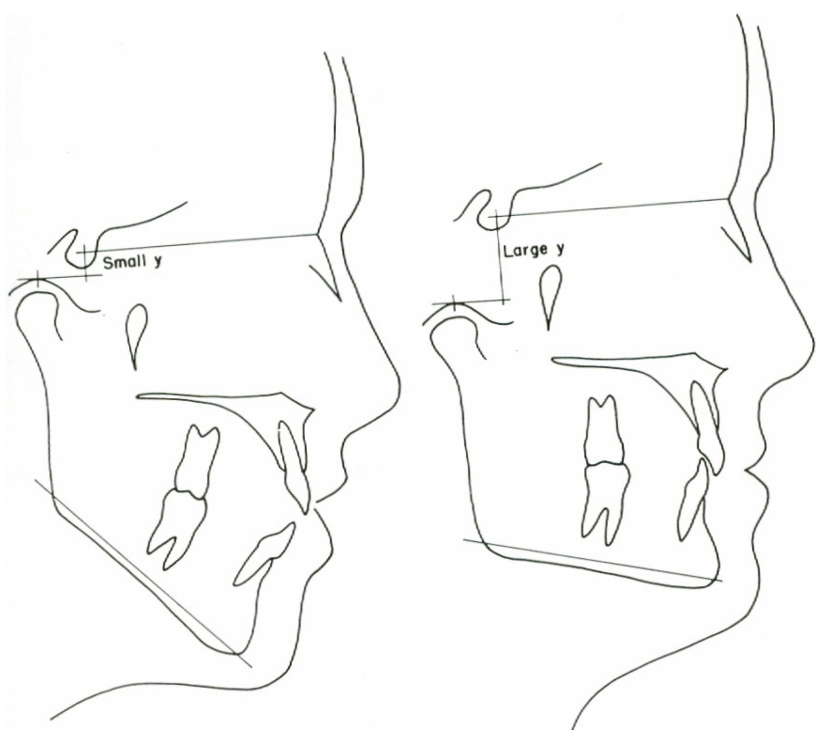

Figure 20. Glenoid fossa position and skeletal discrepancies (Droel and Isaacson, 1972)

The position of the glenoid fossa relative to basicranial structures was also found to be more caudal in low angle subjects when compared with subjects with normal or high angle vertical relationships (Baccetti *et al.*, 1997) .

Generally, and up to a point, 'the better the face, the more the upper face contributes to total facial height'. In 'good faces' the upper facial height to total facial height was found to be 43.84 per cent. As this percentage decreased, the face became 'poor' (Wylie and Johnson, 1952).

Cangialosi's (1984) open bite study serves as a useful guide to illustrate facial proportions and how they relate to AOB deformity (Figure 21) by employing the following landmarks and measurements:

- Posterior face height (PFH)-from sella to gonion.
- Anterior face height (AFH)-from nasion to menton.
- Upper face height (UFH)-from nasion to the palatal plane.
- Lower face height (LFH)-from the palatal plane to menton.
- SN-GoGn-the angle formed by the sella nasion line and the mandibular plane.
- Gonial angle-the angle formed by the posterior border of the ramus of the mandible and the mandibular plane.
- SN-PP-the angle formed by the sella nasion line and the palatal plane.
- PP-GoGn-the angle formed by the palatal plane and the mandibular plane.
- Open bite-measured in millimetres.

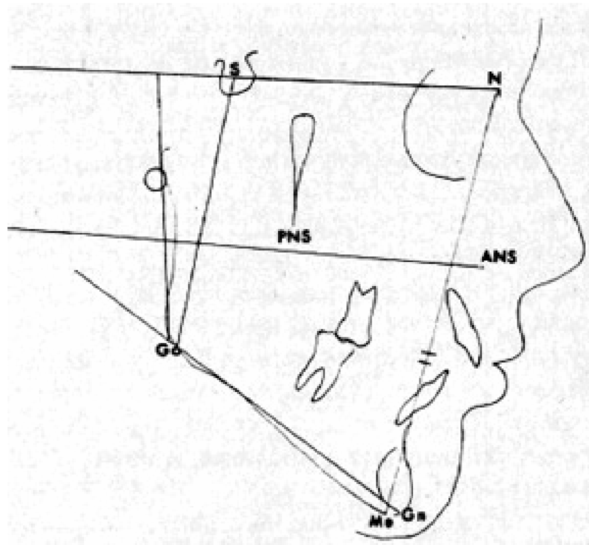

Figure 21. The relationship of facial proportions to anterior open bite (Cangialosi, 1984)

Application of the above analysis to a sample of 60 AOB subjects and 60 normal subjects led to the following conclusions (Cangialosi, 1984):

1. Posterior face height is shorter (73.8mm in the AOB group and 87.8mm in the control group) and overall anterior face height is greater.

2. Lower face height is greater in relation to upper anterior face height (UFH/LFH was 0.740 in the AOB group and 0.812 in the control group).

3. The mandibular plane angle (38.3° in the AOB group and 29.8° in the control group) and the gonial angle (132.5° in the AOB group and 123.9° in the control group) are larger for the AOB group.

4. The PP-GoGn angle is greater (31.4° in the AOB group and 21.9° in the control group), and is due mostly to a downward tipping of the mandibular plane in this sample.

5. Ratios and angles measured remained relatively constant in both mixed- and permanent-dentition groups, indicating that only size (but not facial proportion) changes with age.

6. Measurements made on the group designated as having skeletal open bites were significantly different from those subjects designated as having

dentoalveolar open bites and from the open bite sample as a whole, except for the SN-PP angle.

The phenomenon of anterior open bite is multi-factorial, and there is an almost infinite variety to the dentoskeletal configurations and magnitude of dysplasia associated with it. Arat *et al* found that dentofacial morphology differed in the sagittal components of skeletal open bite, and the differences were most obvious between the Class II and Class III open bite groups. Posterior maxillary dentoalveolar height and mandibular incisor inclination were important factors in the development of open bite in the skeletal Class I and Class II open bite groups, while in the skeletal Class III open bite group, the nasopharyngeal airway and the gonial angle were involved. It is imperative therefore that sagittal components of a skeletal open bite be given careful consideration in the differential diagnosis and treatment planning of such cases (Arat *et al.*, 2005).

The overbite depth indicator (ODI)

According to Kim, an anterior open bite is characterised by divergent upper and lower occlusal planes and marked mesial inclinations of the dentition in the open bite skeletal pattern (Kim, 1987). The open bite skeletal pattern can be determined by the overbite depth indicator (ODI) (Kim, 1974) and the anteroposterior dysplasia indicator (APDI) (Kim and Vietas, 1978). The mean value of the ODI was found to be 74.5° and that of the APDI is 81.4°.

The ODI measurement is defined as the angle of the point A to point B plane (A-B plane) to the mandibular plane combined with the angle of the palatal plane to the Frankfort horizontal (Figure 22). If the latter is positive it is added to the former angle. If it is negative, it is subtracted from the former angle. Frankfort horizontal is measured from anatomic porion to orbitale. Lower values of the ODI indicate open bite tendency. The control group was found to have a mean value of 74.5° and a standard deviation of 6.07°, while a value of 68° or less (one standard deviation below the mean) was used as an indication of open bite tendency (Kim, 1974).

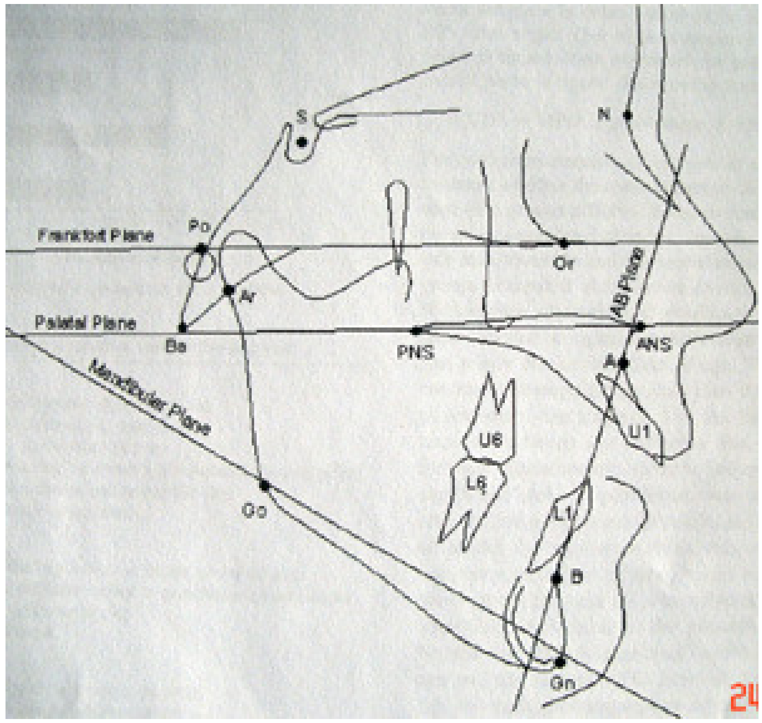

Figure 22. The ODI analysis (Beane, 2003)

The overbite depth indicator might be used to reflect both skeletal and dentoalveolar factors involved in AOB. The ODI was intended to provide information regarding the behaviour of vertical relations and according to Beane (1999), the value of this measurement is that it purports to identify patients who have open bite tendencies (Beane, 1999). It therefore measures open bite tendency and does not identify the morphological components of an open bite

The ODI was also found to be useful in detecting an underlying skeletal pattern present in the deciduous dentition open bite sample that persisted during the longitudinal follow-up (Klocke *et al.*, 2002a). It has been proposed that the overbite depth indicator (Kim, 1974) might help to identify young patients with open bite tendencies. Wardlaw and associates (1992) found the ODI to be the most valuable analytical measurement in the receiver operating characteristic (ROC) analysis (Wardlaw *et al.*, 1992). The ROC analysis is a statistical tool that is used to determine whether a measurement or instrument is reliable and valid for its intended purpose.

A modification of the ODI is the combination factor (CF) introduced by Chang and Moon (1999). When the means of the ODI and APDI representing the vertical and horizontal components are combined, the sum equals 155.9° and is designated as the combination factor. The more the CF falls below 155°, the greater the chance of the presence or development of an open bite (Chang and Moon, 1999).

Chapter 4

Development and introduction of a new lateral cephalometric method: The proposed Dawjee Analysis

Introduction

Scientific appraisal of the craniofacial structures started with the measurements of dry skulls from osseous sites and their application to living subjects. This method was limited and inaccurate due to soft tissue (Athanasiou, 1995) and race variations. It was also unable to relate the hard tissues to the soft tissues, within a living being.

The advent of radiographs in 1895 was revolutionary in that the head could now be measured from different aspects and at different ages within the same individual or group of people. This opened a deluge of studies into craniofacial growth and morphology (Athanasiou, 1995).

In order to standardise longitudinal and comparative studies across the races and ages a standardised technique for the measurements of bony and soft tissue structures was needed. A solution to this that is in use to this day was the introduction in 1931, by Broadbent in Germany and Hofrath in the USA, of the head immobiliser called a cephalostat.

It is understandable that over time, a myriad of cephalometric measurements and techniques have evolved. These were aimed at defining sagittal jaw relations (Downs, 1952; Jacobsen, 1975; Steiner, 1953), vertical jaw relations (Bjork, 1969; Jarabak and Fizzell, 1972; Sassouni, 1969), dentoalveolar relations (Mc Namara, 1984; Steiner, 1960; Tweed, 1954), soft tissue proportions (Holdaway, 1984; Ricketts, 1981; Worms *et al.*, 1976) and the identification of other anomalies.

Since all of these techniques and procedures were initiated in Europe and America, their development and application related mainly to the craniofacial norms and requirements of Caucasians. In 1951 Cotton and co-workers (Cotton *et al.*, 1951), Altemus (Altemus, 1960) and Drummond (Drummond, 1968) developed normal values based on African American race groups, while Barter, Evans, Smith and Becker (Barter *et al.*, 1995), as well as Naidoo and Miles (Naidoo and Miles, 1997) went on to describe norms of cephalometric values for indigenous Negroid African groups. As the accrual of data on cephalometric norms for Africans of Negroid descent increased, it became evident that Negroid craniofacial morphology differed from that of their Caucasian counterparts (Barter *et al.*, 1995). Salient cephalometric traits seen in Africans of Negroid descent include bimaxillary dental and skeletal proclination, a larger arch length and a steeper mandibular plane (Beane *et al.*, 2003; Enlow *et al.*, 1982; Jones, 1989).

In South Africa, the increased availability and accessibility of dental care to previously disadvantaged race groups resulted in an accumulation of patient records at the Dental School of the University of Limpopo and other sister institutions. One of the more common occlusal problems observed by the Orthodontic Department at the University of Limpopo is the anomaly of an anterior open bite (Dawjee *et al.*, 2002). This condition has a multi-factorial aetiology (Burford and Noar, 2003) and is clinically recognisable by a lack of contact between the upper and lower incisal edges (Figure 23).

Figure 23. Anterior occlusal view of an anterior open bite subject

The cephalometric analysis that is used on orthodontic patients who attend the School of Dentistry of the University of Limpopo Oral Health Centre at Medunsa is a blend of components extracted from various established analysis and is referred to as the Medunsa analysis (Figure 24, Table 4). Although this analysis renders diagnostic information about the horizontal and vertical skeletal and dental relationships using standardised values for the Black population group, it does not render adequate detail on vertical discrepancies particularly AOBs, which is a common finding in this race group.

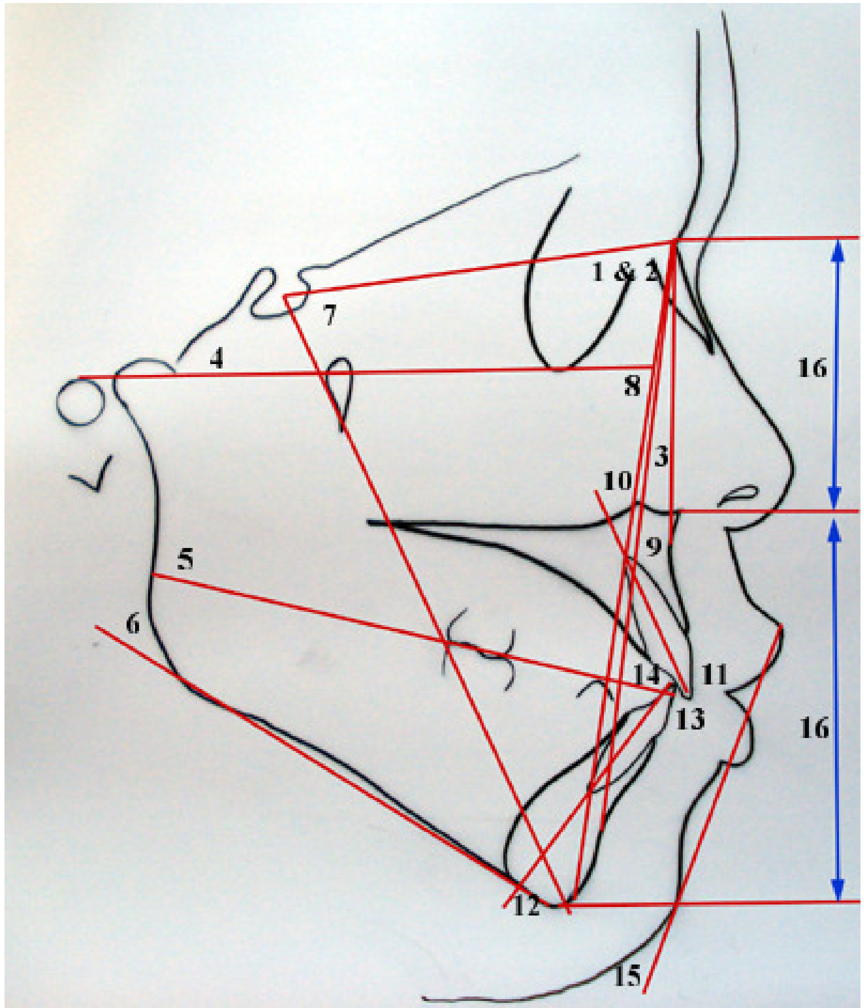

Figure 24. The Medunsa analysis

Table 4. Cephalometric values for the Medunsa analysis

Cephalometric parameter	Normal (mean) values for the S. African Black race group (+/-SD)
1. SNA (°)	87 (+/- 3)
2. SNB (°)	82 (+/- 3)
3. ANB (°)	5 (+/- 2)
4. SN FH (°)	7 (+/- 4)
5. SN OP (°)	16 (+/- 4)
6. SN MP (°)	32 (+/- 5)
7. Y axis (°)	67 (+/- 3)
8. Facial Plane Angle (°)	90 (+/- 2)
9. Convexity (mm)	4 (+/- 2)
10. Upper incisor to NA (°)	22 (+/- 6)
11. Upper incisor to NA (mm)	7 (+/- 3)
12. Lower incisor to NB (°)	38 (+/- 4)
13. Lower incisor to NB (mm)	10 (+/- 2)
14. Inter-incisal angle (°)	116 (+/- 7)
15. Holdaway Angle (°)	20 (+/- 4)
16. UFH:LFH	5:7

While various cephalometric analyses are available to diagnose and identify the morphological components of an AOB (Beane *et al.*, 2003; Cangialosi, 1984; Kim, 1974; Klocke *et al.*, 2002a), the data extracted from these methods are race specific and have not been tested on a South African Black race group. Although these cephalometric methods have their merits in identifying the morphological structures that constitute an AOB, they still fall short of drawing a clear distinction between the elements of a skeletal AOB as opposed to a dental AOB. To this end, a new system of evaluating AOB, the proposed Dawjee Analysis, is presented.

The analysis

The proposed Dawjee Analysis is primarily focused on evaluating craniofacial structures in the vertical dimension. It employs various lateral cephalometric landmarks, planes, angles and triangles as listed below.

Lateral cephalometric landmarks

There are 11 anatomical landmarks necessary for this analysis. These are described below and illustrated in Figure 25.

1. *Sella (S)* - the midpoint of the pituitary fossa of the sphenoid bone.
2. *Nasion (N)* - the intersection of the inter-nasal suture with the naso-frontal suture in the mid-sagittal plane.
3. *Porion (Po)* - the highest point on the superior surface of the bony auditory meatus.
4. *Orbitale (Or)* - the lowest point on the left infra-orbital margin.
5. *Posterior nasal spine (PNS)* - the tip of the posterior spine of the palatal bone.
6. *Anterior nasal spine (ANS)* - the tip of the anterior nasal spine of the palatal bone.
7. *A Point* - the deepest point on the anterior border of the maxilla.
8. *B Point* - the deepest point on the anterior border of the mandibular symphysis.
9. *Occlusal contact point (OCP)*- the most anterior intercuspation contact point between the upper and lower first permanent molars (Dawjee *et al.*, 2005).
10. *Gonion (Go)* - the point on the mandibular jaw angle, which is the most inferiorly, posteriorly and outwardly directed as determined by an intersection point of the lower border of the mandibular body and the posterior border of the ramus (Jacobsen, 1995).
11. *Gnathion (Gn)* - the most antero-inferior point on the contour of the mandibular symphysis.

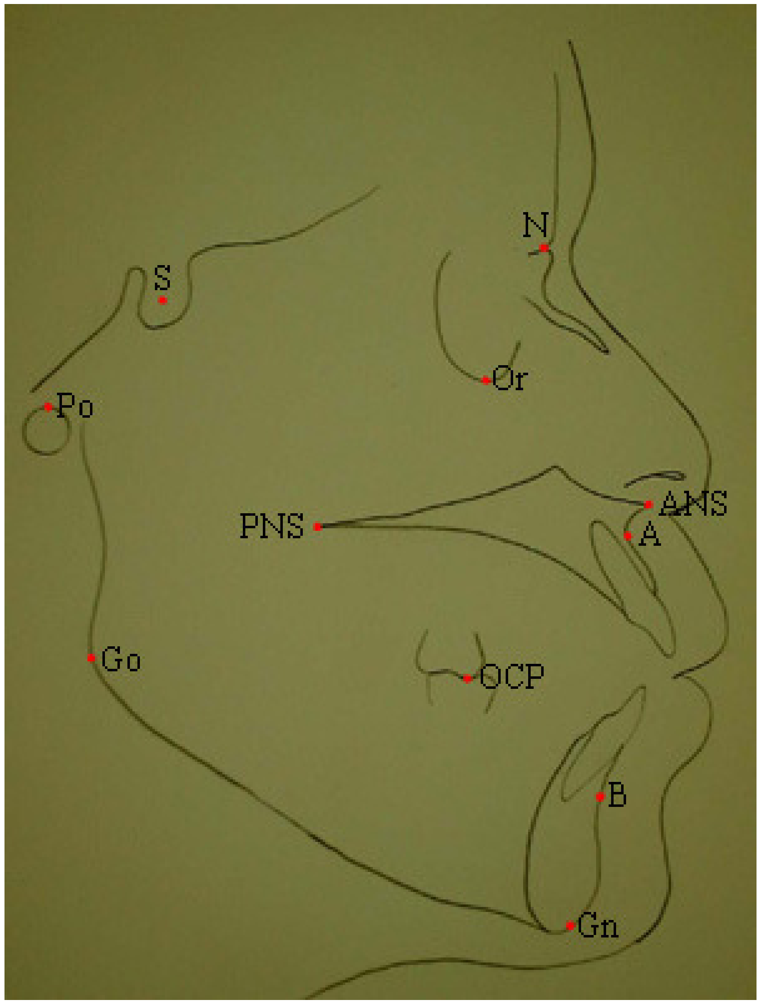

Figure 25. Anatomical landmarks of the proposed Dawjee Analysis

Lateral cephalometric planes and lines

Once identified, the anatomical landmarks are connected in various ways to produce lines, planes and angles as depicted in Figure 26:

1. *Anterior cranial base* extends from S to N (Coben, 1998; Downs, 1952; Steiner, 1953).
2. *Frankfort horizontal plane* extends from porion to orbitale (Tweed, 1954).

3. *S to ANS* is defined by a line joining these two points (Dawjee *et al.*, 2005).
4. *N to PNS* is defined by a line joining these two points (Dawjee *et al.*, 2005).
5. *S to A* is defined by a line joining these two points (Dawjee *et al.*, 2005).
6. *S to B* is defined by a line joining these two points (Dawjee *et al.*, 2005).
7. *Y axis* extends from S to Gn (Downs, 1952; Jarabak and Fizzell, 1972).
8. *Z axis* extends from N to Go (Dawjee *et al.*, 2005). This is referred to the 'Z axis' and has no connection to the 'Z angle or plane' described by Merrifield (Graber and Vanarsdall, 2000).
9. *OCP to A* is defined by a line joining these two points (Dawjee *et al.*, 2005).
10. *OCP to B* is defined by a line joining these two points (Dawjee *et al.*, 2005).

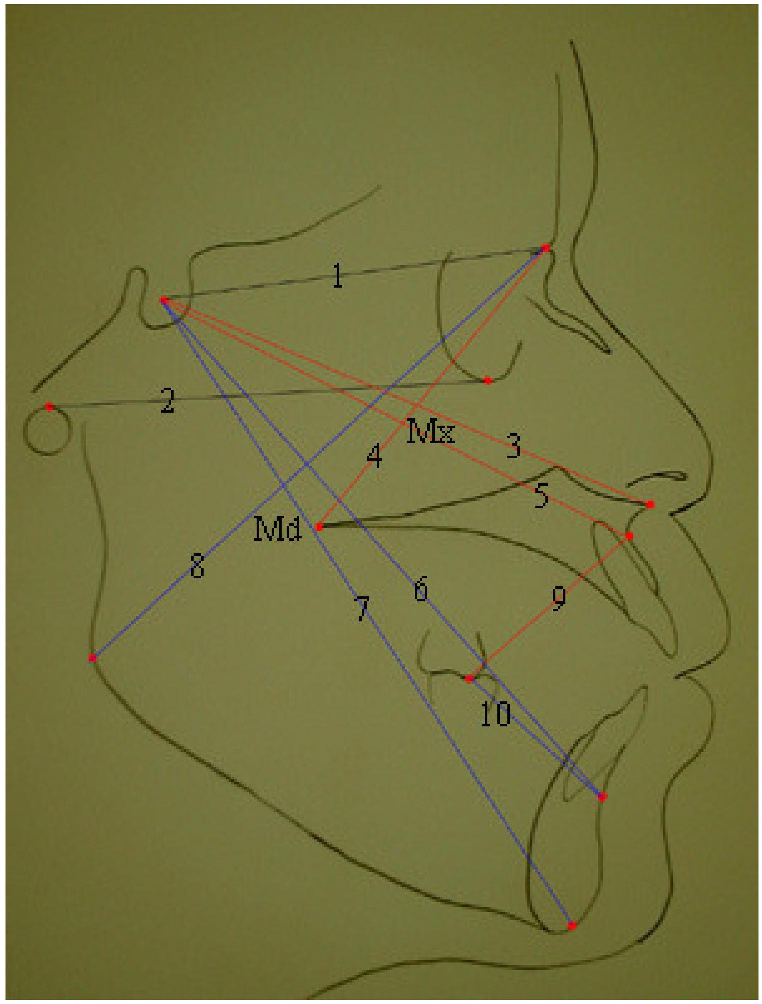

Figure 26. Angles and planes of the proposed Dawjee Analysis

Lateral cephalometric measurements

From the above landmarks and planes, one linear and ten angular measurements can be recorded. These are:

1. *Anterior cranial base inclination* as an angle formed between SN and the Frankfort horizontal plane.
2. *Anterior cranial base length* is the length of S to N expressed in millimetres (Dawjee *et al.*, 2005; Jarabak and Fizzell, 1972).

3. *Anterior maxillary position* is defined by the NS-ANS angle (Dawjee *et al.*, 2005).
4. *Posterior maxillary position* is defined by the SN-PNS angle (Dawjee *et al.*, 2005).
5. *Anterior mandibular position* is defined by the NS-Gn angle (Dawjee *et al.*, 2005).
6. *Posterior mandibular position* is defined by the SN-Go angle (Dawjee *et al.*, 2005).
7. *Point A position* is defined by the NSA angle (Dawjee *et al.*, 2005).
8. *Point B position* is defined by the NSB angle (Dawjee *et al.*, 2005).
9. *Interalveolar angle* is defined by the A-OCP-B angle (Dawjee *et al.*, 2005).
10. *Apex of the maxillary triangle* (Dawjee *et al.*, 2005) is labelled Mx and is located at the intersection of the N-PNS and S-ANS lines. All lines related to the maxilla are represented in red
11. *Apex of the mandibular triangle* (Dawjee *et al.*, 2005) is labelled Md and is located at the intersection of the N-Go and S-Gn lines. All lines related to the mandible are represented in blue.

Appraisal

The innovation of the proposed Dawjee Analysis is in its assessment of the craniofacial structures in the vertical dimension. Many of the landmarks, planes and parameters have been defined and tested by previous researchers (Burford and Noar, 2003; Downs, 1952; Jacobsen, 1975; Jarabak and Fizzell, 1972; Mc Namara, 1984; Sassouni, 1969; Steiner, 1953; Steiner, 1960; Tweed, 1954) and have been copied and incorporated into the proposed Dawjee Analysis.

New reference points introduced for this analysis include the OCP, interalveolar angle, the z-axis, the maxillary triangle and the mandibular triangle. These new measuring parameters, necessitated the introduction of the OCP and the seven planes (Dawjee *et al.*, 2005) as listed above under the heading: cephalometric landmarks and planes. The proposed analysis was specifically designed to enable facial skeletal measurements from both the anteroposterior and posteroanterior craniofacial aspects and in order to facilitate this, the S to ANS, S to A, S to B, OCP to A and OCP to B were introduced as posteroanterior reference planes while the N to PNS and N to Go planes form the anteroposterior reference lines.

From the OCP, planes are constructed to points A and B rather than to ANS or Gn as points A and B are closer to the occlusal reference point (OCP) and would therefore be more appropriate in relating the anterior discrepancies to the occlusal plane than would points ANS and Gn. Although considered, the upper and lower incisal tips were excluded from an angular measurement with reference to OCP because of their susceptibility to factors such as crowding, spacing, angulation, inclination, delayed eruption, and compensatory over eruption. The amount of separation between the upper and lower incisal edges was however employed in the proposed analysis as a linear measure of AOB.

In accordance with other analyses (Downs, 1952; Sassouni, 1955; Steiner, 1953), the proposed Dawjee Analysis also employs the cranial base as a reference plane. All angular measurements except the interalveolar angle are measured from the cranial base, which is said to mature and stabilise early in life (Ford, 1958). Angular measurements are then used to plot the vertical spatial relationship of the maxilla, mandible and anterior alveolar arches.

While most cephalometric analysis project their facial planes, angular and linear measurements from the posterior regions of the face to the anterior hard and soft tissue outline (Downs, 1952; Kim, 1974; Sassouni and Nanda, 1964), the proposed Dawjee Analysis incorporates measurements from both posterior to anterior and vice versa. In common with other analyses, the landmarks used in this analysis are readily identifiable and the various planes can be constructed with ease.

The incorporation of landmarks and parameters from other analyses into the proposed Dawjee Analysis was based on the ease of identification and simplicity of construction. The ANS-Xi-Pm angle of Ricketts (1981) for instance, was not considered in order to maintain simplicity and reduce duplicity. In the proposed analysis ANS is measured against the cranial base, while Xi point can be susceptible of the influence of mandibular ramus orientation. The location and identification of Xi point is also complex in that it requires the construction of four other planes. Likewise condylar axis and Basion were excluded from the proposed analysis, as these parameters are often obscured and not readily identifiable on the lateral cephalogram.

All of the parameters used in the proposed Dawjee Analysis are angular measurements except the cranial base length and the amount of incisor separation in AOB cases. Unlike linear measurements, angular measurements remain consistent regardless of the enlargement factor (Athanasiou, 1995). While linear measurements compute the shortest distance between two points, angular measurements have an advantage in that they require and incorporate a third point and therefore measures the amount of separation between the two points relative to a third point. In the proposed Dawjee Analysis this third reference point is a component of the cranial base and is used in all angular parameters except one, the interalveolar angle. As with other analyses (Downs, 1952; Ricketts, 1981; Steiner, 1953), the cranial base has proven to be easily identifiable, reliable and reproducible. In composing the apex of these angular projections, points S and N of the cranial base would promote stability and reliability of parameters in the proposed Dawjee Analysis rather than introduce inconsistency and variability to the defining parameter.

In growing individuals linear measurements will vary with age. However with angular measurements the trend remains the same as the patient grows. Similarly, with gender differences; females tend to have smaller linear measurements than males, but angular measurements are often similar e.g. ANB, Y axis etc.

The advantage that angular measurements have over linear measurements in computing spatial dimensions can be visualised in the amount of vertical separation between points A and B. Linear measurement between these two points would be more vulnerable to changes in the horizontal relationship of the jaws and would therefore be less reliable when computing vertical discrepancies between these points than would angular measurements. In his assessment of linear measurements to compare AFH, PFH, UAFH and LAFH, Jacobsen (1995) draws attention the variability in dimensions that occurs when these measurements are taken from the landmarks and projected perpendiculars.

The vertical position of the mandible is defined by the angles NSGn and SNGo. Changes in these angles would reflect the skeletal contribution of the mandible to the vertical facial dimension. Although an increase in NSGn can imply a skeletal open bite, it should be measured and valued against a relative decrease in SNGo. The points Gn and Go were specifically selected for the proposed Dawjee Analysis, as they constitute the anterior and posterior boundaries of the mandibular length.

The position of the mandible will be affected by any change in the condyle and glenoid fossa. While such changes may be recorded by the mandibular plane angle or GoGn line (Downs, 1952; Kim, 1974; Sassouni, 1969; Steiner, 1960), the SNGo angle, due to its specificity, would be more sensitive to morphological changes in the TMJ owing to the close approximation of Go to the TMJ.

The SNGo angle is also important in pinpointing the spatial position of the angle of the mandible. This area is suspended by the pterigo-masseteric sling and is influenced by the morphology of the posterior border of the mandibular ramus which undergoes remodelling throughout life (Ranly, 2000). The posterior border of the mandible and mandibular angle are also reactive to changes in the mandibular condyle and glenoid fossa e.g. condylar growth would cause anterior displacement of the chin and accompanying resorption of the posterior mandibular border to bring about bodily mandibular displacement (Enlow, 1990; Schudy, 1965). While the gonial angle (Cangialosi, 1984) describes the morphology of the mandibular angle, it falls short of defining the position and changes this landmark undergoes relative to the cranial base. The SNGo angle therefore attempts to define this point in relation to other craniofacial structures.

The spatial position of the maxilla can be defined by the angles NS-ANS and SN-PNS. The reason for measuring ANS and PNS against the cranial base instead of measuring them to an occlusal reference point for example OCP, is to determine the cant of the palatal plane against a stable and independent reference plane such as the cranial base. ANS and PNS were specifically selected as they represent the two extremes of the palatal plane and any abnormal canting of this plane will affect mandibular rotation and as a consequence, anterior overbite. The angles NS-ANS and SN-PNS therefore point out the skeletal contribution of the maxilla to the vertical dimension. A decrease in NS-ANS can imply a maxillary skeletal contribution to an AOB while an increase can be interpreted as maxillary compensation for an AOB or the maxillary component of a deepbite. NS-ANS readings must however be compared to changes in SN-PNS to establish total maxillary cant. The relevance of selecting ANS and PNS in the proposed Dawjee Analysis is supported and relevant in the treatment planning of orthognathic cases where the osteotomy sites for Le Forte I procedures are always above the palatal plane (Epker and Fish, 1977; Reyneke, 1988). It is therefore essential that standardised values for the proposed Dawjee Analysis be determined for population samples before such comparisons can be applied and deductions drawn for the population under investigation.

Rotation, whether clockwise or counter clockwise of either the maxilla or the mandible is best measured when the dimensions of the jaws and its relationship to a point of reference are considered. The proposed Dawjee Analysis fulfils this requirement in that it measures the boundaries of both jaws (i.e. ANS and PNS for the maxilla and Go and Gn for the mandible) and relates them to the cranial base. This affords the clinician the opportunity to monitor changes in the anterior and posterior regions of the jaws individually and independently.

The dentoalveolar contribution to the vertical dimension is determined from the angles NSA, NSB and A-OCP-B. Once standardised values in a normal population sample are established, the values of these angles will assist in determining the dentoalveolar component to the vertical facial dimension.

The crux of the proposed analysis is its potential ability to identify and distinguish between the skeletal and dentoalveolar components of an AOB. Dentoalveolar positioning will always be affected by changes in the skeletal positions of the upper and lower jaws. With the establishment of standardised values the contribution or compensation of each component can be determined.

The angular measurements used in this proposed analysis can also be employed to indicate and compare facial heights, instead of the linear measurements advocated by other analyses (Jarabak and Fizzell, 1972; Nahoum *et al.*, 1972; Nahoum, 1975; Nahoum, 1977). The angles NS-ANS, NSA, NSB and NS-Gn for example, are indicative of anterior facial height while SN-PNS and SN-Go can measure posterior facial height.

Although incisor separation, expressed in millimetres, is a linear measurement, its interpretation can be complemented by the angle A-OCP-B, which indicates the degree of dentoalveolar separation or compensation. A weakness of the latter parameter is that it is dependant on the occlusion of the upper and lower first molars. The total differences between anterior skeletal and alveolar heights can also be computed from the angles ANS-S-Gn and ASB while individual differences within each jaw can be deduced from the ANS-S-A angle for the maxilla and the Gn-S-B angle for the mandible.

The maxillary triangle has a line from ANS to PNS as its base and its apex is labelled Mx, while a line from Gn to Go defines the base of the mandibular triangle and its apex is labelled Md (Figure 26). Base lines of both triangles have been excluded from the cephalometric tracing for the sake of maintaining simplicity and because linear measurements of the jaws bear no significance on AOB and are therefore not included in the proposed analysis.

The apices of the two triangles Md and Mx are important as their dimensions give a broad estimate of mandibular and maxillary sizes and their orientation. The role of the Mx and Md angle is best visualised by the hypothetical case illustrated in Figure 27 below. In this diagram, the cranial base SN and point Go remains constant, while mandibular symphysis Gn rotates downward and backward and is placed at three different levels namely, Gn1, Gn2 and Gn3. This downward rotation of the mandible has an effect on the Md angle causing it to become more acute. It can also be noted that the Md angle gives a more accurate account of the spatial position of the mandible than would mandibular length. This diagram is presented to illustrate a geometric phenomenon. In the clinical situation, changes in Gn would probably not be so remarkable and would not occur in isolation. Other areas of the craniofacial skeleton such as Go would also remodel and adapt to a different position necessitating an integration and evaluation of the other parameters of the proposed Dawjee Analysis. In a similar way changes in ANS and PNS that alter the orientation of the maxilla would affect the size of the Mx angle.

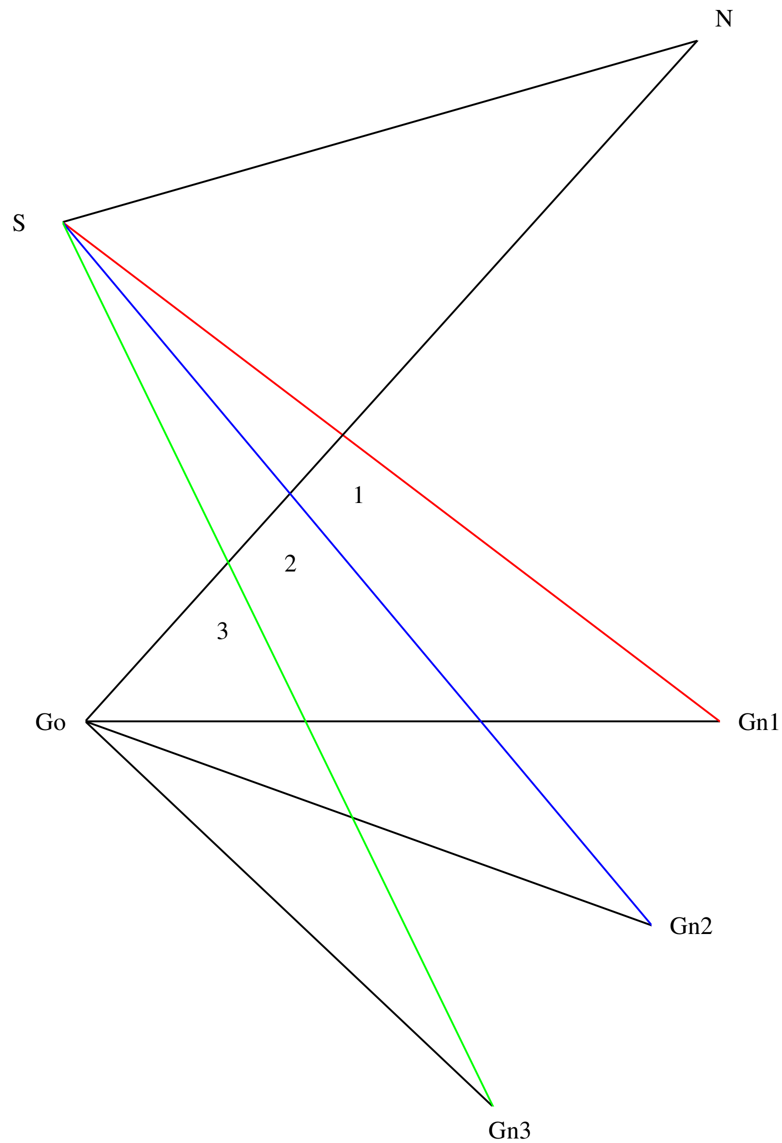

Figure 27. The effect of gnathion position on the mandibular angle

While an increase in these angles could also imply greater jaw length and a decrease can be interpreted as a smaller jaw with regard to the standardised values for the population sample under investigation, it would not be as accurate as a linear measurement in depicting jaw length.

Although the proposed Dawjee Analysis is mainly directed at measuring vertical hard tissue relations, some horizontal relations can also be deduced. The NS-Gn angle for instance measures the vertical position of the anterior part of the mandible but can also gives an indication of the relative horizontal relationship of the mandible. A high value for this angle would be indicative of a vertical grower possibly associated with a skeletal AOB and a retrusive mandible while a low NS-Gn value can allude to a deepbite, which may be associated with a protrusive mandible. As the proposed Dawjee Analysis is primarily aimed at defining vertical facial hard tissue relations, other appropriate and established cephalometric analysis (Downs, 1952; Jacobsen, 1975; Ricketts, 1981; Steiner, 1960) would be more suited to confirm horizontal skeletal relations.

When cephalometric tracings and values (Figures 28 and 29, Table 5) for the proposed Dawjee Analysis between an AOB and a deepbite case are compared, it is evident that there are differences in all of the measured parameters between the two cases. These differences are particularly pronounced in 9 of the 11 parameters, which show differences greater than 5 measuring units used to compute these parameters. Although the anterior cranial base is longer in the deepbite case, it is much steeper (by 9° to the FH plane) in the AOB case, clearly indicative of a skeletal contribution to the vertical height. Measurements of the maxilla and mandible relative to the cranial base indicate that there is a clockwise rotation of both jaws (NSA=48°, NSB=73°) with more pronounced mandibular rotation. In the deepbite case, the anterior alveoli are inclined toward one another (Interalveolar angle=62°) while they are widely separated in the AOB case (Interalveolar angle 94°).

These differences in cephalometric readings between a patient with an open bite and one with a deepbite illustrates that dissimilarities in cephalometric values of the proposed analysis between the two cases are evident and that the parameters employed in the proposed Dawjee Analysis have the potential of diagnosing and assessing vertical discrepancies. Once standardised mandibular and maxillary positions are established, the newly introduced interalveolar angle can be used to evaluate alveolar contributions to, or compensations for, the vertical problem. Alveolar location relative to the cranial base can be also assessed using angles against the SA and SB lines.

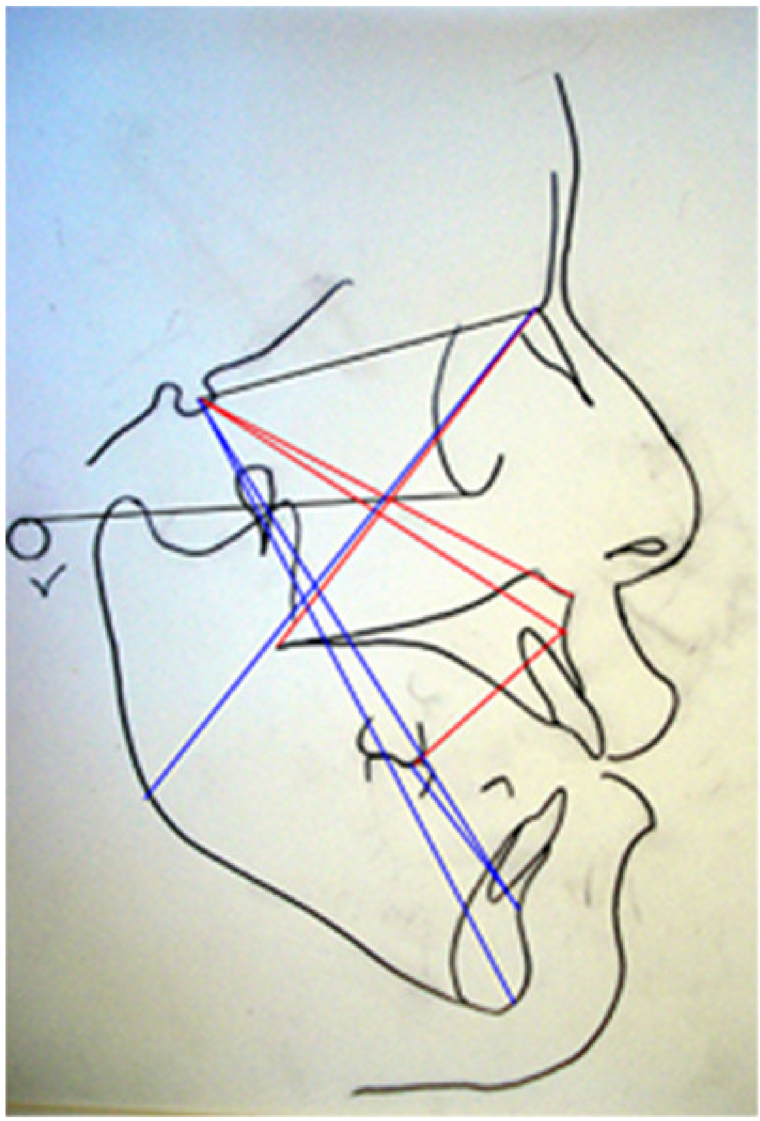

Figure 28. Application of the proposed Dawjee Analysis in an AOB patient

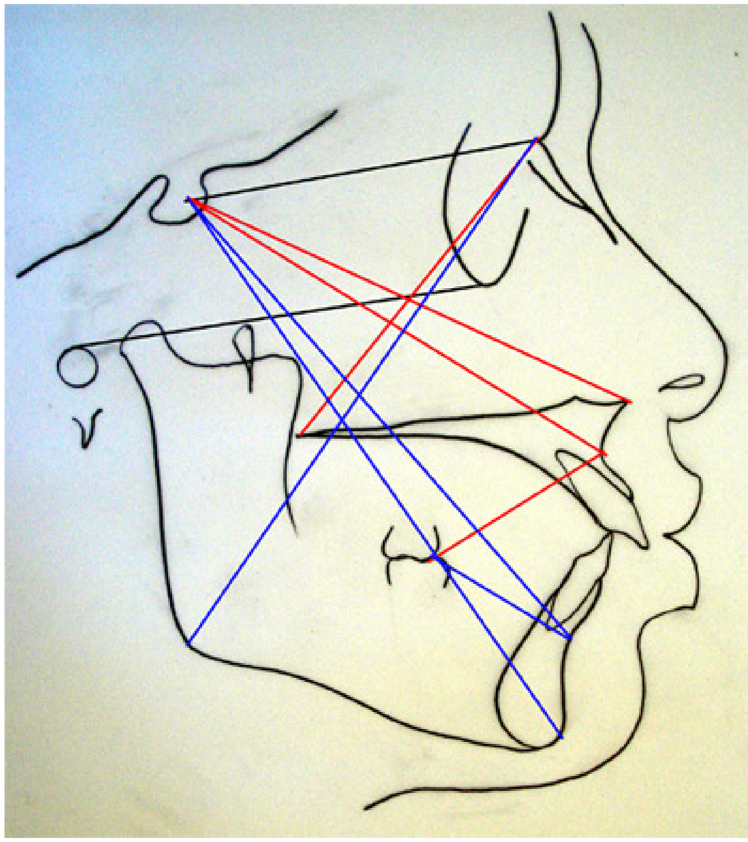

Figure 29. Application of the proposed Dawjee Analysis in a deepbite patient

Table 5. Comparison of cephalometric values for the proposed Dawjee Analysis between an AOB and a deepbite patient

	Open bite patient	Deepbite patient	Difference
Anterior cranial base inclination (º)	11	2	9
Anterior cranial base length (mm)	64	68	4
Anterior maxillary position (º)	43	34	9
Posterior maxillary position (º)	37	40	7
Anterior mandibular position (º)	77	65	12
Posterior mandibular position (º)	36	45	11
Point A position (º)	48	41	7
Point B position (º)	73	55	18
Interalveolar angle (º)	94	62	32
Apex of maxillary triangle (º)	96	104	8
Apex of mandibular triangle (º)	66	70	4

When the two cases were evalusted using other analyses relevant to the measurement of vertical dimension, differences between the AOB and deepbite cephalometric values were also evident (Figures 30 and 31, Table 6). Components of the Sassouni, Ricketts and Harvold analyses were used and these are respectively represented in figures 30 and 31 by green, red and blue lines. Most notable differences between the AOB and deepbite cases were detected in the palatal plane, occlusal plane, mandibular length, lower face height and the mandibular plane (Table 6).

The Sassouni analysis (Sassouni, 1969) demonstrated an anticlockwise rotation of the maxilla relative to the FH (-8° in the AOB case and 2° in the deepbite case). This is contradictory to the finding of the proposed Dawjee Analysis that shows a clockwise rotation of the maxilla. Findings of the latter analysis are supported by other indicators in the proposed Dawjee analysis namely, ANS position (43° in the AOB case and 34° in the deepbite case), PNS position (37° in the AOB case and 40° in the deepbite case) and the position of A point (77° in the AOB case and 65° in the deepbite case) relative to cranial base (Table 5). These findings point to a possible compensatory closure of the maxilla in response to the AOB. Readings of the occlusal plane (14° in the AOB case and 2° in the deepbite case) (Table 6) relate to the difference between the FH and the palatal plane and is therefore not measured against a common and fixed plane as used by the proposed Dawjee Analysis. Measurements of the Sassouni analysis relating to the occlusal plane can also be unclear and ambiguous depending on which occlusal plane is used in AOB patients – the maxillary occlusal plane, the mandibular occlusal plane or the functional occlusal plane.

The Sassouni analysis also fails to distinguish between the dental and skeletal contributions to vertical craniofacial relations. Another difference of the proposed Dawjee Analysis from the Sassouni analysis is that in the proposed Dawjee Analysis the angles can be measured off the cephalometric tracing and need not be projected to their point of convergence, which in most instances of the Sassouni analysis extends beyond the cephalometric tracing.

Changes in components of the Ricketts (Ricketts, 1981) and Harvold (Athanasiou, 1995) analysis, in the mandibular length, lower face height and the mandibular plane between the AOB and deepbite cases (Table 6) are anticipated and predictable although the landmarks used to compute these parameters such as condylion and basion are often obscure and hazy. These parameters of the Ricketts and Harvold analyses that show a difference between the AOB and deepbite cases do not incorporate and reflect on changes in the occlusal and alveolar regions; vital areas which are included in the proposed Dawjee Analysis.

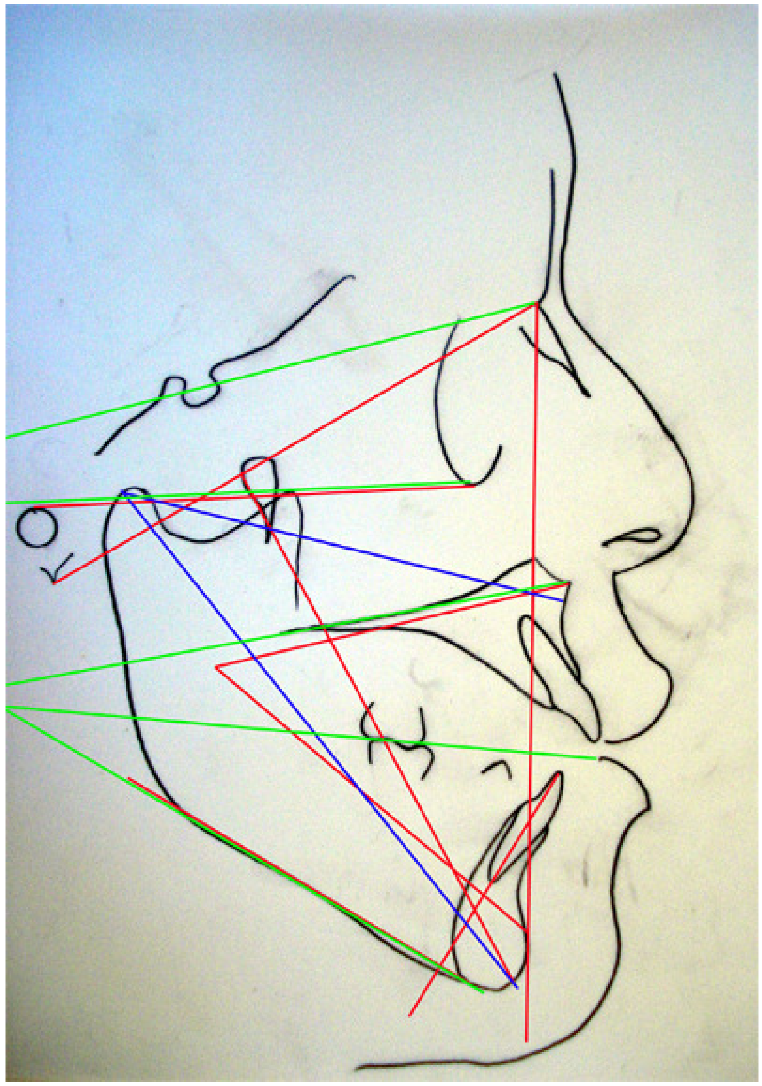

Figure 30. Components of the Harvold, Rickets, and Sassouni analyses of an AOB patient

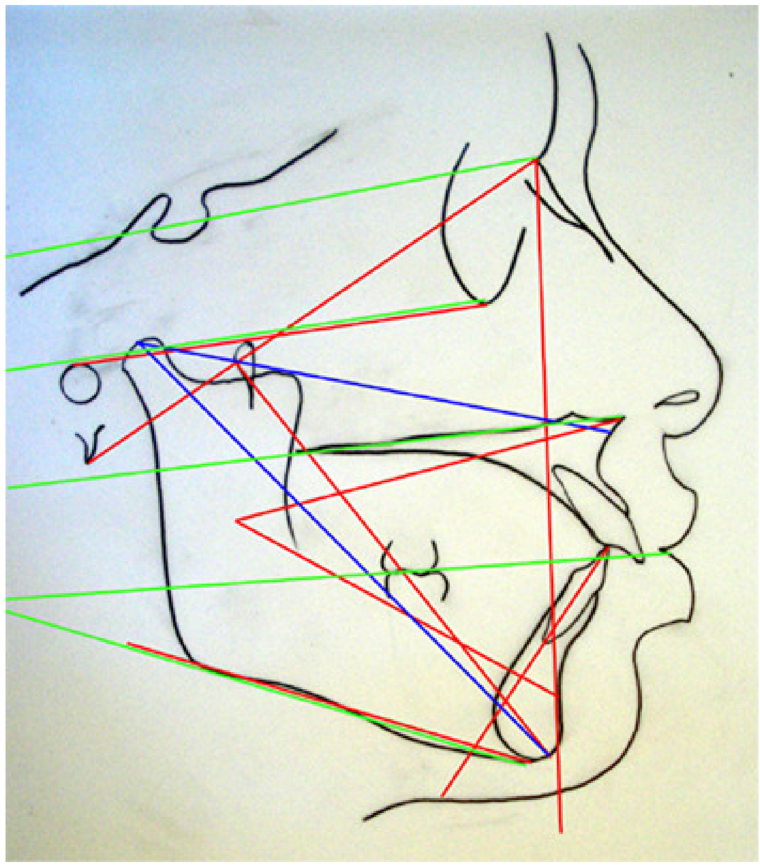

Figure 31. Components of the Harvold, Rickets, and Sassouni analyses of a deepbite patient

Table 6. Comparison of Sassouni, Harvold and Ricketts cephalometric values between an AOB and a deepbite patient

	Open bite patient	Deepbite patient	Difference
Sassouni Values			
SN-FP (º)	11	2	9
FH-PP (º)	-8	2	10
PP-OP (º)	14	2	12
OP-MP (º)	26	20	6
Harvold Values			
Maxillary length (mm)	85	90	5
Mandibular length (mm)	116	110	6
Lower face height (mm)	67	59	8
Ricketts Values			
Facial axis (º)	91	94	3
Mandibular plane (º)	32	24	8
Lower face height (º)	54	43	11
Mandibular incisor inclination (º)	30	34	4

When applying another vertical assessment method, the ODI analysis (Kim, 1974) to the AOB and deepbite cases, a value of 102° was obtained for the deepbite case and a value of 81° for the AOB case. These values are well outside of the predictive values for AOB as proposed by the Kim who found that an ODI value of less than 68° was confirmation of an AOB (Beane *et al.*, 2003; Kim, 1974). This is however an isolated case (n=2) and since the ODI analysis has not been tested on a South African Black population and standardised values for this population group are not available, conclusions about the relevance of the ODI analysis for the South African Black population cannot be made. While the ODI purports to measure open bite tendency, it does fall short of identifying the root cause of the vertical discrepancy (Kim, 1974).

The analysis prescribed by Cangialosi (1984) is another technique used in describing vertical facial dimensions. It measures nine parameters that have been extracted and duplicated from other analyses (Jarabak and Fizzell, 1972; Sassouni and Nanda, 1964). This analysis is also not well supported in separating skeletal from dentoalveolar AOBs in that it makes an unfounded and preliminary assumption that if four of the six recorded values are one standard deviation from the normal, the open bite is considered to be of a dentoalveolar nature. The analysis also fails to identify and specify which of the nine parameters constitute the four-value category and which make up the six-value group. In the application of this cephalometric method to a population sample, Cangialosi (1984) concluded that the study accentuated the difficulty in separating skeletal and dentoalveolar open bites (Cangialosi, 1984).

The two cases presented in this chapter are of matching age, gender and race. At this juncture the findings from these two isolated cases (n=2) are not representative of the population and are used merely to illustrate that differences in cephalometric values for the proposed Dawjee Analysis between an AOB and a deepbite case do exist. Findings from these two cases should therefore be interpreted with caution, as conclusions cannot be widely implemented unless the analysis is applied to a larger and more representative sample of the population. However, comparison of the two cases does point to the fact that differences in cephalometric values of the proposed Dawjee Analysis between the AOB and the deepbite subjects are apparent and this should support and warrant scientific investigation as to whether this difference is an isolated occurrence.

Malocclusion in the vertical dimension is a common phenomenon (Steiner, 1953), manifesting clinically as either an open or a deepbite. Identification of the morphological traits and source of the problem is critical in order to apply the appropriate treatment, but the process can often be confusing and cumbersome (Cangialosi, 1984). By determining mandibular and maxillary positions and alveolar location in the vertical plane, this preliminary presentation of the proposed Dawjee Analysis attempts to stimulate and initiate further investigation into the subject in order to enhance the diagnosis and treatment management of vertical craniofacial abnormalities.

Chapter 5

Clinical application of the proposed Dawjee Analysis

Anterior open bite (AOB) malocclusion is a common orthodontic concern and according to Beane (Beane et al., 2003) the NHANES III (National Health and Nutrition Estimates Survey) study cites that the condition can occur from 2,5 to 4 times more often in African American Blacks than in Whites. Aetiological factors that have been implicated in the development of the condition include, unfavourable growth pattern (Schudy, 1965), finger sucking habits (Mizrahi, 1978), enlarged lymphoid tissue (Linder-Aronson, 1970), abnormal tongue and orofacial muscular activity (Moss and Salentijn, 1971), and genetic causes (Swineheart, 1942). These factors can result in a dental open bite, a skeletal open bite or a combination of the two (Richardson, 1969).

In order to realize and apply aspects of the literature review, the aetiology, diagnosis, treatment and appraisal of the outcome, an AOB case is presented. It is essentially aimed at associating the aetiological components of AOB and the effect that they have on craniofacial morphology. The application of a treatment method is described and cephalometric changes before and after treatment is discussed.

Case presentation

A 23-year old Black female patient presented at the Orthodontic Department of the School of Dentistry, University of Limpopo, South Africa, complaining that her upper and lower front teeth do not meet. She had no family history of the condition and a dental history revealed that she had a habit of thumb sucking until the age of twelve years.

Clinically the following was noted (Figure 32, Figure 33, Figure 34, Figure 35 and Figure 36)

1. A bimaxillary protrusive facial profile.
2. Incompetent lips at rest.
3. Disclusion of the upper and lower anterior teeth from 3 to 3.
4. An anterior open bite of 7mm.
5. Incisal abrasion of the 11 and 21.
6. Class I buccal occlusion on left side and a half cusp Class II on the right side.
7. Two millimetres of spacing mesially and distally on both the 13 and 23.
8. Six millimetres of spacing between the lower incisors from 33 to 43.
9. An upper midline shift of 3mm to the left.

Figure 32. Frontal view: Pre-treatment

Figure 33. Lateral view: Pre-treatment

Figure 34. Anterior occlusal view: Pre-treatment

Figure 35. Right occlusal view: Pre-treatment

Figure 36. Left occlusal view: Pre-treatment

Oral hygiene, speech and swallowing were normal and the patient had no other dentofacial concerns. Because the habit had stopped eleven years ago and the patient's growth was complete, orthodontics, or a combination of orthodontics and orthognathic surgery, were the only treatment options available. The patient was however reluctant to undergo any form of surgery.

From an orthodontic perspective, two treatment modalities were proposed to manage the AOB:

1. Extraction of upper and lower premolars followed by full fixed orthodontics or
2. Non-extraction full fixed orthodontic therapy only.

After informed deliberation, the patient opted for the second treatment plan.

Active treatment lasted for approximately 15 months and consisted initially of upper and lower 2x4 utility archwires with reverse tip back bends mesial to the first molars. This was followed with full archwires modified with reverse curves of Spee in the upper archwire and an exaggerated curve in the lower. Final archwires were supplemented with anterior elastics to maintain bite closure.

At the end of treatment, acceptable results were achieved with a normal overbite and overjet of 2mm each. Buccal occlusion on the left was Class I while the right side remained half cusp Class II, accounting for the persistence an upper midline shift of 3mm to the left (Figure 37, Figure 38, Figure 39, Figure 40 and Figure 41). Retention was maintained for a year and consisted of fixed upper and lower 3-3 retainers.

Figure 37. Frontal view: Post-treatment

Figure 38. Lateral view: Post-treatment

Figure 39. Anterior occlusal view: Post-treatment

Figure 40. Right occlusal view: Post-treatment

Figure 41. Left occlusal view: Post-treatment

Cephalometric Analysis

While various cephalometric analyses are available to diagnose and identify the morphological components of an AOB (Cangialosi, 1984; Kim, 1974; Nahoum, 1975; Sassouni, 1955; Sassouni and Nanda, 1964; Tweed, 1946), this case presentation attempts to illustrate the clinical and practical application and relevance of the proposed Dawjee Analysis (Dawjee *et al.*, 2005). By comparing the pre-treatment cephalometric values with post-treatment cephalometric values parameters of cohesion and diversity in the vertical plane are illustrated (Figure 42, Figure 43 and Table 7).

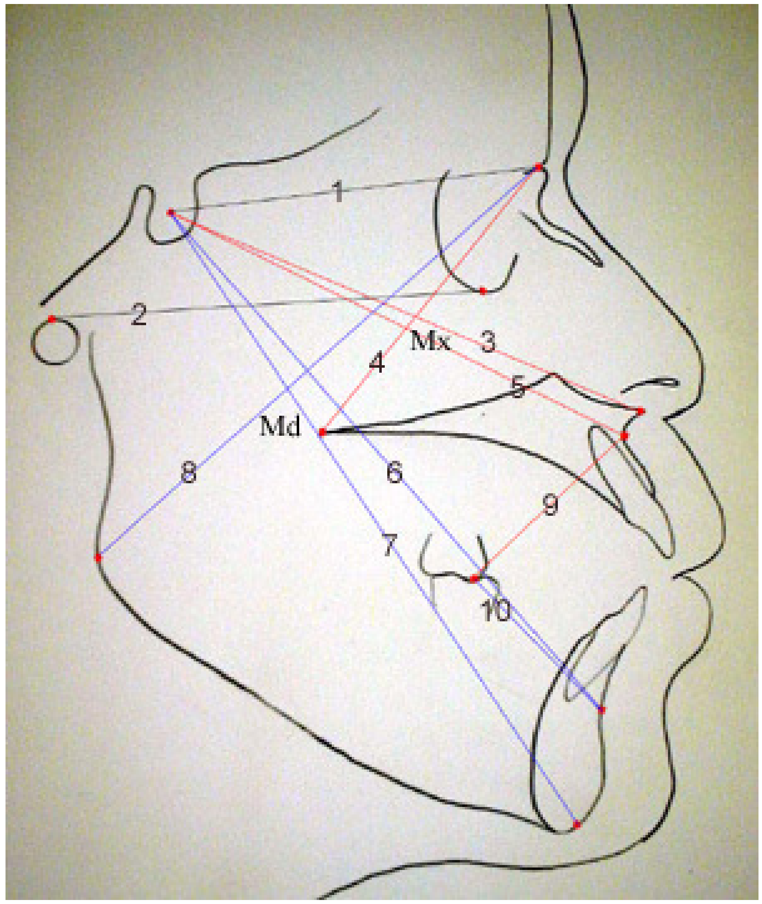

Figure 42. Pre-treatment cephalometric evaluation using the proposed Dawjee analysis

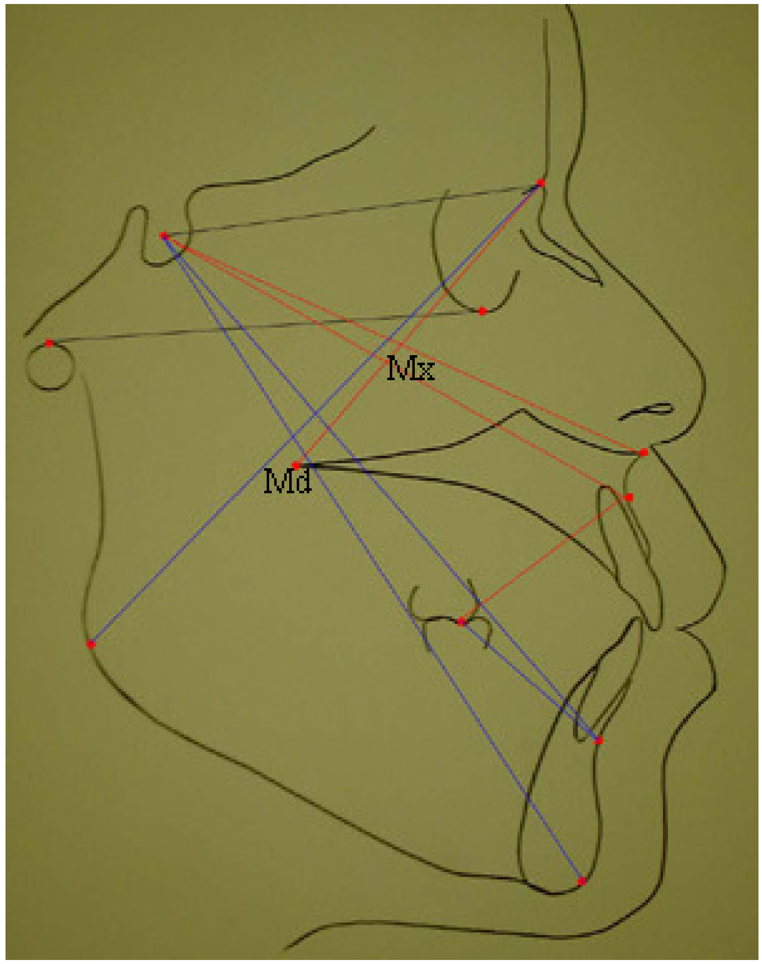

Figure 43. Post-treatment cephalometric evaluation using the the proposed Dawjee analysis

Table 7. Pre-treatment and post-treatment cephalometric values of the proposed Dawjee analysis

	Pre-treatment values	Post-treatment values
Anterior cranial base inclination	5°	5°
Anterior cranial base length	68mm	68mm
Anterior maxillary position	30°	33°
Posterior maxillary position	43°	41°
Anterior mandibular position	64°	65°
Posterior mandibular position	34°	39°
Point A position	34°	37°
Point B position	56°	58°
Interalveolar angle	83°	75°
Apex of maxillary triangle	107°	106°
Apex of mandibular triangle	82°	76°

Case Discussion

Although the orthodontic treatment of this patient was without incident, some biomechanical observations need reflection. While the first premolars were considered for extraction, and retraction of the anterior segments by way of the drawbridge concept (Beane, 1999) would have resulted in bite closure, a reduction of the bimaxillary protrusion, midline correction and a defined Class I occlusion; this patient was happy with her horizontal facial profile and did not want to have any teeth removed. Furthermore, extractions could encroach on tongue space and it was a concern that this may compromise post-treatment stability.

Reverse tip back bends in a utility archwire are effective in extruding incisors, but cause reciprocal mesialisation and buccal displacement of molars. This problem can be overcome with the use of transpalatal and lingual arches. To retain overbite correction, anterior box elastics were used when full archwires were inserted and posterior segments levelled. Post treatment intra oral photographs (Figure 39, Figure 40 and Figure 41) were taken immediately after a scaling and account for the irritation and bleeding around the gingival margins. Photographs could not be taken later when the gingiva healed, as the patient relocated immediately after deband.

Lingually bonded fixed retainers were preferred instead of removable Hawley retainers as the former are less likely to interfere with the posterior occlusion and cause relapse. As the patient relocated to a rural district after treatment, study casts that were sent to the Orthodontic Department approximately a year after treatment show no evidence of relapse (Figure 44, Figure 45 and Figure 46). Health service constraints and accessibility in the patient's new and rural location ruled out the possibility of obtaining a post retention orthopantomogram or lateral cephalogram.

Figure 44. Post retention study models: Frontal view

Figure 45. Post retention study models: Right view

Figure 46. Post retention study models: Left view

When the cephalometric values for the proposed Dawjee Analysis between pre-treatment (Figure 42) and post-treatment (Figure 43) tracings are compared (Table 7), it becomes evident and it is expected, that the cranial base length and inclination did not change. Treatment changes in the palatal plane point to a clockwise rotation of the maxilla as evidenced by a 3-degree drop in the anterior part of the maxilla and a two-degree elevation in the posterior region. Although the anterior mandibular position (Gn) of the mandible remained unchanged, the mandibular angle (i.e. Go point relevant to cranial base) dropped from 34 to 39 degrees pointing to a 5-degree counter clockwise rotation of the mandibular angle.

Anterior interalveolar distance decreased remarkably with treatment as evidenced by a downward repositioning of point A by three degrees, a decrease in interalveolar angle of eight degrees and the establishment of a positive overbite of two millimetres.

A reduction in the apex of the mandibular triangle (Md) should be interpreted with caution. While this angle is dominated by mandibular length, which in this case has not changed, the four-degree loss in Md must be due to a downward and forward repositioning of Go as confirmed by the five-degree drop in posterior mandibular position.

Components of the Sassouni, Ricketts and Harvold analyses were also used to compare the pre and post treatment cephalograms and these are once again respectively represented in figures 47 and 48 by green, red and blue lines.

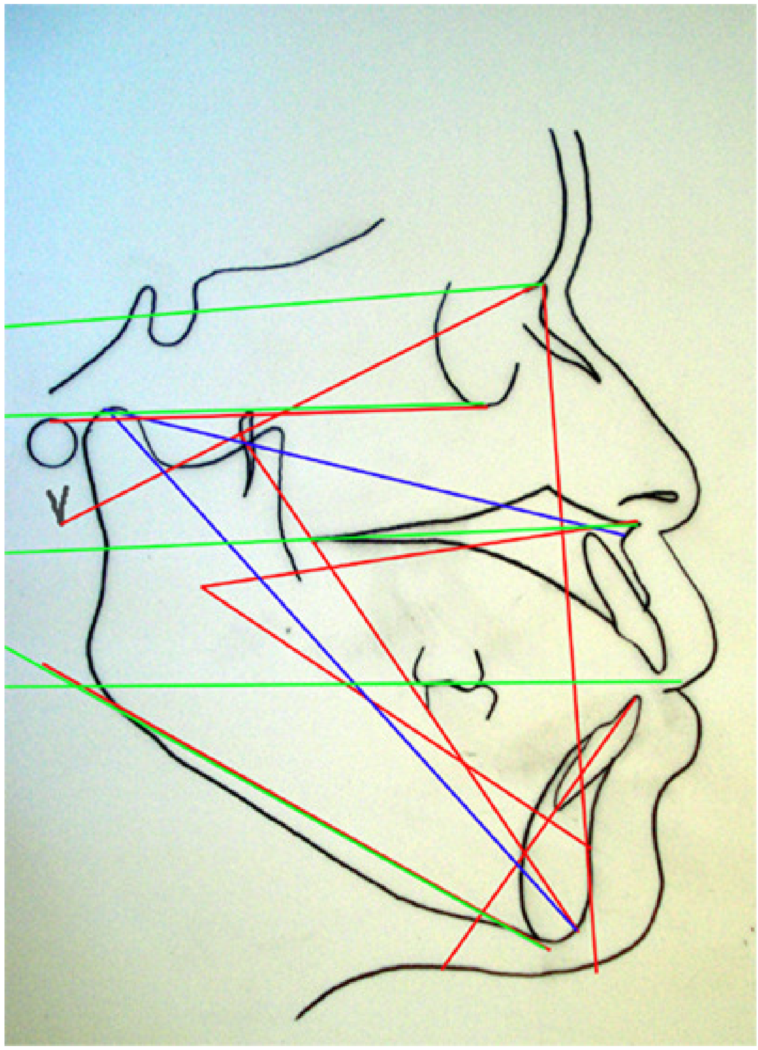

Figure 47. Pre-treatment cephalometric analyses using components of the Harvold, Ricketts and Sassouni techniques

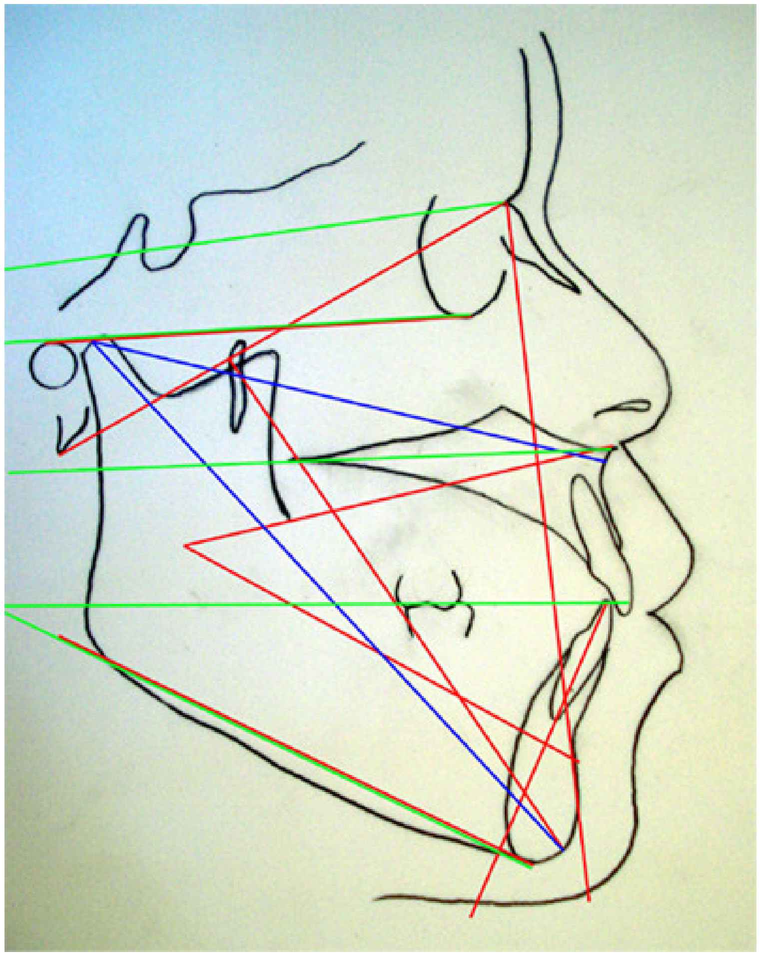

Figure 48. Post-treatment cephalometric analyses using components of the Harvold, Ricketts and Sassouni techniques

Although two parameters of significance showed no change, differences that were evident between the pre and post treatment values of these analyses are listed in Table 8 and can be isolated as:

1. A clockwise rotation of the maxilla by 2°
2. An increase of the mandibular plane relative to the occlusal plane of 2°
3. An increase of maxillary and mandibular lengths by 2 and 5 mm respectively
4. An increase in lower face height of 5mm

5. An increase in the facial axis and mandibular plane of 3° and 2° respectively
6. An uprighting of the lower incisor by 8°

These findings once again illustrate the relevance and specificity of the proposed Dawjee Analysis in describing open bite deformities. The changes described above are expected due to a change in the palatal plane, which was established by the proposed Dawjee Analysis. Other than the facial axis, the parameters listed in Table 8 measures changes within the area of change and not against a stable area distant from it. Orthodontic treatment, particularly in this patient is directed at altering tooth position and as a consequence alveolar remodelling occurs which in turn will influence jaw rotation and orientation. It would therefore be telescopic and pointless to plot these changes within the confines of the upper and lower jaws. The proposed Dawjee Analysis attempts to address this deficiency by measuring change away from change through the use of the cranial base as a reference plane.

Table 8 Comparison of pre- and post-treatment cephalometric values of the Harvold, Ricketts and Sassouni analyses

	Pre-treatment	Post-treatment	Change
Sassouni Values			
SN-FP (°)	2	2	0
FH-PP (°)	-1	1	2
PP-OP (°)	1	1	0
OP-MP (°)	28	25	3
Harvold Values			
Maxillary length (mm)	92	94	2
Mandibular length (mm)	119	124	5
Lower face height (mm)	62	67	5
Ricketts Values			
Facial axis (°)	82	85	3
Mandibular plane (°)	31	29	2
Lower face height (°)	42	42	0
Mandibular incisor inclination (°)	40	32	8

Case Conclusion

Malocclusion in the vertical dimension is a common phenomenon (Schudy, 1964), manifesting clinically as either an open or a deepbite. Identification of the morphological traits and source of the problem, so as to apply the appropriate treatment, can often be confusing and cumbersome (Cangialosi, 1984).

By using a reliable, reproducible and independent reference plane and mapping the mandibular, maxillary and alveolar positions in the vertical plane, the proposed Dawjee Analysis (Dawjee *et al.*, 2005) attempts to enhance the morphological diagnoses and clinical management of vertical craniofacial abnormalities through the separation of skeletal and dental components of an AOB. Comparison of the pre and post treatment cephalometric values (Table 7), indicate that while some changes did occur in the mandibular and maxillary positions, the bulk of bite closure (8°) occurred in the interalveolar region. This treatment outcome is an expected and anticipated response as it is aligned with the restrictive effect of the aetiology on the anterior dentoalveolar region, the patient's age and her state of osseous maturity.

While this patient was treated to a favourable and stable functional and aesthetic result, with post-treatment cephalometric readings showing marked improvement, the cephalometric values are specific to this case study and therefore, accentuates the need to subject the analysis to a larger and more representative sample of this population so that standardised values of the proposed Dawjee Analysis can be established and applied.

Chapter 6

Developing standardised values for the proposed Dawjee Analysis

Aims and Objectives

The purpose of this part of the study was to develop standardised cephalometric values for the proposed Dawjee Analysis that would enhance the identification of craniofacial factors in the sagittal plane that contribute to anterior open bite deformities.

The objectives of this study were:

1. To introduce a cephalometric method that will incorporate existing parameters and present new parameters for the analysis of the lateral cephalogram in the vertical plane. This cephalometric method has been described and preliminary data from the emerging thesis has already been published (Dawjee *et al.*, 2005).
2. To retrospectively investigate the prevalence of AOB occurring in patients attending the Dental School of the University of Limpopo, over a 15-year period and report thereon with respect to age, gender, severity and possible aetiology.
3. To develop a set of standardised normal values for the proposed Dawjee Analysis in a sample of South African Black subjects having skeletal and dental Class I relationships with a 2mm overbite and overjet and to present these values as standardised reference.
4. To apply the newly proposed analysis to a sample of Black subjects with AOB.

5. To identify morphological differences if any between a control group (as defined in objective 3 above) and a group of AOB subjects using the proposed Dawjee Analysis and to formulate criteria for easy assessment of AOB deformities.

Null Hypothesis

The null hypothesis of this research states that there is no difference in the lateral cephalometric values of the proposed Dawjee Analysis between AOB subjects and a control group in a given population sample of South African Blacks.

Subjects and method

A new lateral cephalometric method is described and focuses primarily on evaluating craniofacial structures in the vertical dimension. This cephalometric method employs various cephalometric landmarks, planes, angles and triangles in assessing vertical dentofacial relations. While many of these parameters have been adapted from previous researchers, new landmarks, planes and measurements are also introduced and defined. A comprehensive explanation of the analysis is given in chapter four and its application to a clinical case is presented in chapter five.

To investigate the prevalence of AOB, records of all patients visiting the Orthodontic Department of the School of Dentistry of the University of Limpopo, from 1992 to 2006, were retrieved and reviewed. The School of Dentistry was formerly known as the Medunsa Oral Health Centre (MOHC), however, in 2005 MEDUNSA (Medical University of Southern Africa) merged with the University of the North to become the University of Limpopo.

All patients with an AOB were documented with regard to age, gender, severity and aetiology. The criteria for determining open bite was a measure of at least 1 mm vertical separation between the incisal edges of the upper and lower incisors when the posterior teeth are in occlusion, as determined from the lateral cephalograms and confirmed by the study models. Determination of the amount AOB (Figure 49) from the lateral cephalogram was defined as a vertical space between the maxillary and mandibular incisors perpendicular to the occlusal plane (Janson *et al.*, 2003).

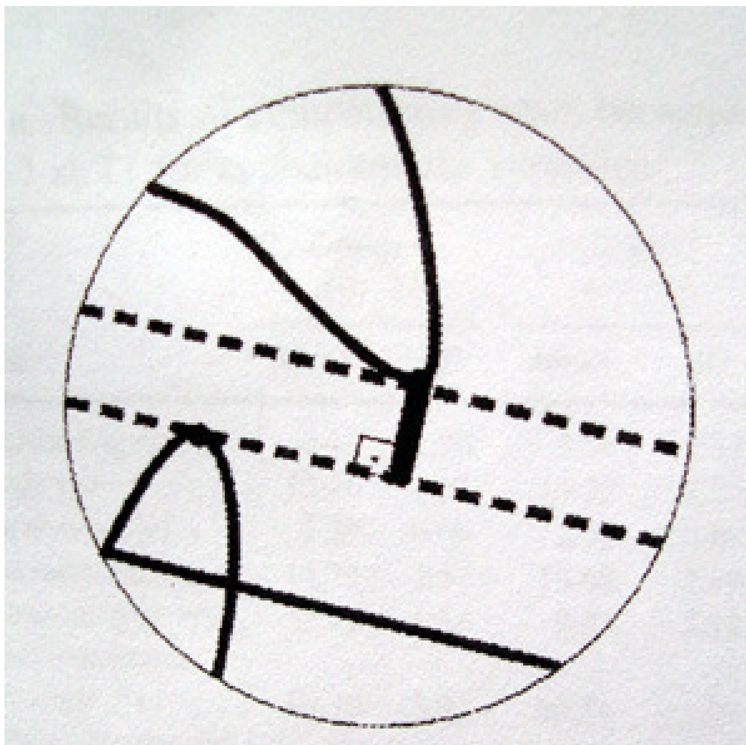

Figure 49. Measuring vertical incisor separation (Janson *et al.*, 2003)

To develop a set of standardised normal values for the proposed Dawjee Analysis in Black subjects, cephalograms of at least 50 adult male and 50 adult female Black subjects were retrieved from the archive of records in the orthodontic department. These radiographs are from the 'buddy' cases that pre-final year dental students have been taking of their classmates as a component of their training since inception of the BDS (Bachelor of Dental Science) course in 1981, as well as radiographs of Black patients with normal cephalometric values as determined by Barter et al (1995) and Naidoo and Miles (1997) (Barter *et al.*, 1995; Naidoo and Miles, 1997). Most (77%) of the subjects that were included to establish standardised normal values for this new analysis were extracted from student self-training cases that exhibited ideal or near perfect occlusion. The rest were taken from patient archives. While the latter did display Class I skeletal and dental relationships, the lateral cephalograms of these patients were registered due to a minor occlusal discrepancies e.g. minor crowding. (This policy of taking lateral cephalograms in clinically evident Class I patients with minor malocclusion has rightly come under criticism and review).

Using a standardised technique, all cephalometric radiographs were taken with a Siemens Orthopantomograph 10 with a Cephalostat OC10 x-ray machine (Siemens Corp., Erlangen, Germany). Emphasis for inclusion into this study was placed on dental maturity rather than chronological age. All subjects selected for this study had a full complement of teeth from 7 to 7 with a Class I molar relation and Class I skeletal relation. Study models of this cohort were also used to confirm the occlusal relationships, overjet, and overbite.

As this was a retrospective investigation spanning over a fifteen-year period, it is important to note that all preliminary records were taken and documented by pre-final and final year dental students. These records are first scrutinized by an orthodontic consultant or orthodontic registrar (i.e. an orthodontic specialist in training) before they were again verified by a panel of orthodontic staff from the Orthodontic Department of the School of Dentistry, who unanimously decided on the quality and accuracy of the records, diagnosis and treatment plan.

One hundred cephalograms that made up the control group were then retraced manually using a clutch pencil with a 0.5mm H4 pencil lead on a 15X26 cm matte acetate paper over a standard illuminated view box.

Tracings were done in accordance to the requirements of the proposed Dawjee Analysis (Dawjee *et al.*, 2005) and were prepared with the aid of an Ormocepha® template. The eleven prescribed measurements were extracted from each tracing. Linear measurements were rounded off to the nearest one mm and angular measurements to the nearest degree. Linear and angular measurements were read on a transparent mm ruler and protractor. Each measurement was repeated to ensure that the observer had not misread the instrument and if a difference was found between the two readings a third and final reading was taken.

The only linear measurement that will be exclusively extracted from the cephalometric tracing and used in the proposed Dawjee Analysis is the cranial base length (SN). Unlike angular measurements, linear measurements are influenced by magnification that occurs as a result of the x-ray beam not being parallel to all points of the object and differences in distances between the x-ray source (focus), the object and the film (Athanasiou, 1995). It is inevitable therefore that some degree of magnification will be present in all radiographs. In order to standardise the magnification factor and maintain control and consistency over SN, fixed focus object and object film distances were used for all lateral cephalograms used in this study.

Inter and intra examiner variability were standardised by the academic staff of the Orthodontic Department of the School of Dentistry of the University of Limpopo. Three examiners participated in establishing the accuracy and reproducibility of the cephalometric landmarks and measurements were repeated on 15 cephalograms after a 3-week interval. Intra-examiner error was determined by the coefficient of reliability, which had a mean of 0.91 while the intra class correlation for inter examiner reliability came to 0.87. Measurements between the examiners were therefore accurate and reliable.

The proposed Dawjee Analysis was also applied to a separate sample of 105 AOB cephalograms extracted from the retrospective AOB prevalence investigation. The male to female ratio in this sample of AOB subjects were 46:59. Subjects in this sample were also in their permanent dentition stage, having their first molars in a Class I relation with an AOB of one mm or more. Subjects with fully erupted third molars in occlusion were excluded due to their close proximity to the mandibular hinge axis (Nahoum *et al.*, 1972) and the amplified impact any anomalies of these teeth, such as a pericoronitis, abnormal eruption patterns or elevated distal cusps, would have on the overbite. Dental relations were confirmed from the clinical records as well as the study models. Cephalograms were traced under the same stringent conditions used on the cephalograms in the control group and twelve parameters inclusive of incisor separation were measured in the AOB sample. The AOB group were subdivided into three distinctly separate groups of different severity based on the extent of separation of the incisors in the vertical plane.

Standardisation methods that were used on the control group were also applied to the AOB group. Intra and inter examiner variability of the cephalometric tracings were also tested and verified by the academic staff of the Orthodontic Department and measurement reliability demonstrated a high correlation.

Data was collected from a total of 205 cephalometric tracings consisting of 100 subjects in the control group and 105 subjects in the AOB group. Subjects in the control group were equally divided into males and females while the AOB group consisted of 46 males and 59 females.

The AOB group was subdivided into three grades based on the severity of incisor separation. Grade 1 had an incisor separation of 1-3mm, Grade 2 a separation of 4-6mm, while Grade 3 consisted of patients with an incisor separation of 7 or more mm.

In order to assess and compare the validity and utility of the proposed Dawjee Analysis other cephalometric methods were also applied to 20 control and 20 AOB subjects extracted from the original sample of 100 and 105 respectively. These vertical cephalometric methods included the AFH / PFH (Jarabak and Fizzell, 1972; Siriwat and Jarabak, 1985), UFH / LFH, Sassouni (Sassouni, 1955), ODI (Kim, 1974) and Steiner (Steiner, 1960) analyses.

Ethical Considerations and Consent

All records were obtained from the archive of orthodontic files available in the Orthodontic Department of the School of Dentistry of the University of Limpopo. Permission to use these records was sought and obtained from the Head of the Orthodontic Department as well as from the Hospital Superintendent.

The research protocol was presented to the Research Ethics and Publication Committee and the academic staff of the School of Dentistry, University of Limpopo who approved and endorsed the protocol and granted ethical clearance to proceed with the research project (REPC approval number: DP/01/06).

Chapter 7

Results

All the data collected for this study are presented in the addenda and have been allocated into tables according to groups, gender and grades. A synopsis of these records is presented below.

Prevalence of anterior open bite

Descriptive statistics for the number of patients attending the Dental school, the Orthodontic Department, and the percentage of those complaining of a malocclusion over a period of 15 years are presented in Table 9 and Figure 50. Over the 15-year period extending from 1992 to 2006, 382530 patients visited the Dental school and 6524 (i.e. 1.98%) complained of malocclusion.

Table 9. Patient attendance at the Dental School over a 15-year period

YEAR	Patients visiting the dental school	Patients visiting the orthodontic department	% Complaining of malocclusion
1992	17836	160	0.89
1993	18608	184	0.98
1994	19520	227	1.16
1995	16500	257	1.55
1996	15403	247	1.6
1997	18902	349	1.85
1998	24440	426	1.74
1999	22227	459	2.06
2000	22491	287	1.27
2001	20399	374	1.83
2002	20293	472	2.32
2003	21324	565	2.65
2004	22639	707	3.1
2005	21825	782	3.58
2006	22930	798	3.48
TOTAL	328530	6524	1.98

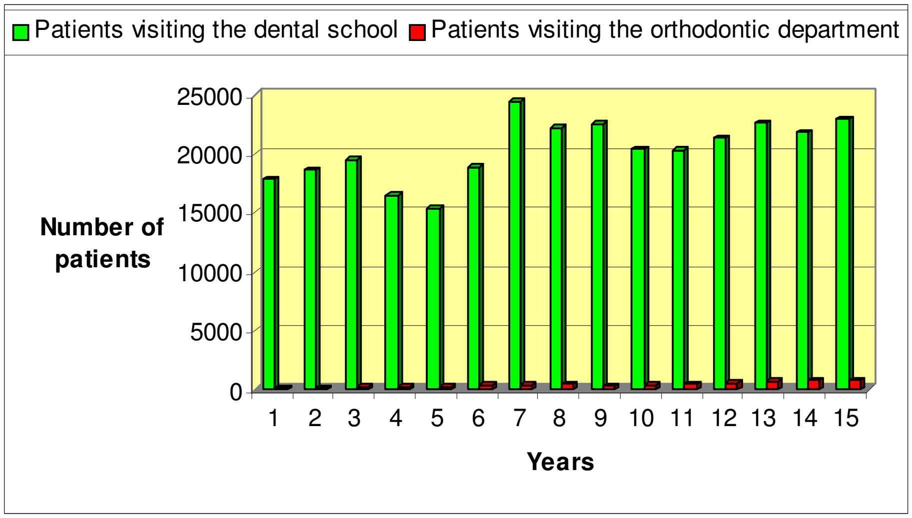

Figure 50. Patient visits to the Orthodontic Department and Dental School

Orthodontic records of all patients visiting the Orthodontic Department over the 15-year period were retrieved from the archives and reviewed. The 105 patients selected for the experimental (AOB) group were extracted from the 631 patients shown in Table 10 (Figure 51) and these were patients who conformed to the inclusion requirements mentioned in the methodology of this study. The prevalence or pinpoint estimate of AOB in patients with malocclusion and the 95% confidence interval, i.e. the interval estimate for the prevalence of AOB, was determined for the years 1992 through 2006 (Table 10). This confidence interval implies that there exists a 95% confidence that the true but unknown prevalence of AOB will be within the intervals mentioned.

Table 10. Prevalence of anterior open bite

Year	Patients visiting the department	Patients with AOB	Prevalence of AOB (%)	95% Confidence interval %
1992	160	26	16.25	(10.22 ; 22.79)
1993	184	22	11.96	(7.0 ; 16.92)
1994	227	41	18.06	(12.84 ; 23.28)
1995	257	33	12.84	(8.56 ; 17.13)
1996	247	26	10.53	(6.50 ; 14.56)
1997	349	50	14.33	(10.51 ; 18.15)
1998	426	41	9.62	(6.71 ; 12.54)
1999	459	44	9.59	(6.78 ; 12.39)
2000	287	19	6.62	(3.57 ; 9.67)
2001	374	39	10.43	(7.20 ; 13.66)
2002	472	46	9.75	(6.94 ; 12.53)
2003	565	57	10.09	(7.52 ; 12.66)
2004	707	58	8.20	(6.11 ; 10.30)
2005	782	63	8.06	(6.09 ; 10.03)
2006	798	66	8.27	(6.30 ; 10.24)
Total	6524	631	9.67	(8.95 ; 10.40)

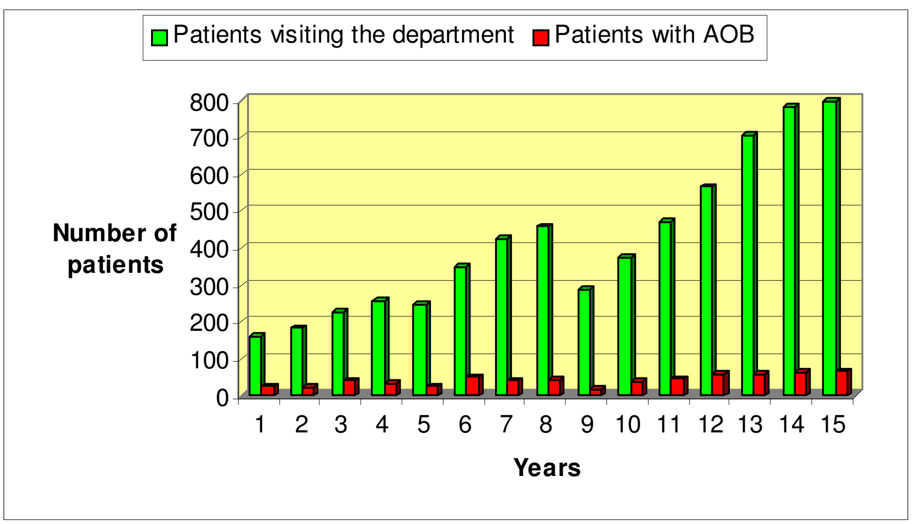

Figure 51. Patients with anterior open bite compared to the total patients visiting the Orthodontic Department

The gender and age distribution of patients presenting with AOB for the 15-year period is illustrated in Table 11 and Figure 52.

Table 11. The gender and age distribution of patients presenting with anterior open bite

Year	Patients with AOB	Males	Females	% Males	% Females	Under 13 years	Over 13 years	% under 13	% over 13
1992	26	11	15	42	58	18	8	69	31
1993	22	11	11	50	50	14	8	64	36
1994	41	18	23	44	56	28	13	68	32
1995	33	19	14	58	42	24	9	73	27
1996	26	13	13	50	50	16	10	62	38
1997	50	22	28	44	56	39	11	78	22
1998	41	17	24	41	59	31	10	76	24
1999	44	18	26	41	59	29	15	66	34
2000	19	10	9	53	47	12	7	63	37
2001	39	19	20	49	51	22	17	56	44
2002	46	25	21	54	46	30	16	65	35
2003	57	22	35	39	61	38	19	67	33
2004	58	29	29	50	50	41	17	71	29
2005	63	26	37	41	59	44	19	70	30
2006	66	31	35	47	53	42	24	64	36
Total	631	291	340	46	54	428	203	68	32

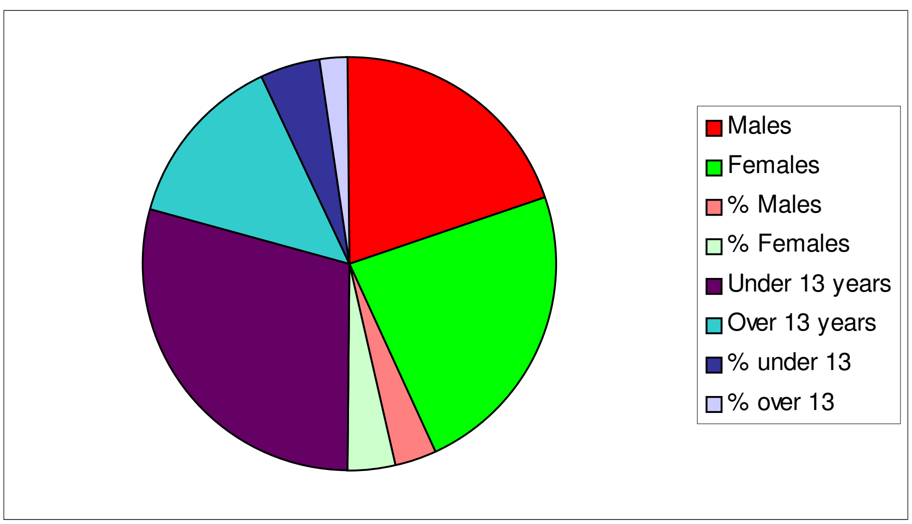

Figure 52. Age and gender distribution of anterior open bite

With regard to the aetiology of AOB (Table 12; Figure 53), the following causative factors were identified and recorded from the patient files.

Table 12. Distribution of anterior open bite subjects according to aetiology

Aetiology	Patient number	% of total AOB subjects
Thumb/finger sucking	187	29.6
Allergies/nasal obstruction	78	12.4
Family history	88	14
Cleft palate	7	1.1
Downs syndrome	2	0.3
Unknown causes	269	42.6
Total	631	100

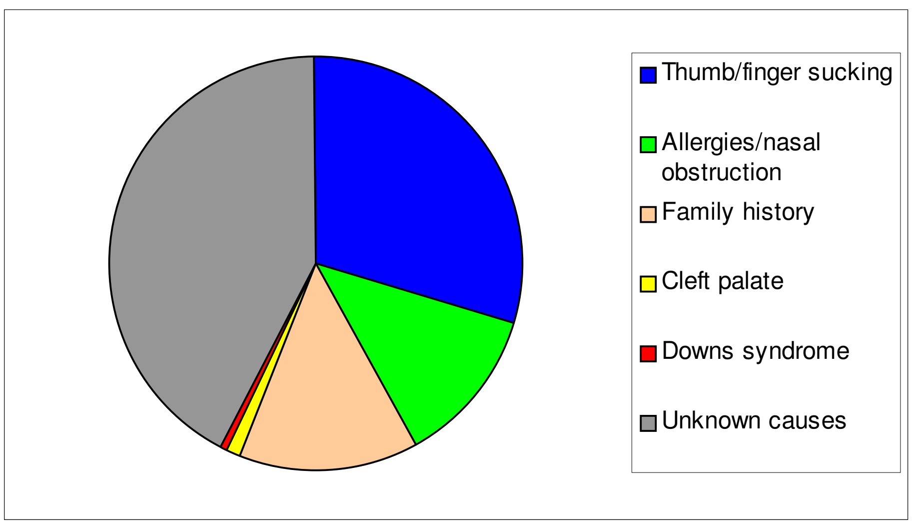

Figure 53. Aetiological distribution of anterior open bite

Normal values for the proposed Dawjee Analysis

The proposed Dawjee Analysis was applied to a control group of 100 normal Black subjects who complied with the criteria laid down in the methodology of this research project. As described in chapter 6, the cohort was equally divided into 50 males and 50 females. Eleven parameters i.e. ten angular and one linear measurement were recorded from each lateral cephalogram. Data from this sample is contained in the addenda and was analysed with the aid of Stata Statistical Software® (Statacorp, 2003). Descriptive statistics to determine the mean, standard deviation and normal values for the control group were determined and are displayed in the Table 13.

Table 13. Descriptive statistics for the control group

Parameter		Males (n=50)	Females (n=50)	Total (n=100)
Variable 1:	Mean	-	-	-
Incisor separation	Standard deviation (SD)	-	-	-
	Normal values (mean +/- SD*)	-	-	-
Variable 2:	Mean	69.1000	69.2200	69.1600
Anterior cranial base length	Standard deviation (SD)	4.2100	4.1800	4.1700
	Normal values (mean +/- SD)	64.89 ; 73.31	65.04 ; 73.40	66.99 ; 73.33
Variable 3:	Mean	7.5600	6.8600	7.2100
Anterior cranial base inclination	Standard deviation (SD)	4.1900	3.8800	4.0300
	Normal values (mean +/- SD)	3.37 ; 11.75	2.98 ; 10.74	3.18 ; 11.24
Variable 4:	Mean	35.6200	35.3800	35.5000
Anterior maxillary position	Standard deviation (SD)	4.3000	3.9000	4.0900
	Normal values (mean +/- SD)	31.31 ; 39.92	31.48 ; 39.28	31.41 ; 39.59
Variable 5:	Mean	39.2200	39.1600	39.1900
Posterior maxillary position	Standard deviation (SD)	3.4400	4.1500	3.7900
	Normal values (mean +/- SD)	35.78 ; 42.66	35.01 ; 43.31	33.40 ; 42.98
Variable 6:	Mean	68.9000	68.3000	68.6000
Anterior mandibular position	Standard deviation (SD)	5.0300	5.0300	5.0100
	Normal values (mean +/- SD)	63.87 ; 73.93	63.27 ; 73.33	63.59 ; 73.61
Variable 7:	Mean	36.9800	37.6000	37.2900
Posterior mandibular position	Standard deviation (SD)	4.9200	4.1100	4.5200
	Normal values (mean +/- SD)	32.06 ; 41.90	33.49 ; 41.71	32.77 ; 41.81

Variable 8:	Mean	42.3400	41.7000	42.0200
Point A position	Standard deviation (SD)	5.0000	4.8400	4.9100
	Normal values (mean +/- SD)	37.34 ; 47.34	36.86 ; 46.54	37.11 ; 46.03
Variable 9:	Mean	60.5000	60.1400	60.3200
Point B position	Standard deviation (SD)	4.6900	4.2500	4.4600
	Normal values (mean +/- SD)	55.81 ; 65.19	55.89 ; 64.39	55.86 ; 64.78
Variable 10:	Mean	79.1400	78.5000	78.8200
Interalveolar angle	Standard deviation (SD)	7.9900	8.4200	8.1700
	Normal values (mean +/- SD)	71.15 ; 87.13	70.08 ; 86.92	70.65 ; 86.99
Variable 11:	Mean	105.1400	105.1600	105.1500
Apex of the maxillary triangle	Standard deviation (SD)	3.3400	3.5800	3.4400
	Normal values (mean +/- SD)	101.80 ; 108.48	101.58 ; 108.74	101.71 ; 108.59
Variable 12:	Mean	74.7000	74.5800	74.6400
Apex of the mandibular triangle	Standard deviation (SD)	2.8300	2.9100	2.8600
	Normal values (mean +/- SD)	71.87 ; 77.53	71.67 ; 77.49	71.78 ; 77.50

*+/- One SD defines limits of the normal values

Application of the proposed Dawjee Analysis to anterior open bite subjects

From the investigative study into the prevalence of AOB, a sample of 105 AOB subjects were extracted, who conformed to the requirements of the methodology as described in chapter 6. This sample consisted of 46 males and 59 females. Ten angular and two linear measurements were recorded from each lateral cephalogram. Data from this AOB sample was analysed with Stata Statistical Software® (Statacorp, 2003). All data and analytical printouts are presented in the addenda.

Descriptive statistics was also applied to the AOB group and the following means, standard deviations and the range of severity were determined (Table 14).

Table 14. Descriptive statistics for the anterior open bite group

Parameter		Males (n=46)	Females (n=59)	Total (n=105)
Variable 1:	Mean	5.1400	5.7500	5.4800
Incisor separation	Standard deviation (SD)	2.5300	2.9300	2.7700
	Severity (mean +/- SD*)	2.61 ; 7.67	2.82 ; 8.68	2.71 ; 8.25
Variable 2:	Mean	68.1100	69.6800	68.9900
Anterior cranial base length	Standard deviation (SD)	3.6200	4.5200	4.2000
	Severity (mean +/- SD)	64.49 ; 71.73	65.16 ; 74.20	64.79 ; 77.19
Variable 3:	Mean	8.8300	8.7500	8.7800
Anterior cranial base inclination	Standard deviation (SD)	5.3400	3.1600	4.2300
	Severity (mean +/- SD)	3.49 ; 14.17	5.59 ; 11.91	4.55 ; 13.01
Variable 4:	Mean	36.0400	36.1200	36.0900
Anterior maxillary position	Standard deviation (SD)	4.0300	2.9200	3.4300
	Severity (mean +/- SD)	32.01 ; 40.07	33.20 ; 39.04	32.66 ; 39.52
Variable 5:	Mean	42.5400	41.3900	41.9000
Posterior maxillary position	Standard deviation (SD)	4.1900	3.0900	3.6400
	Severity (mean +/- SD)	38.38 ; 46.73	33.30 ; 44.48	38.26 ; 45.54
Variable 6:	Mean	69.2800	70.0700	69.7200
Anterior mandibular position	Standard deviation (SD)	5.8900	3.9300	4.8800
	Severity (mean +/- SD)	63.39 ; 75.17	66.14 ; 74.00	64.84 ; 74.60
Variable 7:	Mean	42.2400	40.4700	41.2500
Posterior mandibular position	Standard deviation (SD)	4.7600	3.3500	4.11
	Severity (mean +/- SD)	37.48 ; 47.00	37.12 ; 43.82	37.14 ; 45.36

Variable 8:	Mean	41.0000	41.7100	41.4000
Point A position	Standard deviation (SD)	4.7800	3.4500	4.0800
	Severity (mean +/- SD)	36.22 ; 45.78	38.26 ; 45.16	37.32 ; 45.48
Variable 9:	Mean	61.9600	62.3900	62.2000
Point B position	Standard deviation (SD)	5.7400	3.9200	4.7800
	Severity (mean +/- SD)	56.22 ; 67.70	58.74 ; 66.31	57.42 ; 66.98
Variable 10:	Mean	91.1300	89.4200	90.1700
Interalveolar angle	Standard deviation (SD)	11.7700	11.6300	11.6700
	Severity (mean +/- SD)	79.36 ; 102.90	77.79 ; 101.05	78.50 ; 101.84
Variable 11:	Mean	105.5400	101.2700	101.3900
Apex of the maxillary triangle	Standard deviation (SD)	5.1700	5.5000	5.3300
	Severity (mean +/- SD)	100.37 ; 110.71	95.77 ; 106.77	96.06 ; 106.72
Variable 12:	Mean	69.0200	69.8100	69.4700
Apex of the mandibular triangle	Standard deviation (SD)	3.5800	3.9800	3.8100
	Severity (mean +/- SD)	65.44 ; 72,60	65.83 ; 73.79	65.66 ; 73.42

*+/- One SD defines severity limits

Control and anterior open bite group comparison

The control and the AOB groups as well as male and female subgroups were simultaneously analysed with respect to the 11 parameters (variables 2 to 12) using a two way ANOVA with an interaction term. Significant results from this analysis are highlighted as having p values < 0.05 (Table 15).

As Variable 1 i.e. incisor separation, is zero for the control group, the above test could not be applied. A t-test was used whereby the AOB group was compared to zero and found to be significantly higher than the control group ($p< 0.0001$; t-test; mean 5.48).

Table 15 below draws comparison between the mean values of the two groups i.e. the control and the AOB group. In Table 13 and 14 above, the limit of the values should ideally and statistically be set at mean +/- 2SD and not 1 SD. However in the clinical scenario, difference between two individuals may not be of clinical importance if the limits of the values encompass 2 SD beyond the mean. The mean +/- 1 SD in Tables 13 and 14 reflect the normal values for an individual within the group while Table 15 is a computation of the statistical difference between the means of the two groups.

Table 15. ANOVA of anterior open bite and control groups with an interactive term

Parameter	Group/Gender/Interaction	p Values	Result
Variable 2:	Group	0.6490	AOB not significantly different from control group (68.99 vs. 69.16)
Anterior cranial base length	Gender	0.1503	Males and females do not differ significantly (68.63 vs. 69.47)
	Group & gender interaction	0.2169	No interaction between group and gender
Variable 3:	Group	0.0073	AOB significantly greater than the control group (8.78 vs. 7.21)
Anterior cranial base inclination	Gender	0.5032	Males and females do not differ significantly (8.17 vs. 7.88)
	Group & gender interaction	0.5949	No interaction between group and gender
Variable 4:	Group	0.1200	AOB not significantly different from control group (36.09 vs. 35.50)
Anterior maxillary position	Gender	0.3823	Males and females do not differ significantly (35.82 vs. 35.78)
	Group & gender interaction	0.5860	No interaction between group and gender
Variable 5:	Group	0.0000	AOB significantly greater than the control group (41.90 vs. 39.19)
Posterior maxillary position	Gender	0.2446	Males and females do not differ significantly (40.81 vs. 40.37)
	Group & gender interaction	0.2942	No interaction between group and gender
Variable 6:	Group	0.1235	AOB not significantly different from control group (69.72 vs. 68.60)
Anterior mandibular position	Gender	0.8942	Males and females do not differ significantly (69.08 vs. 69.26)
	Group & gender interaction	0.3203	No interaction between group and gender
Variable 7:	Group	0.0000	AOB significantly greater than the control group (41.25 vs. 37.29)
Posterior mandibular position	Gender	0.7244	Males and females do not differ significantly (39.50 vs. 39.14)
	Group & gender interaction	0.2210	No interaction between group and gender
Variable 8:	Group	0.2953	AOB not significantly different from control group (41.40 vs. 42.02)
Point A position	Gender	0.9548	Males and females do not differ significantly (41.70 vs. 41.71)
	Group & gender interaction	0.2868	No interaction between group and gender
Variable 9:	Group	0.0049	AOB significantly less than the control group (62.20 vs. 60.32)

Point B position	Gender	0.9552	Males and females do not differ significantly (61.20 vs. 61.36)
	Group & gender interaction	0.5434	No interaction between group and gender
Variable 10:	Group	0.0000	AOB significantly greater than the control group (90.17 vs. 78.82)
Interalveolar angle	Gender	0.4105	Males and females do not differ significantly (84.89 vs. 84.41)
	Group & gender interaction	0.7081	No interaction between group and gender
Variable 11:	Group	0.0000	AOB significantly less than the control group (101.39 vs. 105.15)
Apex of the maxillary triangle	Gender	0.8429	Males and females do not differ significantly (103.42 vs. 103.06)
	Group & gender interaction	0.8184	No interaction between group and gender
Variable 12:	Group	0.0000	AOB significantly less than the control group (69.47 vs. 74.64)
Apex of the mandibular triangle	Gender	0.4800	Males and females do not differ significantly (71.98 vs. 72.00)
	Group & gender interaction	0.3380	No interaction between group and gender

Anterior open bite intra-group analyses

The AOB group was also statistically analysed to draw comparison between the mild, moderate and severe grades of AOB severity. Descriptive statistics was applied to the three levels of AOB severity and the results from these tests are presented in Table 16.

Table 16. Descriptive statistics for the three grades of anterior open bite severity

Parameter		Mild (n=28)	Moderate (n=42)	Severe (n=35)
Variable 1:	Mean	2.41	4.95	8.57
Incisor separation	Standard deviation (SD)	0.68	0.82	2.08
Variable 2:	Mean	69.11	68.69	69.26
Anterior cranial base length	Standard deviation (SD)	4.52	4.68	3.34
Variable 3:	Mean	9.39	8.67	8.43
Anterior cranial base inclination	Standard deviation (SD)	4.16	3.91	4.71
Variable 4:	Mean	36.79	35.63	36.06
Anterior maxillary position	Standard deviation (SD)	2.88	3.44	3.80
Variable 5:	Mean	41.14	42.26	42.06
Posterior maxillary position	Standard deviation (SD)	3.68	3.79	3.43
Variable 6:	Mean	69.57	69.74	69.83
Anterior mandibular position	Standard deviation (SD)	4.65	4.88	5.19
Variable 7:	Mean	41.86	41.07	40.97
Posterior mandibular position	Standard deviation (SD)	4.01	4.23	4.12
Variable 8:	Mean	41.07	41.24	41.86
Point A position	Standard deviation (SD)	2.92	4.25	4.70
Variable 9:	Mean	62.00	61.95	62.66
Point B position	Standard deviation (SD)	5.10	4.61	4.83
Variable 10:	Mean	91.21	87.55	92.49
Interalveolar angle	Standard deviation (SD)	10.13	11.66	12.48

Variable 11:	Mean	100.50	102.12	101.23
Apex of the maxillary triangle	Standard deviation (SD)	6.37	4.82	5.04
Variable 12:	Mean	69.29	69.60	69.46
Apex of the mandibular triangle	Standard deviation (SD)	3.71	4.08	3.66

Within the AOB group, grade and gender were also simultaneously analysed with respect to the 12 parameters using a two-way ANOVA with an interaction term. Findings from these analyses are illustrated below (Table 17).

The AOB group was subdivided into mild, moderate and severe grades based on the degree of incisor separation. Mild grades had an incisor separation of 1-3mm, moderate between 4-6mm and severe grades were classified as having an incisor separation of 7 or more mm. An intra-group analysis (Table 17) of AOB using ANOVA between grade and gender with an interactive term found that:

1. There was a significant difference between the grades for incisor separation ($p<0.0000$)
2. The anterior cranial base length showed significant differences ($p<0.0235$) particularly in the mild group (66.64 in males:71.57 in females) and there was interaction between grade and gender ($p<0.0415$)
3. The posterior mandibular position showed a significant gender difference ($p<0.0425$) particularly in the moderate group (42.56 in males:39.96 in females)
4. Point B position showed an interaction between grade and gender ($p<0.0431$)
5. The apex of the mandibular triangle also exhibited interaction between grade and gender ($p<0.0317$)

Table 17. ANOVA between grades and gender with an interactive term

Parameter	Grade/Gender/Interaction	p Values	Result
Variable 1:	Grade	0.0000	Grades differ significantly
Incisor separation	Gender	0.2822	Males and females do not differ significantly
	Grade and gender interaction	0.4191	There is no interaction between grade and gender
Variable 2:	Grade	0.8500	Grades do not differ significantly
Anterior cranial base length	Gender	0.0235	Males and females differ significantly
	Grade and gender interaction	0.0415	There is interaction between grade and gender
Variable 3:	Grade	0.6076	Grades do not differ significantly
Anterior cranial base inclination	Gender	0.7509	Males and females do not differ significantly
	Grade and gender interaction	0.1286	There is no interaction between grade and gender
Variable 4:	Grade	0.3356	Grades do not differ significantly
Anterior maxillary position	Gender	0.9606	Males and females do not differ significantly
	Grade and gender interaction	0.1840	There is no interaction between grade and gender
Variable 5:	Grade	0.3328	Grades do not differ significantly
Posterior maxillary position	Gender	0.0952	Males and females do not differ significantly
	Grade and gender interaction	0.0626	There is no interaction between grade and gender
Variable 6:	Grade	0.9971	Grades do not differ significantly
Anterior mandibular position	Gender	0.5599	Males and females do not differ significantly
	Grade and gender interaction	0.3403	There is no interaction between grade and gender
Variable 7:	Grade	0.7044	Grades do not differ significantly
Posterior mandibular position	Gender	0.0425	Males and females differ significantly
	Grade and gender interaction	0.4603	There is no interaction between grade and gender

Variable 8:	Grade	0.8002	Grades do not differ significantly
Point A position	Gender	0.5642	Males and females do not differ significantly
	Grade and gender interaction	0.1607	There is no interaction between grade and gender
Variable 9:	Grade	0.8978	Grades do not differ significantly
Point B position	Gender	0.8709	Males and females do not differ significantly
	Grade and gender interaction	0.0431	There is interaction between grade and gender
Variable 10:	Grade	0.4832	Grades do not differ significantly
Interalveolar angle	Gender	0.7782	Males and females do not differ significantly
	Grade and gender interaction	0.2457	There is no interaction between grade and gender
Variable 11:	Grade	0.1911	Grades do not differ significantly
Apex of the maxillary triangle	Gender	0.3975	Males and females do not differ significantly
	Grade and gender interaction	0.5109	There is no interaction between grade and gender
Variable 12:	Grade	0.9329	Grades do not differ significantly
Apex of the mandibular triangle	Gender	0.2470	Males and females do not differ significantly
	Grade and gender interaction	0.0317	There is interaction between grade and gender

ANOVA was also applied between the three groups for each of the 12 parameters to find any statistically significant difference among the groups (Table 18).

The three grades were also tested using an ANOVA (Table 18) and it was found that:

1. Incisor separation between the mild, moderate and severe grades is significantly different ($p<0.0000$)
2. Anterior cranial base length between the mild and moderate grades is significant ($p<0.0399$)
3. The posterior maxillary position between the mild and severe grades is significant ($p<0.0416$)
4. Point B position between the mild and severe grades is significant ($p<0.0397$)

Table 18. Comparison of p values between the grades of anterior open bite severity

Parameter	Mild and moderate grade	Mild and severe grade	Moderate and severe grade
Variable 1:			
Incisor separation	p = 0.0000	p = 0.0000	p = 0.0000
Result	Significantly different	Significantly different	Significantly different
Variable 2:			
Anterior cranial base length	p = 0.0399	p = 0.1498	p = 0.5060
Result	Significantly different	Not significantly different	Not significantly different
Variable 3:			
Anterior cranial base inclination	p = 0.3980	p = 0.6258	p = 0.6969
Result	Not significantly different	Not significantly different	Not significantly different
Variable 4:			
Anterior maxillary position	p = 0.8164	p = 0.7174	p = 0.8754
Result	Not significantly different	Not significantly different	Not significantly different
Variable 5:			
Posterior maxillary position	p = 0.3131	p = 0.0416	p = 0.2171
Result	Not significantly different	Significantly different	Not significantly different
Variable 6:			
Anterior mandibular position	p = 0.3154	p = 0.3227	p = 0.9904
Result	Not significantly different	Not significantly different	Not significantly different
Variable 7:			
Posterior mandibular position	p = 0.5471	p = 0.9640	p = 0.4712
Result	Not significantly different	Not significantly different	Not significantly different

Variable 8:			
Point A position	p = 0.2098	p = 0.0876	p = 0.5691
Result	Not significantly different	Not significantly different	Not significantly different
Variable 9:			
Point B position	p = 0.2079	p = 0.0397	p = 0.3292
Result	Not significantly different	Significantly different	Not significantly different
Variable 10:			
Interalveolar angle	p = 0.7213	p = 0.2549	p = 0.0877
Result	Not significantly different	Significantly different	Not significantly different
Variable 11:			
Apex of the maxillary triangle	p = 0.5351	p = 0.5454	p = 0.1643
Result	Not significantly different	Not significantly different	Not significantly different
Variable 12:			
Apex of the mandibular triangle	p = 0.5855	p = 0.1011	p = 0.1982
Result	Not significantly different	Not significantly different	Not significantly different

Parameters of statistically significance difference were also found between a sample the 20 control and 20 AOB subjects that were subjected to the AFH / PFH (Jarabak and Fizzell, 1972; Siriwat and Jarabak, 1985), UFH / LFH, Sassouni (Sassouni, 1955), ODI (Kim, 1974) and Steiner (Steiner, 1960) analyses. This is illustrated in Figure 54 where AFH / PFH is coloured in green, UFH / LFH in blue, the ODI analysis in purple, components of the Steiner in yellow and the Sassouni analysis is displayed in red. Descriptive statistics with p values of these analyses are presented in Tables 19-25 and notable differences between the control and AOB sample are:

1. The AFH was found to be greater in the AOB group (127.6mm vs. 121.8mm)
2. The LFH was also larger in the AOB group and accounts for the increased AFH (76.55mm vs. 72,35mm)
3. The upper incisors were more proclined in the AOB group (30.05° vs. 19.5°)
4. The lower incisors were also proclined in the AOB group although not as much as the upper incisors (39.35° vs. 33.95°)
5. The inter-incisal angle was more acute in the AOB group due to incisor proclination (104.15° vs. 120.65°)
6. The palatal plane displayed a counter clockwise rotation in the AOB group (13.25° vs. 8.45°)

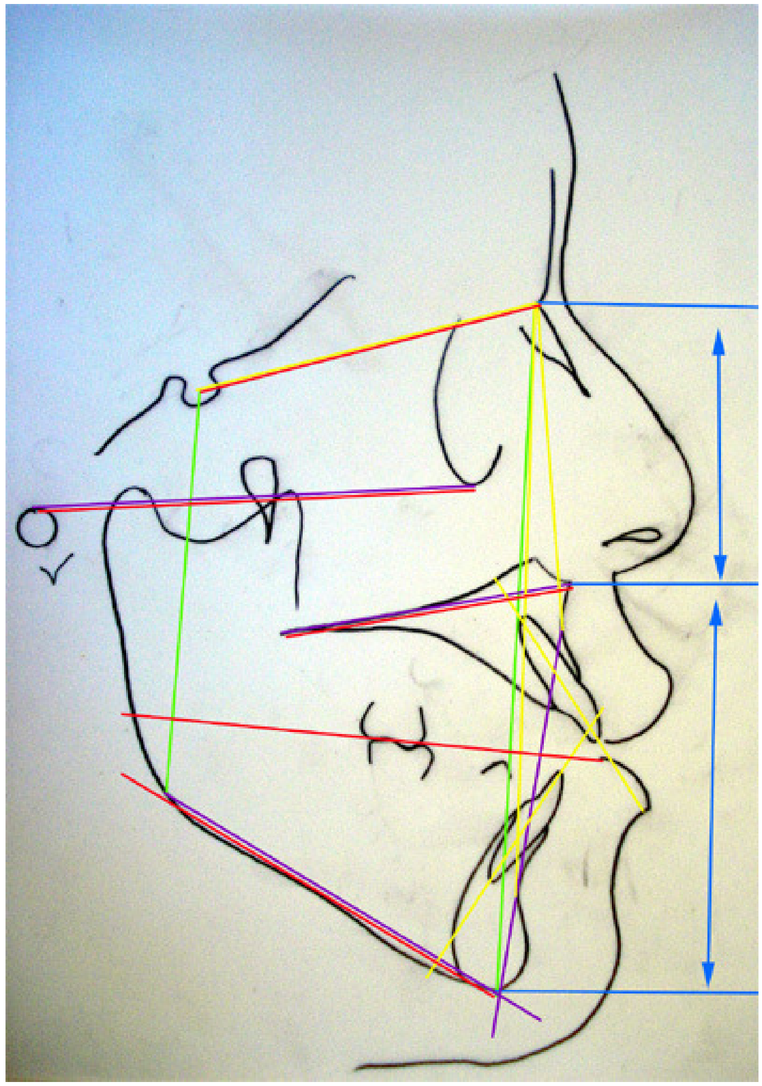

Figure 54. Comparable analyses used to evaluate AOB

Table 19. Mean, standard deviation and p values for AFH and PFH

	PFH (mm)			AFH (mm)			PFH/AFH%		
	Mean	St. Dev.	P Value	Mean	St. Dev.	P Value	Mean	St. Dev.	P Value
Normal	75.3	6.75	0.5518	121.8	6.23	0.0239	61.93	5.88	0.3516
AOB	76.8	8.90		127.6	9.04		60.20	5.72	

Table 20. Mean, standard deviation and p values for UFH and LFH

	UFH (mm)			LFH (mm)			UFH/LFH%		
	Mean	St. Dev.	P Value	Mean	St. Dev.	P Value	Mean	St. Dev.	P Value
Normal	50.25	3.30	0.7004	72.35	6.34	0.0410	70.07	8.80	0.1566
AOB	50.80	5.40		76.55	6.23		66.51	6.61	

Table 21. Mean, standard deviation and p values for the ODI analysis

	FH-PP (º)			MP-AB (º)			ODI Values		
	Mean	St. Dev.	P Value	Mean	St. Dev.	P Value	Mean	St. Dev.	P Value
Normal	-2.8	3.39	0.4390	69.80	4.31	0.1144	67	3.98	0.0846
AOB	-3.85	4.94		66.95	6.58		63.1	8.89	

Table 22. Mean, standard deviation and p values for the Steiner analysis

	SNA (º)			SNB (º)			ANB (º)		
	Mean	St. Dev.	P Value	Mean	St. Dev.	P Value	Mean	St. Dev.	P Value
Normal	87.85	5.94	.04487	82.95	5.02	0.0732	5.9	2.46	0.5579
AOB	86.65	3.70		80.45	3.37		3.35	2.34	

Table 23. Mean, standard deviation and p values for the Steiner analysis (continued)

	UPP 1 (º)			LOW 1(º)			INTER 1(º)		
	Mean	St. Dev.	P Value	Mean	St. Dev.	P Value	Mean	St. Dev.	P Value
Normal	19.5	7.52	0.0001	33.95	4.19	0.0033	120.65	7.82	0.0001
AOB	30.05	7.49		39.35	6.40		104.15	10.83	

Table 24. Mean, standard deviation and p values for the Sassouni analysis

	SN-FH (º)			FH-PP (º)		
	Mean	St. Dev.	P Value	Mean	St. Dev.	P Value
Normal	7.25	4.22	0.1573	-2.8	3.39	0.4390
AOB	8.85	2.56		-3.85	4.94	

Table 25. Mean, standard deviation and p values for the Sassouni analysis (continued)

	PP-OP (º)			OP-MP (º)		
	Mean	St. Dev.	P Value	Mean	St. Dev.	P Value
Normal	8.45	5.27	0.0237	23.10	5.84	0.9343
AOB	13.25	7.39		22.95	5.58	

Chapter 8

Discussion

The Dental Faculty of the Medical University of Southern Africa (MEDUNSA) was started in 1980. The history of MEDUNSA is inextricably linked to the political transformations seen in South Africa. MEDUNSA was built during the apartheid era in the northwest regions of Pretoria to service the densely populated Black townships of Ga-Rankuwa and Soshanguve. The dental faculty of MEDUNSA was known as the Medunsa Oral Health Centre (MOHC). With the dismantling of apartheid it became evident that community service and the training of medical personnel had to be extended and redistributed, leading to a merger between MEDUNSA and the University of the North (another predominantly Black university) to form the University of Limpopo. As a result, the Dental Faculty assumed the name 'School of Dentistry of the University of Limpopo'.

It is understandable therefore that the majority of patients visiting the dental school are from the surrounding Black communities who present with dentofacial problems specific to their race (Altemus, 1968; Dawjee *et al.*, 2002; Drummond, 1968; Enlow *et al.*, 1982). Results from the retrospective prevalence study confirm an increase in patient attendance at the dental school over the 15-year period with a concurrent increase in patients complaining of malocclusion. Of the 17836 patients that visited the dental school in 1992, 160 patients i.e. 0.89% visited the Orthodontic Department complaining of malocclusion. At the end of this retrospective study, in 2006, 22930 patients visited the dental school with 798 of these, patients i.e. 3.48% seeking orthodontic care (Table 9 and Figure 50). Over the 15-year period the patient attendance at the dental school increased progressively by 28.56%, while patients seeking orthodontic treatment increased by 398.75%. Although the number of patients seeking orthodontic care is small when compared to the overall patient attendance (0.89% in 1992 and 3.48% in 2006) the fourfold increase in demand for orthodontic treatment must be addressed. This significant increase could be attributed to the change in political and socio-economic conditions and the improvement of self-perception and esteem among previously disadvantaged race groups in South Africa. Based on the government policy of utility, only a quarter of patients complaining of malocclusion will receive state subsidised treatment because the need for relief of pain and the restoration of function supersedes aesthetic enhancement and improvement. This strategy is a result of budget and manpower constraints.

The Department of Orthodontics attends to and treats a variety of dentofacial problems. On average 9.67 % of patients who seek orthodontic treatment complain of AOB (Table 10 and Figure 51) and the condition affects more females than it does males with a percentage ratio of 46%:54%. It is interesting to note that while there is a gradual increase of patients presenting with AOB from 22 in the 1992 to 66 patients in the 2006 (Table 10 and Figure 51), the overall prevalence of AOB has declined from 16.25% to 8.27% (Table 10 and Figure 51). In other words more patients visiting the orthodontic department are complaining less of AOB. The reasons are written in the statistics and history books – racially integrated and equal education, urbanisation, media influences and socio-economic improvement – all of which makes thumb or digit sucking, the most prevalent cause of AOB, socially unacceptable.

Chronologically (Table 11 and Figure 52) the prevalence study found that the AOB patients under 13 years were twice as many as patients over 13-year old (68%: 32%). This difference could be attributed to differential and delayed incisor eruption (Moorrees, 1959; Thilander, 1995) as well as maturation, peer pressure and a discontinuance of detrimental and socially undesirable oral habits which has been found to be the highest contributor to AOB (29.6%). Other causes that were found to contribute to AOB are listed in Table 12 and illustrated in Figure 53.

Inadequate documentation of records and poor dental histories, possibly due to communication barriers, as well as incomplete incisor eruption (‘pseudo open bites’) were classified as, and account for the high percentage of ‘unknown causes’ of AOB. Allergies and nasal obstruction also feature prominently (Table 12 and Figure 53) as a cause of AOB (12.4%) and this may also accounts for the higher prevalence of AOB among patients under 13-years old who are generally susceptible to enlarged adenoids.

The exact cause of AOB appear to be an interplay of all of several factors (Brenchley, 1991; Mills, 1983; Nahoum, 1975; Nanda, 1988; Speidel *et al.*, 1972) Information on the factors that contribute to AOB were retrieved from patient examination files in the Orthodontic Department of the University of Limpopo. It encompasses patient records from the time of inception of the Orthodontic Department in 1992 to the end of this study i.e. 2006. At inception of the department in 1992 the record and examination process may have been short of ideal due to ‘teething problems’ and deficiencies in manpower expertise in the initial stages of setting up the Orthodontic Department. However, as the Department grew patient examination and data collection became more efficient. The electronic capturing of patient data is anticipated in the foreseeable future and would enhance patient records in the Department of Orthodontics of the University of Limpopo.

Nasal obstruction for instance, is no longer documented as an anecdotal report from the patient, instead a full history and examination is now undertaken to confirm the diagnosis of nasal obstruction. Non-misting of intraoral mirrors placed over the nares during expiration is regarded as a clinical indicator of nasal obstruction and although nasal obstruction is not a de facto cause, it has been cited as contributing to the development of AOB (Karacay *et al.*, 2006; Linder-Aronson, 1970).

Probing questions listed on the examination form also help detect a family history of AOB. When documenting the family history of AOB, patients are quizzed about the presence of AOB in siblings, parents, parental siblings, grand parents and first cousins.

From the aforementioned discussion it is evident that the high prevalence of AOB among South African Blacks necessitated a diagnostic tool to assist in identifying the morphological causes of AOB so that the appropriate treatment methods can be employed. The proposed Dawjee Analysis was therefore developed as an attempt to expand and supplement current assessment methods in the evaluation of AOB and vertical facial evaluation. While many of the landmarks, planes and parameters of this new analysis were reproduced from earlier analyses, new landmarks, planes and parameters have been introduced. These include:

1. Occlusal contact point (OCP)
2. Line S to ANS
3. Line N to PNS
4. Line S to A
5. Line S to B
6. Z axis extending from N to Go
7. Line OCP to A
8. Line OCP to B
9. Anterior maxillary position
10. Posterior maxillary position
11. Anterior mandibular position
12. Posterior mandibular position
13. Point A position
14. Point B position
15. Interalveolar angle
16. Apex of the maxillary triangle
17. Apex of the mandibular triangle

Despite these new additions, the analysis is specific in that unlike other analyses (Cangialosi, 1984; Kim, 1974; Sassouni and Nanda, 1964), it measures two linear and ten angular measurements, all of which are focussed on the vertical facial dimensions.

With the exception of ANS and PNS, which are sometimes burnt out or obscured by overlapping structures, all other cephalometric landmarks are readily identifiable. Several factors affect the identification and location of a landmark. According to Athanasiou (1995) these include:

- The radiographic image which will be affected by factors such as tissue density, object film distance, kV levels and the type of recording receptor that is used.
- Definition and reproducibility of the landmark which relates to the anatomic position of the landmark and the difficulty of identifying it with precision. For instance, PNS was more readily identifiable than ANS and both were found to be less difficult to locate than Xi point or condylion.
- Examiner and registration procedures which will depend on the working conditions and training of the operator. This error can be reduced and controlled by calibration of examiners.

Tracings should be done with a 0.5mm pencil as a dull tracing pencil can affect the accuracy of an important cephalometric reading (Hixon, 1972).

The location of gonion point may sometimes be tricky and questionable. To overcome this, the technique prescribed by Jacobsen (Figure 55) was used to find this point repeatedly and accurately (Jacobsen, 1995).

Another landmark that may pose a weakness in the analysis is OCP as it requires the presence occlusal contact of the upper and lower first molars. For comparative purposes in individual orthodontic cases, missing first molars may be substituted with the second molars and if orthognathic surgery is proposed in such cases, the first molars may be replaced with implants or fixed prosthesis depending on the complexity of the case. In this way a substitute point of reference between upper and lower first molars can be re-established. For the purpose of scientific studies however, it is advisable that the upper and lower first molars be present in all subjects of the sample under investigation.

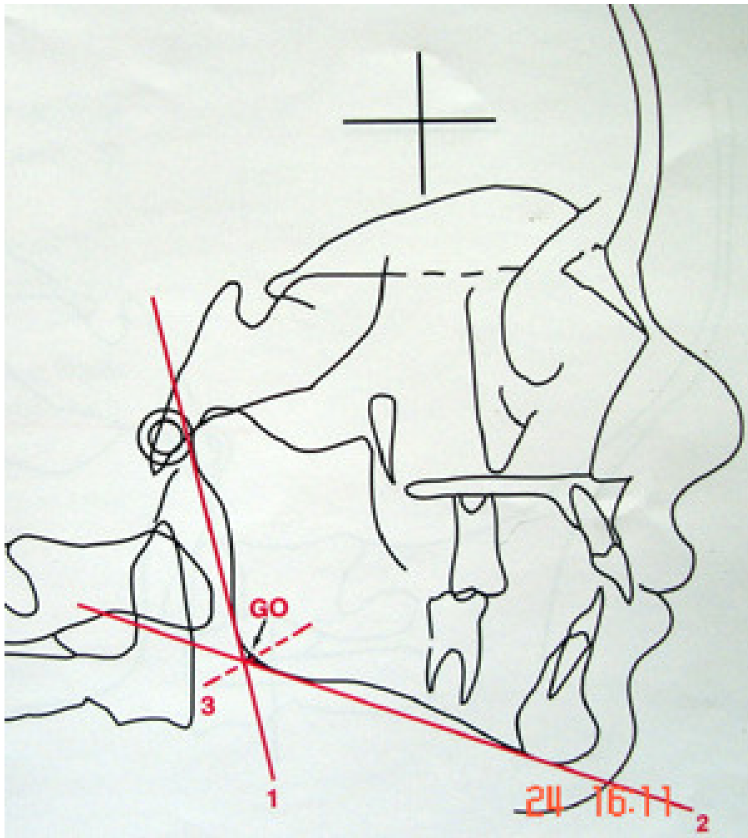

Figure 55. Locating gonion point (Jacobsen, 1995)

One of the objectives of cephalometric analysis is that it should assist us in predicting how patient will respond to treatment rather than solely describing morphology. By applying the analysis to an orthodontically treated patient (Chapter 5) salient morphological changes before and after treatment became evident. However, this was a solitary case and in order to apply the analysis repeatedly and accurately to the greater population, normal values were determined in a control group of a South African Black population sample. These values are summarised in Tables 26 with the parameters of these measurements illustrated in Figure 56.

Table 26. Standardised values for the proposed Dawjee Analysis

Parameter		Males	Females	Combined Value
1. Incisor separation (mm)	Mean	-	-	-
	Normal value	-	-	-
2. Anterior cranial base length (mm)	Mean	69.1000	69.2200	69.1600
	Normal value	64.89 ; 73.31	65.04 ; 73.40	66.99 ; 73;33
3. Anterior cranial base inclination (°)	Mean	7.5600	6.8600	7.2100
	Normal value	3.37 ; 11.75	2.98 ; 10.74	3.18 ; 11.24
4. Anterior maxillary position (°)	Mean	35.6200	35.3800	35.5000
	Normal value	31.31 ; 39.92	31.48 ; 39.28	31.41 ; 39.59
5. Posterior maxillary position (°)	Mean	39.2200	39.1600	39.19
	Normal value	35.78 ; 42.66	35.01 ; 43.31	33.40 ; 42.98
6. Anterior mandibular position (°)	Mean	68.9000	68.3000	68.6000
	Normal value	63.87 ; 73.93	63.27 ; 73.33	63.59 ; 73.61

7. Posterior mandibular position (°)	Mean	36.9800	37.6000	37.2900
	Normal value	32.06 ; 41.90	33.49 ; 41.71	32.77 ; 41.81
8. Point A position (°)	Mean	42.3400	41.7000	42.0200
	Normal value	37.34 ; 47.34	36.86 ; 46.54	37.11 ; 46.03
9. Point B position (°)	Mean	60.5000	60.1400	60.3200
	Normal value	55.81 ; 65.19	55.89 ; 64.39	55.86 ; 64.78
10. Interalveolar angle (°)	Mean	79.1400	78.5000	78.8200
	Normal value	71.15 ; 87.13	70.08 ; 86.92	70.65 ; 86.99
11. Apex of the maxillary triangle (°)	Mean	105.1400	105.1600	105.1500
	Normal value	101.80 ; 108.48	101.58 ; 108.74	101.71 ; 108.59
12. Apex of the mandibular triangle (°)	Mean	74.7000	74.5800	74.6400
	Normal value	71.87 ; 77.53	71.67 ; 77.49	71.78 ; 77.50

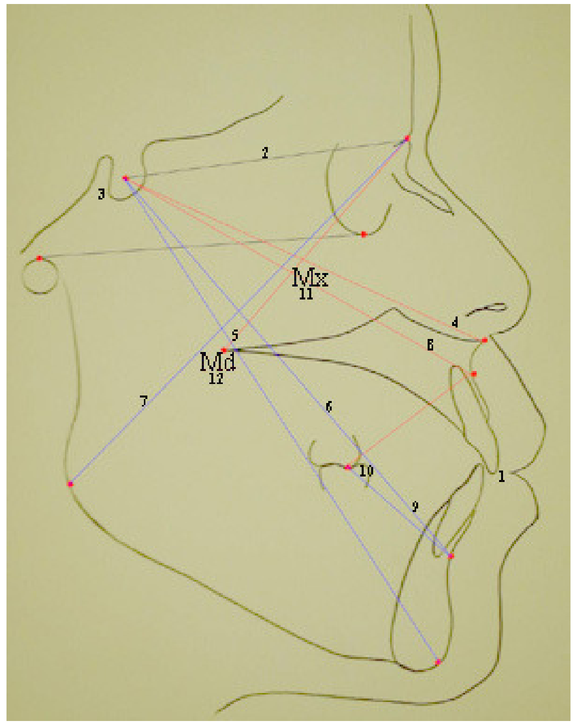

Figure 56. Twelve parameters of the proposed Dawjee Analysis

Diagnosis involves a comparison to population standards and the determination of normal values are important in that when a patient's measurements are close to the mean, the analysis is of lesser importance as the clinician can, with modern orthodontic biomechanics, easily camouflage mild skeletal dysplasia. The most critical test of any cephalometric analysis is the detail it reveals and the clinical insight it provides of patients who have several measures far from their expected values, which in this study has been calibrated to the mean +/- 1 SD. For patients whose values are outside of this range, routine treatment may be inadequate. Should only the mean value be known and no idea of variance be given, the clinician cannot know how far from the norm the patient's measures are.

Descriptive statistical analysis was also applied to the data collected from the AOB group to determine the means and range of variation for that group (Table 14).

When comparisons were drawn between the control and AOB group with regard to the 12 parameters (Table 15) using t-test for incisor separation and ANOVA for the remaining parameters, with p- values set at < 0.05, it was found that values for the AOB group, was significantly larger than the control group in five of the measurements namely:

1. Incisor separation ($p<0.0001$)
2. Anterior cranial base inclination ($p<0.0073$)
3. Posterior maxillary position ($p<0.0000$)
4. Posterior mandibular position ($p<0.0000$)
5. Interalveolar angle ($p<0.0000$)

Measurements for the AOB group were also found to be significantly smaller than the control group for the following parameters:

1. Point B position ($p<0.0049$)
2. Apex of the maxillary triangle ($p<0.0000$)
3. Apex of the mandibular triangle ($p<0.0000$)

Essentially these eight differences respectively imply that in AOB subjects:

1. There is a negative overbite, which is clinically evident as a vertical separation of the upper and lower incisors by 1mm or more.
2. The anterior cranial base is steeper and this morphological trait would contribute to an increase in the UFH and AFH. While this morphological entity cannot be altered clinically, it does portray the contribution of the anterior cranial base to overall facial height (Enlow *et al.*, 1982)
3. The maxilla is canted downward posteriorly setting the stage for premature buccal occlusal contact, downward and backward rotation of the mandible, relative upward canting of the upper anterior occlusal plane and an AOB. Treatment in these instances must be directed at levelling the maxilla with a high pull headgear and/or the use of a posterior occlusal bite plane.

4. There is downward positioning of gonion, which may be interpreted as an elongation of the mandibular ramus.
5. There is separation of anterior mandibular and maxillary alveolar and basal bone, an area that is also vulnerable to changes in incisor inclination
6. There is compensatory vertical remodelling of the anterior part of the mandible.
7. There is counter clockwise rotation of the maxilla and this can influence the UFH to LFH ratio.
8. There is clockwise rotation of the mandible.

Gender and group interactions were also investigated (Table 15) to determine if there were any differences between the males and females within the control and AOB group and no differences were found among the sexes between the groups.

In a cephalometric study on the morphological features of AOB, conducted by Dung and Smith (1988) most patients with open bites did not have cephalometric criteria that were suggestive of open bites, and most patients who had cephalometric measurements considered to be suggestive of open bites did not in fact have open bites. They concluded that the problem of predicting open bite tendencies might be caused by using the wrong cephalometric variables (Dung and Smith, 1988).

Other cephalometric studies have repeatedly confirmed that patients with AOB differ from the random population in having characteristics such as a steep mandibular plane; an increased anterior facial height to posterior facial height ratio; a low upper facial height to lower facial height ratio; an increased gonial angle; divergent cranial base, palatal and occlusal planes; and increased sella condylar distance (Cangialosi, 1984; Droel and Isaacson, 1972; Jacobsen, 1995; Jarabak and Fizzell, 1972; Sassouni, 1969; Schudy, 1965; Steiner, 1960).

Findings from this current cephalometric study and its application to a South African Black population sample have confirmed that, of the 12 parameters used in the proposed Dawjee Analysis, nine of them, inclusive of incisor separation, show differences between the control and the AOB samples. The null hypothesis of this research which states there is no difference in the cephalometric values of the proposed Dawjee Analysis between AOB subjects and a control group in a given population sample has therefore been defeated and is rejected by the findings of this study.

A patient's data may not fall into a well-defined diagnostic category, or clinicians may disagree about the correct diagnosis or the most appropriate therapy. What one clinician may see as a high angle case may not be what another classifies as a high angle case. AOB caused by a dental abnormality is conventionally considered to be a mild form of open bite, whereas that which is associated with a skeletal abnormality constitutes a severe form.

The burning question that demands an answer is: when is an AOB skeletal and when is it dental? The answer is contained in the interalveolar angle of the analysis. If all other parameters of the proposed Dawjee Analysis are normal and the interalveolar angle is increased, then the AOB is dental in nature. If the interalveolar angle is enlarged and all other variables show skeletal diversion, then the AOB is skeletal in origin. If the analysis shows skeletal diversion but the interalveolar angle is normal or decreased, then there may be alveolar compensation and the case would need further clinical assessment.

Application of other cephalometric methods to assess vertical facial discrepancies disclosed some interesting observations. The ODI analysis, though relevant to other population groups (Kim *et al.*, 2002), showed no meaningful difference between the normal and AOB subjects in this population sample. As it was not a component of this study, research into developing standardised ODI values for this population sample would be interesting and of clinical value.

The three areas of statistical difference namely the palatal plane, AFH and LFH between the AOB and control groups are all associated with the distal and downward cant of the posterior maxilla.

While the Sassouni analysis does not display any areas of skeletal variation other than the palatal plane, the Steiner analysis confirmed that the position of the upper and lower incisors, are strongly associated with AOB. In AOB cases the upper and lower incisors are proclined with a concomitant decrease in the interalveolar angle.

When comparing the findings of the other cephalometric methods to that of the proposed Dawjee Analysis, it becomes evident that the former emphasises the anterior dentoalveolar region and the palatal plane while the latter takes both the anterior and posterior craniofacial dimensions into consideration and relates them to an accepted and standard reliable and reproducible reference plane: the anterior cranial base.

It would be of benefit to the population and patients of this study sample to supplement the components of other cephalometric analysis that show statistically significant differences between control and AOB groups to the proposed Dawjee Analysis in order to confirm and support the morphological component causing the AOB. AFH, LFH, the palatal plane-occlusal plane angle, upper and lower incisor angle as well as the inter-incisal angle are measurements that can be applied to enhance the proposed Dawjee Analysis.

Chapter 9

Conclusion

When a patient asks for straight teeth she/he deserves the best. Apart from providing such a patient with paramount aesthetics and function the orthodontist's objective must include the most stable result that he or she can provide. Biological principles that govern the dentition, growth and facial norms within a multiracial and multi-cultural society must be respected, appreciated and considered in the holistic management of the orthodontic patient.

Moyers rightly claims "the public, who created us legally, underwrote our education, and licensed us, has a right to hold us accountable for the quality of the services it receives. We are therefore obliged to insist upon the best possible orthodontic service for all". In clinical diagnosis and treatment it is an accepted fact that "differences of opinion can cause more trouble than differences of fact" (Moyers, 1984a) and based on these grounds this research has attempted to carefully and systematically evaluate the validity of a new and fresh approach to the cephalometric diagnoses of vertical facial discrepancies.

The cardinal role of cephalometric analysis in orthodontic diagnoses and treatment planning is to identify and evaluate the morphological bases of dentofacial anomalies. We do not need a lateral cephalogram to tell us that the patient has an AOB or a long lower face. These are straightforward clinical observations. The recordings and measurements taken from a lateral cephalogram must assist us in identifying anatomical markers that would aid us in devising the most appropriate treatment plan for the problem at hand. In terms of vertical facial analysis, the proposed Dawjee Analysis tries to uphold these criteria. The technique is an adaptation of other analyses complemented by the introduction of one new landmark (OCP) and seven new planes. It measures a total of 11 parameters of which eight are diagnostic. The ninth diagnostic parameter (incisor separation) is self-evident both clinically and cephalometrically. The strength of the analysis lies in its attempt to distinguish between the skeletal and dental nature of an AOB in this population sample and this can serve as an important aid to both orthodontists and maxillofacial surgeons when making treatment decisions in patients from this population with AOB. Other cephalometric methods investigated in this study disclose more information about the palatal plane orientation and anterior dentoalveolar region and these can be applied to supplement and confirm the findings of the proposed Dawjee Analysis in vertical facial assessment. Established and popular cephalometric methods such as the Wits analysis and the ANB angle can also be incorporated to assess horizontal jaw relationships (Downs, 1952; Jacobsen, 1975; Steiner, 1953).

Recommendations

Although, from the findings of this study, AOB appears to be on the decline with regard to the population group evaluated in this research, concerted effort must be made to educate the public about the detrimental effects of thumb and finger sucking, particularly in light of government cutbacks on tertiary health care and specialised orthodontic care.

While the proposed Dawjee Analysis is a useful diagnostic tool in assessing vertical facial discrepancies in the sagittal plane, it could be supplemented with other analytical methods of assessing AOB as well as components that assess horizontal facial disharmonies.

This study was directed at South African Blacks mainly because AOB was found to be more common in this race group. In order to extend its utility the analysis would need to be tested on other race groups to determine its sensitivity and applicability to other races. While it was not the intention of this study to use the proposed analysis as a growth direction predictor and the age of the sample used in this study was well above 13 years, it would be interesting to document the changes seen before and after 13 years with the proposed Dawjee analysis, particularly in light of the 50% reduction in AOB between these age groups as found by this study.

It would also be interesting and expand the use of the proposed analysis to a sample of the Caucasian population where a study could compare values of the proposed Dawjee Analysis between deepbite and subjects with a normal overbite or draw comparison between brachifacial and dolicofacial samples.

A weakness of the analysis was identified as the OCP (occlusal contact point). Replacements and substitutes for this point have been suggested.

There are a myriad of tools to measure facial morphology and disturbances thereof and the proposed Dawjee Analysis serves as an alternate method to map both skeletal and dental components in the assessment of AOB. This analysis can be added to the armamentarium of diagnostic aids and should be exposed and publicized to relevant target groups.

Finally, in the face of advancing technology and progress in 3D imaging one has to question whether cellulose film radiography and cephalometric analyses are becoming obsolete. Are we migrating to a treatment platform where respect and protection for patient autonomy, will through the use of digital imaging, necessitate that patients simulate and select their own desired treatment outcomes? This would seem to be the direction that orthodontics in first world countries is moving to. But for underdeveloped, developing and economically impecunious countries, standard radiographs and cephalometric analysis will remain an essential and important diagnostic tool.

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_case study

An introductory report on a new cephalometric method: the Dawjee analysis

An introductory report on a new cephalometric method: The Dawjee Analysis
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Keywords: Cephalometric analysis, cephalometric landmarks, cephalometric planes

SUMMARY

A new method of lateral cephalometric analysis referred to as the Dawjee analysis is introduced. Landmarks, planes and angles are defined, and the technique is outlined. The Dawjee analysis is primarily focused on evaluating craniofacial structures in the vertical dimension and this introductory presentation demonstrates its application in both open and deep bite cases. Studies are in progress to develop a set of standardised values for this technique in a South African population sample.

INTRODUCTION AND REVIEW

Anthropologist and anatomists were the first to evaluate craniofacial patterns using dimensions obtained from dry skulls. The measurements of dry skulls from osseous sites, and their application to living subjects are called craniometry, and while useful at the time, these readings had limited value.

The introduction of radiographs by Wilhelm Conrad Röentgen in 1895 contributed a new perspective to medicine and dentistry. Radiographs of the head could now be measured from different aspects making it possible to study craniofacial development with greater precision. In 1931 Broadbent in Germany and Hofrath in the USA simultaneously presented a standardised technique for the production of radiographs of the head using an immobiliser called a cephalostat. Measurements on the radiograph of the shadows of bony and soft tissue structures became known as roentgenographic cephalometry. This procedure has proven invaluable in longitudinal growth studies, as well as the diagnosis, management and post-treatment appraisal of craniofacial morphology.

It is understandable that over time, a myriad of cephalometric measurements and techniques have evolved. These were aimed at defining sagittal jaw relations[1-3], vertical jaw relations[4-6], dentoalveolar relations[7-9], soft tissue proportions[10-12] and the identification of other anomalies.

Since all of these techniques and procedures were initiated in Europe and America, their development and application related mainly to the craniofacial norms and requirements of Caucasians. In 1951 Cotton and co-workers[13], Altemus[14] and Drummond[15] developed normal values based on African American race groups, while Barter, Evans, Smith and Becker[16], as well as Naidoo and Miles[17] went on to describe norms of cephalometric values for indigenous African groups.

As the accrual of data on cephalometric norms for Africans increased, it became evident that African craniofacial morphology differed from that of their European counterparts. Salient traits seen in African cephalometry include bimaxillary dental and skeletal proclination, a larger arch length and a steeper mandibular plane[18-20].

In South Africa, the increased availability and accessibility of dental care to previously disadvantaged race groups resulted in an accumulation of patient records at the Medunsa Oral Health Centre (MOHC) of the University of Limpopo and other similar institutions. One of the more common occlusal problems observed by the Orthodontic Department at the MOHC is the anomaly of an anterior open bite (AOB)[21]. This condition has a multi-factorial aetiology[22] and is clinically recognisable by a lack of contact between the upper and lower incisal edges (Fig.1).

Fig.1. An example of an anterior open bite (AOB)

While various cephalometric analyses are available to diagnose and identify the morphological components of an AOB[20,23-25], these methods are cumbersome and usually not relevant to the South African Black race group. To this end a new system of evaluating AOB, the Dawjee Analysis, has been designed.

The Analysis

The Dawjee analysis is primarily focused

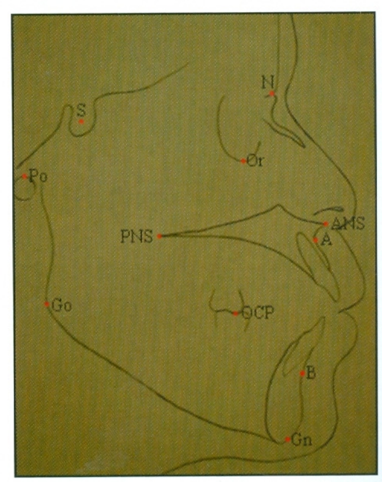

Fig. 2. Lateral cephalogram indicating landmarks used in the Dawjee analysis

on evaluating craniofacial structures in the vertical dimension. It employs various cephalometric landmarks, planes, angles and triangles as listed below.

Lateral cephalometric landmarks (Fig. 2)

1. Sella (S) - the midpoint of the pituitary fossa of the sphenoid bone.
2. Nasion (N) - the intersection of the inter-nasal suture with the naso-frontal suture in the mid-sagittal plane.
3. Porion (Po) - the highest point on the superior surface of the bony auditory meatus.
4. Orbitale (Or) - the lowest point on the left infra-orbital margin.
5. Posterior nasal spine (PNS) - the tip of the posterior spine of the palatal bone.
6. Anterior nasal spine (ANS) - the tip of the anterior nasal spine of the palatal bone.
7. A Point - the deepest point on the anterior border of the maxilla.
8. B Point - the deepest point on the anterior border of the mandibular symphysis.
9. Occlusal contact point (OCP) the most anterior intercuspation contact point between the upper and lower first permanent molars.
10. Gonion (Go) - the point on the mandibular jaw angle, which is the most inferiorly, posteriorly and outwardly directed.
11. Gnathion (Gn) - the most antero-inferior point on the contour of the mandibular symphysis.

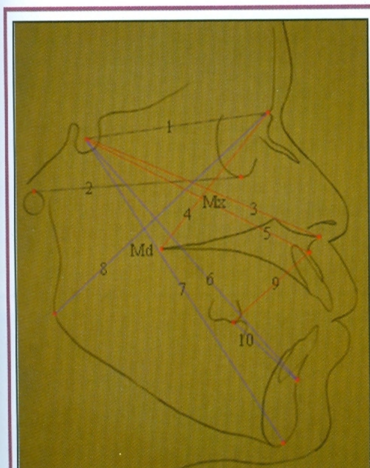

Fig. 3. Lateral cephalogram indicating lines and planes in an open bite subject

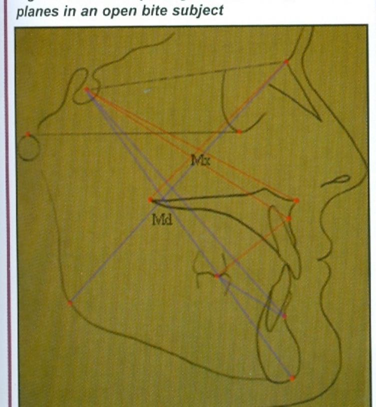

Fig. 4. Lateral cephalogram indicating lines and planes in a deep bite subject

Lateral cephalometric planes and lines (Fig. 3)

1. Anterior cranial base extends from S to N.
2. Frankfort horizontal plane extends from porion to orbitale.
3. S to ANS is defined by a line joining these two points.
4. N to PNS is defined by a line joining these two points.
5. S to A is defined by a line joining these two points.
6. S to B is defined by a line joining these two points.
7. Y axis extends from S to Gn.
8. Z axis extends from N to Go.
9. OCP to A is defined by a line joining these two points.
10. OCP to B is defined by a line joining these two points

Table I. Comparison of cephalometric values between an open and a deep bite case

	Open bite patient	Close bite patient
Anterior cranial base inclination	5°	8°
Anterior cranial base length	68mm	74mm
Anterior maxillary position	30°	36°
Posterior maxillary position	43°	36°
Anterior mandibular position	64°	62°
Posterior mandibular position	34°	40°
Point A position	34°	41°
Point B position	56°	51°
Inter-alveolar angle	83°	65°
Apex of the maxillary triangle	107°	108°
Apex of the mandibular triangle	82°	78°

Lateral cephalometric measurements

From the above landmarks and planes, one linear and ten angular measurements can be recorded as follows:

1. Anterior cranial base inclination as an angle formed between SN and the Frankfort horizontal plane.
2. Anterior cranial base length is the length of S to N expressed in millimetres.
3. Anterior maxillary position is defined by the NS-ANS angle.
4. Posterior maxillary position is defined by the SN-PNS angle.
5. Anterior mandibular position is defined by the NS-Gn angle.
6. Posterior mandibular position is defined by the SN-Go angle.
7. Point A position is defined by the NSA angle.
8. Point B position is defined by the NSB angle.
9. Inter-alveolar angle is defined by the A-OCP-B angle.
10. Apex of the maxillary triangle is labelled Mx and is located at the intersection of the N-PNS and S-ANS lines. All lines related to the maxilla are represented in red
11. Apex of the mandibular triangle is labelled Md and is located at the intersection of the N-Go and S-Gn lines. All lines related to the mandible are represented in blue.

DISCUSSION AND CONCLUSION

The innovation of the Dawjee analysis is in its assessment of the craniofacial structures in the vertical dimension. Many of the landmarks, planes and parameters have been defined by previous researchers[1-9] and are in common use. New reference points introduced for this analysis include the OCP, inter-alveolar angle, the z-axis, the maxillary triangle and the mandibular triangle.

The maxillary triangle has a line from ANS to PNS as its base and its apex is labelled Mx, while a line from Gn to Go defines the base of the mandibular triangle, and its apex is labelled Md (Figs. 3 & 4). Base lines of both triangles have been excluded from the cephalometric tracing for their insignificance and for the sake of simplicity. The angles Md and Mx are important as their dimensions give a broad estimate of mandibular and maxillary sizes. As this is only a preliminary report, it is anticipated that with further research, a ratio between Mx and Md will be investigated to describe the horizontal relations between the two jaws.When the values between the open (fig. 3.) and deep bite (fig. 4.) tracings are compared (table I), it is evident that in the deep bite subject, the anterior cranial base is steeper and longer; the maxillary complex and anterior alveolus is rotated clockwise; the anterior alveoli are inclined toward one another; and, as assessed by the triangular apices, the mandible is smaller. This difference of readings from a patient with an open bite and one with a deep bite demonstrates the sharp contrast between the two cases and exemplifies the contribution of the Dawjee analysis in the diagnosis and assessment of vertical discrepancies. Once mandibular and maxillary positions are determined, the newly introduced inter-alveolar angle can be used to evaluate alveolar contributions to, or compensations for, the vertical problem. Alveolar location relative to the cranial base can be assessed using the SA and SB lines.

The findings presented in this manuscript are of two isolated cases and should be interpreted with caution, as conclusions cannot be widely implemented unless the analysis is applied to a larger and more representative sample.

Malocclusion in the vertical dimension is a common phenomenon[26], manifesting clinically as either an open or a deep bite. Identification of the morphological traits and source of the problem is critical in order to apply the appropriate treatment, but the process can often be confusing[24] and cumbersome. By determining mandibular and maxillary positions and alveolar location in the vertical plane, this preliminary presentation of the Dawjee analysis hopes to clear some of the uncertainties surrounding vertical craniofacial abnormalities.

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The rest of this article's references (19-26) wil be published on www.sada.co.za

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CASE REPORT

Non-surgical Treatment of Anterior Open Bite and Its Assessment Using the Dawjee Analysis: A Case Report

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ABSTRACT

Anterior open bite (AOB) is a dentofacial problem occurring more commonly in race groups of African origin[1]. Although multi-factorial, the aetiology exerts its influence in tandem with craniofacial development. Diagnosis is confirmed by a cephalometric assessment and points either to a skeletal origin, a dental source, or both. Depending on the time of diagnosis and severity of the condition, treatment can vary from interceptive procedures, orthodontics only, or a combination of orthodontic treatment and orthognathic surgery.

A case study is presented of an adult female with AOB who was treated non-surgically. The diagnosis, treatment technique and outcome are described, as well as a pre- and post-treatment evaluation of the cephalograms using the Dawjee analysis. Comparison of pre- and post-treatment cephalometric values show a definite dentofacial improvement, and identifies specific morphologic areas that have changed as a result of treatment. Transformations in anteroposterior maxillary and mandibular positions and orientation are readily detectable, as well as a repositioning of the alveolar processes.

While pre and post treatment cephalometric values presented for this patient compare well, these values are case specific and cannot be implemented widely unless the analysis is applied to a larger and more representative population sample and standardised measurements have been established.

Keywords: Anterior open bite, Cephalometric analysis, Orthodontic treatment

INTRODUCTION

Anterior open bite (AOB) malocclusion is a common orthodontic concern and according to Beane[1] the NHANES III study cites that the condition can occur from 2,5 to 4 times more often in Blacks than in Whites. Aetiological factors that have been implicated in the development of the condition include unfavourable growth pattern[2], finger sucking habits[3], enlarged lymphoid tissue[4], abnormal tongue and orofacial muscular activity[5], and genetics[6]. These factors can result in a dental open bite, a skeletal open bite, or a combination of the two[7].

It is essential that the clinician recognises the various aetiological components causing the AOB and their effect on craniofacial morphology so that the appropriate treatment may be undertaken. While most AOBs in the primary and mixed dentition correct spontaneously[8], various treatment options are available to manage those AOBs that persist. These treatment modalities are dictated by the underlying aetiology and include orthodontics only, orthognathic surgery, or a combination of the two[9,10].

CASE PRESENTATION

A 23-year old Black female patient presented at the Orthodontic Department of the Medunsa Oral Health Centre (MOHC), University of Limpopo, South Africa, complaining that her upper and lower front teeth did not meet. She had no family history of the condition and a dental history revealed that she had a habit of thumb sucking until the age of 12.

Clinically the following was noted (figs. 1- 5):

1. A bimaxillary protrusive facial profile
2. Incompetent lips at rest
3. Disclusion of the upper and lower anterior teeth from 3 to 3
4. An anterior open bite of 7mm
5. Incisal wear of the 11 and 21
6. Class I buccal occlusion on left side and a half cusp Class II on the right side
7. Two millimetres of spacing mesially and distally on both the 13 and 23
8. Six millimetres of spacing between the lower incisors from 33 to 43

Oral hygiene, speech and swallowing were normal and the patient had no other dentofacial concerns. Because the habit had stopped eleven years ago and the patient's growth was complete, orthodontics, or a combination of orthodontics and orthognathic surgery, were the only treatment options available. The patient was, however, reluctant to undergo any form of surgery.

Fig. 1. Pretreatment frontal view of the face

Fig. 2. Pretreatment lateral view of the face

From an orthodontic perspective, two treatment modalities were proposed to manage the AOB:

1. Extraction of upper and lower premolars followed by full fixed orthodontics, or
2. Non-extraction full fixed orthodontic therapy only.

After informed deliberation, the patient opted for the second treatment plan.

Active treatment lasted for approximately 15 months and consisted initially of up-

Fig. 3. Pretreatment anterior occlusal view

Fig. 4. Pretreatment right occlusal view

Fig. 5. Pretreatment left occlusal view

per and lower 2x4 utility archwires with reverse tip back bends mesial to the first molars. This was followed with full archwires swept with reverse curves of Spee. Final archwires were supplemented with anterior elastics to maintain bite closure.

At the end of treatment acceptable results were achieved with a normal overbite and overjet of 2mm each. Buccal occlusion on the left was Class I while the right side remained half cusp Class II, accounting for an upper midline shift of 3mm to the left (Figs. 6-10). Retention was maintained for a year and consisted of fixed upper and lower 3-3 retainers.

CEPHALOMETRIC ANALYSIS

While various cephalometric analyses are available to diagnose and identify the morphological components of an AOB[11-14], these methods are not race specific and standardised values for the South African Black race group are not available. To this end a new system of evaluating AOB, the Dawjee Analysis[15], has been designed for this ethnic group. This analysis is primarily focused

Fig. 6. Post-treatment frontal view of the face

Fig. 7. Post-treatment lateral view of the face

on evaluating craniofacial structures in the vertical dimension.

DISCUSSION

Although the orthodontic treatment of this patient was without incident, some biomechanical observations need reflection. While the first premolars were considered for extraction and by way of the drawbridge concept[16], would have resulted in bite closure, a reduction of the bimaxillary protrusion, midline correction and a defined Class I occlusion; the patient was happy with

Fig. 8. Post-treatment anterior occlusal view

Fig. 9. Post-treatment right occlusal view

Fig. 10. Post-treatment left occlusal view

Table 1. Comparison of pre- and post-treatment cephalometric values		
	Pre-treatment values	Post-treatment values
Anterior cranial base inclination	5°	5°
Anterior cranial base length	68 mm	68 mm
Anterior maxillary position	30°	33°
Posterior maxillary position	43°	41°
Anterior mandibular position	64°	65°
Posterior mandibular position	34°	39°
Point A position	34°	37°
Point B position	56°	58°
Inter-alveolar angle	83°	75°
Apex of the maxillary triangle	107°	106°
Apex of the mandibular triangle	82°	76°

her horizontal facial profile and did not want to have any teeth removed. Furthermore, extractions could encroach on tongue space and may have compromised post-treatment stability.

Reverse tipback bends in a utility archwire are effective in extruding incisors, but cause reciprocal mesialization and buccal displacement of molars. This problem can be overcome with the use of transpalatal and lingual arches. To retain overbite correction it is essential that anterior box elastics are used when full archwires are inserted and posterior segments leveled. Post-treatment intraoral photographs (figs. 8-10) were taken immediately after a scaling and accounts for the irritation and bleeding around the gingival margins. Photographs could not be taken later when the gingival healed, as the patient relocated immediately after deband.

Lingually bonded fixed retainers were preferred instead of removable

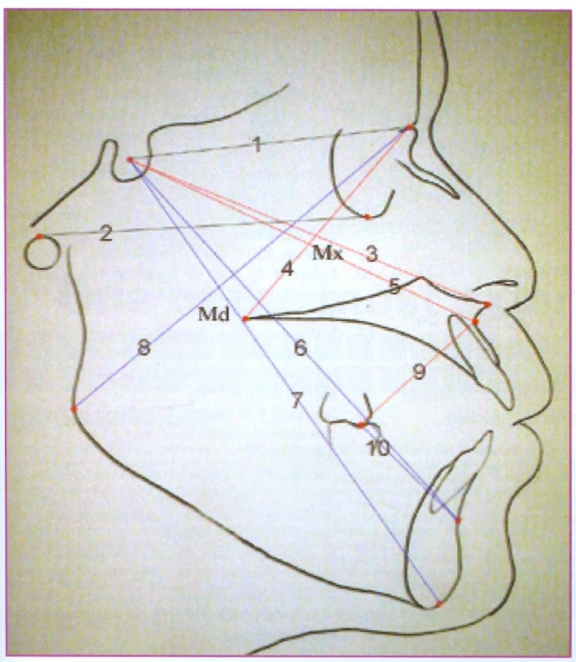

Fig. 11. Pre-treatment lateral cephalogram demonstrating lines and planes used in the Dawjee analysis[15]

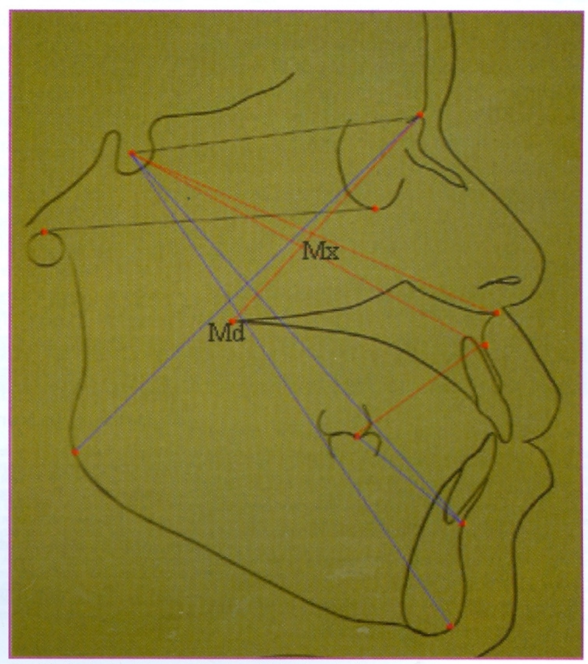

Fig. 12. Analysis of the post-treatment lateral cephalogram.


Fig. 13. Post retention cast – frontal view

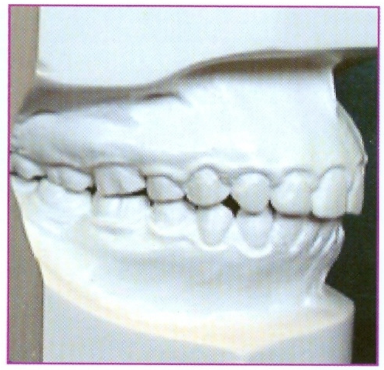
Fig. 14. Post retention cast – right view

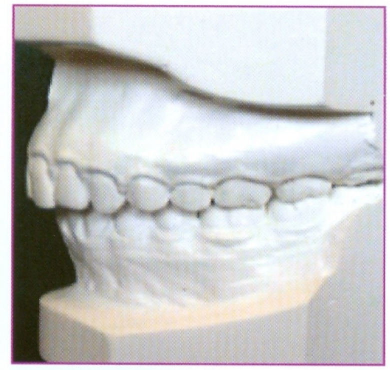
Fig. 15. Post retention cast – left view

retainers as the former are less likely to interfere with the posterior occlusion and risk the possibility of relapse. As the patient relocated to a rural district after treatment, study casts that were sent to the Orthodontic Department approximately a year after treatment, show no evidence of relapse (Figs. 13-15). Service limitation in the patient's location ruled out an orthopantomogram or lateral cephalogram.

When the values between pre-treatment (fig.11) and post-treatment (fig.12) tracings are compared (table I), it is evident and obvious that the cranial base length and inclination did not change. Treatment changes in the palatal plane point to a clockwise rotation and while the anterior mandibular position (Gn) remained unchanged, the mandibular angle rotated counter clockwise.

Anterior inter-alveolar distance decreased remarkably with treatment as evidenced by a downward repositioning of point A by three degrees, a decrease in inter-alveolar angle of eight degrees and the establishment of a positive overbite of two millimetres.

A reduction in the mandibular angle (Md) of the mandibular triangle should be interpreted with caution. While this angle is dominated by mandibular length, which in this case has not changed, the four degrees loss in Md must be due to a downward and forward repositioning of Go as confirmed by the five degree gain in posterior mandibular position.

CONCLUSION

Malocclusion in the vertical dimension is a common phenomenon[17], manifesting clinically as either an open or a deep bite. Identification of the morphological traits and source of the problem so as to apply the appropriate treatment can often be confusing and cumbersome[18]. By determining mandibular and maxillary positions and alveolar location in the vertical plane, the Dawjee analysis[15] hopes to clear some of the uncertainties surrounding the diagnoses and management of vertical craniofacial abnormalities.

While this patient was treated to a favourable and stable functional and aesthetic result, and post-treatment cephalometric readings show marked improvement, these readings are case specific and cannot be implemented widely unless the analysis is applied to a larger and more representative sample.

Research is currently in progress as part of a thesis to develop standardised values for the Dawjee analysis, which can have widespread clinical use and assist in comparative craniofacial studies.

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Additional references (15-18) are available on www.sadanet.co.za

Addenda

All measurements are expressed in degrees except for the anterior cranial base length and incisor separation that are expressed in millimetres.

Cephalometric data

Table 27. Cephalometric values - control group

Patient number	Anterior cranial base length	Anterior cranial base inclination	Anterior maxillary position	Posterior maxillary position	Anterior mandibular position	Posterior mandibular position	Point A position	Point B position	Interalveolar angle	Apex of the maxillary triangle	Apex of the mandibular triangle
1	78	3	32	37	64	40	36	54	82	111	78
2	67	8	38	42	70	38	42	61	88	101	73
3	75	3	30	45	59	44	31	50	61	104	78
4	63	7	38	37	67	42	43	60	66	104	79
5	72	5	35	40	62	45	40	60	87	105	72
6	68	6	33	41	67	38	40	58	80	106	73
7	66	3	30	45	66	38	37	57	78	105	76
8	65	11	40	38	70	30	47	62	68	103	79
9	66	10	34	42	65	39	40	60	85	105	75
10	74	12	37	34	72	33	43	62	90	108	74
11	67	13	41	36	73	30	48	63	69	102	78
12	67	16	46	33	79	33	54	70	88	101	71
13	79	3	34	36	64	41	36	53	82	112	77

14	68	8	39	42	70	39	42	60	89	100	73
15	76	3	31	44	60	45	31	52	60	104	78
16	61	7	36	39	67	44	44	61	66	101	79
17	70	3	33	42	62	46	40	61	87	105	72
18	68	6	33	41	68	38	40	61	80	106	73
19	66	3	30	46	65	39	36	57	79	105	76
20	72	11	38	38	74	32	46	65	83	106	74
21	69	1	30	40	66	40	40	59	82	110	74
22	68	8	37	41	71	34	45	63	69	102	73
23	68	4	29	41	70	37	44	63	78	109	72
24	71	13	37	38	74	31	46	65	83	105	74
25	69	0	30	40	66	40	40	59	82	110	73
26	66	11	36	42	71	33	45	62	69	102	74
27	67	6	28	42	70	36	44	64	78	110	74
28	67	7	31	38	71	35	42	65	84	111	72
29	63	7	38	40	71	32	45	65	81	102	75
30	68	5	34	45	77	30	42	61	80	101	69
31	70	6	34	35	71	38	42	61	84	111	72
32	65	7	41	37	71	35	45	62	81	102	75
33	70	5	37	42	77	42	42	59	80	101	69
34	74	3	35	42	60	44	38	52	76	103	77
35	67	11	41	35	70	32	47	61	68	104	79
36	68	10	35	39	65	41	40	57	85	105	75
37	76	11	39	32	71	35	43	61	90	108	74
38	65	13	40	37	73	28	48	64	69	103	78

39	66	15	45	34	79	32	53	71	88	102	70
40	75	5	35	42	60	44	38	51	76	103	77
41	78	3	31	38	64	39	36	55	81	111	78
42	69	6	34	40	67	40	40	59	80	105	73
43	67	3	31	44	66	39	37	56	78	105	75
44	66	11	41	37	70	31	47	63	68	104	80
45	67	10	35	41	65	40	40	58	86	106	75
46	75	14	38	33	72	34	43	62	91	109	74
47	65	13	39	38	73	28	48	66	69	103	79
48	65	14	44	35	79	31	55	72	88	101	70
49	73	13	37	37	74	33	46	64	83	105	74
50	70	2	31	38	67	41	40	58	82	110	73
51	68	9	38	42	70	35	45	62	69	102	74
52	66	9	38	43	70	37	42	62	88	101	73
53	74	4	30	46	59	43	31	51	61	104	78
54	63	7	37	39	67	41	43	61	66	103	79
55	70	3	34	41	63	45	40	60	87	105	71
56	69	3	30	40	70	37	44	62	78	110	72
57	69	7	32	36	71	37	41	63	84	111	71
58	66	11	41	35	70	31	47	64	68	103	79
59	67	10	34	41	64	40	40	58	87	105	75
60	75	13	38	32	72	34	43	61	90	110	74
61	65	13	40	37	73	29	47	64	69	103	80
62	66	13	44	34	79	32	54	70	88	100	70
63	74	13	39	36	74	33	46	63	81	105	74

64	66	7	41	37	71	35	45	61	81	101	75
65	71	5	37	42	77	42	42	58	79	101	68
66	74	4	35	42	60	44	38	52	76	102	78
67	78	3	32	37	64	40	36	54	82	110	76
68	80	3	32	37	64	40	36	54	81	112	77
69	67	10	38	42	70	38	42	60	88	100	73
70	75	3	32	45	59	44	30	50	60	104	78
71	60	7	35	24	67	39	43	62	66	105	79
72	69	3	32	43	63	43	39	62	87	105	72
73	72	3	32	46	60	41	38	55	76	103	77
74	74	3	30	40	64	38	36	57	82	111	76
75	76	4	33	40	64	37	36	57	82	110	76
76	69	6	33	41	67	39	40	60	80	106	73
77	65	3	30	44	65	38	38	57	78	105	76
78	69	0	30	40	66	40	40	58	82	110	73
79	67	9	36	41	71	33	44	65	69	102	74
80	68	4	29	40	70	37	44	62	78	110	72
81	68	7	35	37	69	36	42	63	84	110	72
82	64	7	42	38	71	32	45	64	81	102	75
83	69	5	37	44	77	40	41	60	80	101	69
84	65	9	39	44	70	38	42	62	88	99	73
85	73	3	32	45	59	42	31	52	59	104	78
86	64	7	37	37	67	43	43	59	66	103	79
87	73	3	36	39	63	45	38	58	87	105	71
88	71	6	36	38	67	38	40	57	80	106	74

89	65	13	41	36	73	31	48	63	69	104	79
90	67	15	41	33	79	31	54	70	89	101	72
91	72	13	39	38	74	31	46	66	83	105	74
92	69	0	31	41	66	40	41	59	82	110	73
93	67	9	38	40	72	35	45	63	69	102	74
94	69	4	30	38	71	37	44	63	78	110	72
95	67	3	31	45	64	38	37	57	78	105	76
96	66	11	38	35	70	32	47	63	68	103	79
97	68	11	33	40	65	41	40	58	86	105	75
98	77	12	38	33	72	35	43	61	90	107	74
99	69	7	33	36	71	38	43	61	84	111	72
100	66	6	40	38	71	35	45	63	81	106	75
Mean	**69.16**	**7.21**	**35.5**	**39.19**	**68.6**	**37.29**	**42.02**	**60.32**	**78.82**	**105.15**	**74.64**

Table 28. Cephalometric values – control group: male subjects

Patient number	Anterior cranial base length	Anterior cranial base inclination	Anterior maxillary position	Posterior maxillary position	Anterior mandibular position	Posterior mandibular position	Point A position	Point B position	Interalveolar angle	Apex of the maxillary triangle	Apex of the mandibular triangle
1	78	3	32	37	64	40	36	54	82	111	78
2	67	8	38	42	70	38	42	61	88	101	73
3	75	3	30	45	59	44	31	50	61	104	78
4	63	7	38	37	67	42	43	60	66	104	79
5	72	5	35	40	62	45	40	60	87	105	72
6	68	6	33	41	67	38	40	58	80	106	73
7	66	3	30	45	66	38	37	57	78	105	76
8	65	11	40	38	70	30	47	62	68	103	79
9	66	10	34	42	65	39	40	60	85	105	75
10	74	12	37	34	72	33	43	62	90	108	74
11	67	13	41	36	73	30	48	63	69	102	78
12	67	16	46	33	79	33	54	70	88	101	71
13	79	3	34	36	64	41	36	53	82	112	77
14	68	8	39	42	70	39	42	60	89	100	73
15	76	3	31	44	60	45	31	52	60	104	78
16	61	7	36	39	67	44	44	61	66	101	79
17	70	3	33	42	62	46	40	61	87	105	72
18	68	6	33	41	68	38	40	61	80	106	73
19	66	3	30	46	65	39	36	57	79	105	76
20	72	11	38	38	74	32	46	65	83	106	74

21	69	1	30	40	66	40	40	59	82	110	74
22	68	8	37	41	71	34	45	63	69	102	73
23	68	4	29	41	70	37	44	63	78	109	72
24	71	13	37	38	74	31	46	65	83	105	74
25	69	0	30	40	66	40	40	59	82	110	73
26	66	11	36	42	71	33	45	62	69	102	74
27	67	6	28	42	70	36	44	64	78	110	74
28	67	7	31	38	71	35	42	65	84	111	72
29	63	7	38	40	71	32	45	65	81	102	75
30	68	5	34	45	77	30	42	61	80	101	69
31	70	6	34	35	71	38	42	61	84	111	72
32	65	7	41	37	71	35	45	62	81	102	75
33	70	5	37	42	77	42	42	59	80	101	69
34	74	3	35	42	60	44	38	52	76	103	77
35	67	11	41	35	70	32	47	61	68	104	79
36	68	10	35	39	65	41	40	57	85	105	75
37	76	11	39	32	71	35	43	61	90	108	74
38	65	13	40	37	73	28	48	64	69	103	78
39	66	15	45	34	79	32	53	71	88	102	70
40	75	5	35	42	60	44	38	51	76	103	77
41	78	3	31	38	64	39	36	55	81	111	78
42	69	6	34	40	67	40	40	59	80	105	73
43	67	3	31	44	66	39	37	56	78	105	75
44	66	11	41	37	70	31	47	63	68	104	80
45	67	10	35	41	65	40	40	58	86	106	75

46	75	14	38	33	72	34	43	62	91	109	74
47	65	13	39	38	73	28	48	66	69	103	79
48	65	14	44	35	79	31	55	72	88	101	70
49	73	13	37	37	74	33	46	64	83	105	74
50	70	2	31	38	67	41	40	58	82	110	73
Mean	**69.1**	**7.56**	**35.62**	**39.22**	**68.9**	**36.98**	**42.34**	**60.5**	**79.14**	**105.14**	**74.7**

Table 29. Cephalometric values – control group: female subjects

Patient number	Anterior cranial base length	Anterior cranial base inclination	Anterior maxillary position	Posterior maxillary position	Anterior mandibular position	Posterior mandibular position	Point A position	Point B position	Interalveolar angle	Apex of the maxillary triangle	Apex of the mandibular triangle
1	68	9	38	42	70	35	45	62	69	102	74
2	66	9	38	43	70	37	42	62	88	101	73
3	74	4	30	46	59	43	31	51	61	104	78
4	63	7	37	39	67	41	43	61	66	103	79
5	70	3	34	41	63	45	40	60	87	105	71
6	69	3	30	40	70	37	44	62	78	110	72
7	69	7	32	36	71	37	41	63	84	111	71
8	66	11	41	35	70	31	47	64	68	103	79
9	67	10	34	41	64	40	40	58	87	105	75
10	75	13	38	32	72	34	43	61	90	110	74
11	65	13	40	37	73	29	47	64	69	103	80
12	66	13	44	34	79	32	54	70	88	100	70
13	74	13	39	36	74	33	46	63	81	105	74
14	66	7	41	37	71	35	45	61	81	101	75
15	71	5	37	42	77	42	42	58	79	101	68
16	74	4	35	42	60	44	38	52	76	102	78
17	78	3	32	37	64	40	36	54	82	110	76
18	80	3	32	37	64	40	36	54	81	112	77
19	67	10	38	42	70	38	42	60	88	100	73

20	75	3	32	45	59	44	30	50	60	104	78
21	60	7	35	24	67	39	43	62	66	105	79
22	69	3	32	43	63	43	39	62	87	105	72
23	72	3	32	46	60	41	38	55	76	103	77
24	74	3	30	40	64	38	36	57	82	111	76
25	76	4	33	40	64	37	36	57	82	110	76
26	69	6	33	41	67	39	40	60	80	106	73
27	65	3	30	44	65	38	38	57	78	105	76
28	69	0	30	40	66	40	40	58	82	110	73
29	67	9	36	41	71	33	44	65	69	102	74
30	68	4	29	40	70	37	44	62	78	110	72
31	68	7	35	37	69	36	42	63	84	110	72
32	64	7	42	38	71	32	45	64	81	102	75
33	69	5	37	44	77	40	41	60	80	101	69
34	65	9	39	44	70	38	42	62	88	99	73
35	73	3	32	45	59	42	31	52	59	104	78
36	64	7	37	37	67	43	43	59	66	103	79
37	73	3	36	39	63	45	38	58	87	105	71
38	71	6	36	38	67	38	40	57	80	106	74
39	65	13	41	36	73	31	48	63	69	104	79
40	67	15	41	33	79	31	54	70	89	101	72
41	72	13	39	38	74	31	46	66	83	105	74
42	69	0	31	41	66	40	41	59	82	110	73
43	67	9	38	40	72	35	45	63	69	102	74
44	69	4	30	38	71	37	44	63	78	110	72

45	67	3	31	45	64	38	37	57	78	105	76
46	66	11	38	35	70	32	47	63	68	103	79
47	68	11	33	40	65	41	40	58	86	105	75
48	77	12	38	33	72	35	43	61	90	107	74
49	69	7	33	36	71	38	43	61	84	111	72
50	66	6	40	38	71	35	45	63	81	106	75
Mean	**69.22**	**6.86**	**35.38**	**39.16**	**68.3**	**37.6**	**41.7**	**60.14**	**78.5**	**105.16**	**74.58**

Table 30. Cephalometric values - anterior open bite subjects

Patient number	Incisor separation	Anterior cranial base length	Anterior cranial base inclination	Anterior maxillary position	Posterior maxillary position	Anterior mandibular position	Posterior mandibular position	Point A position	Point B position	Interalveolar angle	Apex of the maxillary triangle	Apex of the mandibular triangle
1	1	63	17	38	42	73	43	42	65	101	100	64
2	1	64	6	39	36	68	45	43	63	82	106	66
3	2	65	13	40	41	72	38	42	64	96	103	70
4	2	68	3	33	45	62	52	37	57	106	100	68
5	2	67	10	40	40	75	43	42	76	109	101	66
6	2	65	12	43	40	75	42	47	67	81	99	64
7	2	68	12	38	39	68	42	42	62	96	102	70
8	2	63	17	40	44	73	42	44	64	85	96	67
9	2	65	8	37	44	72	45	42	63	99	89	64
10	2	73	8	38	40	67	40	41	60	81	103	73
11	2	72	9	34	38	67	37	39	59	85	108	76
12	2	71	14	39	39	72	42	44	63	87	84	68
13	2	61	9	36	43	72	42	40	64	107	100	67
14	2	74	9	36	42	72	39	41	66	102	102	71
15	3	75	7	36	37	68	37	40	60	92	106	73
16	3	80	9	33	39	63	39	38	50	78	108	78
17	3	76	5	36	37	66	43	40	57	78	105	71
18	3	68	5	38	45	70	45	42	63	76	100	67
19	3	69	9	36	44	73	39	42	63	86	100	68

20	3	72	6	35	42	66	40	39	57	75	85	74
21	3	69	9	39	38	70	40	40	62	92	102	70
22	3	68	7	32	38	72	45	39	63	105	108	64
23	3	74	6	34	38	65	43	37	58	93	106	72
24	3	74	0	30	50	55	54	34	51	98	101	70
25	3	68	10	35	46	72	38	38	62	93	100	72
26	3	66	17	40	48	77	39	45	69	100	92	65
27	3	70	13	37	35	73	38	46	66	89	108	71
28	3	67	13	38	42	70	40	44	62	82	100	71
29	4	67	11	37	48	72	42	48	65	98	97	66
30	4	67	9	33	42	65	42	39	58	87	104	72
31	4	68	3	28	50	52	53	31	48	97	102	77
32	4	66	7	39	41	73	38	47	66	72	100	69
33	4	67	8	36	36	69	36	41	61	76	108	75
34	4	69	7	34	43	65	38	41	59	83	95	77
35	4	67	12	36	36	74	34	38	63	73	108	72
36	4	71	11	38	43	68	40	42	59	90	97	72
37	4	81	11	37	43	65	42	40	58	90	99	73
38	4	61	9	41	47	74	43	45	67	100	93	65
39	4	67	12	37	38	76	41	44	68	115	105	66
40	4	70	11	38	41	65	41	40	59	88	96	70
41	4	62	6	36	47	67	44	39	58	94	97	71
42	4	64	12	34	38	69	40	40	60	86	108	72
43	4	67	14	39	35	73	35	46	67	95	109	73
44	5	60	7	35	47	68	44	37	59	80	100	70

45	5	67	10	35	43	67	40	39	59	80	102	72
46	5	77	0	32	44	63	50	35	55	100	103	67
47	5	66	5	37	45	70	42	41	60	80	100	71
48	5	64	5	33	41	65	47	38	57	68	108	68
49	5	72	16	41	42	78	39	48	72	100	99	64
50	5	69	4	37	48	73	45	43	63	90	96	63
51	5	66	15	40	42	75	38	43	69	95	96	67
52	5	71	14	36	39	72	36	44	64	85	105	72
53	5	64	8	36	39	71	39	44	63	98	105	70
54	5	67	10	36	44	70	43	42	62	80	100	67
55	5	68	7	35	42	71	43	41	63	87	102	66
56	5	66	4	37	38	72	42	47	64	64	104	67
57	5	69	4	37	44	71	49	43	60	78	100	60
58	6	77	10	40	37	76	36	47	67	90	103	68
59	6	67	8	36	40	72	34	43	65	81	104	74
60	6	72	8	37	40	73	41	44	65	82	105	71
61	6	69	12	34	41	73	41	43	64	75	106	67
62	6	68	12	38	44	75	37	41	66	97	99	67
63	6	76	6	33	41	69	39	39	60	94	106	74
64	6	76	6	27	42	62	37	35	57	82	110	80
65	6	77	11	87	42	72	42	46	67	95	103	67
66	6	74	10	35	39	65	43	40	59	70	107	72
67	6	67	12	33	42	68	43	37	59	70	104	70
68	6	73	-3	24	46	64	48	28	55	107	111	68
69	6	67	9	37	43	76	37	42	68	110	103	68

70	6	62	11	37	52	71	41	41	64	95	90	63
71	7	69	4	29	35	64	45	34	55	81	117	72
72	7	69	4	34	43	67	46	39	59	106	104	67
73	7	66	12	41	41	73	36	46	65	75	98	70
74	7	68	14	41	38	75	38	46	67	93	100	68
75	7	72	13	39	43	74	39	42	65	100	98	69
76	7	70	10	38	40	72	43	47	65	85	102	64
77	7	67	3	28	46	63	39	32	57	96	106	79
78	7	68	3	43	46	76	42	49	67	78	91	68
79	7	72	10	39	42	71	39	47	64	77	99	70
80	7	73	10	36	43	74	38	44	63	92	101	68
81	7	70	14	41	38	76	37	46	70	108	101	69
82	7	75	4	36	46	72	42	38	64	120	100	67
83	8	66	16	37	43	72	38	42	64	100	99	70
84	9	70	8	34	42	67	44	37	62	105	103	70
85	9	70	6	34	49	64	52	39	58	109	97	64
86	9	68	9	40	42	70	79	46	70	107	100	64
87	12	68	13	34	42	63	43	37	58	79	103	73
88	8	78	11	38	42	75	39	45	66	93	100	66
89	8	63	12	40	41	76	39	47	70	84	99	69
90	9	72	10	39	40	74	36	47	65	93	101	70
91	9	66	6	34	43	74	43	44	65	93	103	63
92	8	67	9	35	42	67	43	41	61	72	102	71
93	8	67	6	33	41	69	38	41	59	85	105	72
94	8	69	2	30	44	62	47	33	52	83	104	72

95	8	74	16	39	38	80	35	43	71	106	103	66
96	8	68	8	38	43	63	47	43	58	112	100	70
97	8	66	13	40	43	71	41	46	66	94	98	69
98	8	65	18	40	34	78	31	49	67	80	106	72
99	9	74	8	34	42	71	37	40	63	82	104	72
100	9	66	4	36	51	70	45	41	61	82	94	66
101	9	74	6	34	39	65	43	41	59	101	106	71
102	10	66	-3	33	43	64	43	37	56	103	104	74
103	11	72	8	32	38	63	42	44	67	102	86	66
104	13	66	2	32	44	68	41	39	59	74	106	71
105	17	70	6	31	45	61	42	33	55	87	103	79
Mean	**5.47**	**68.99**	**8.78**	**36.57**	**41.9**	**69.72**	**41.61**	**41.4**	**62.2**	**90.17**	**101.39**	**69.47**

Table 31. Cephalometric values - male anterior open bite subjects

Patient number	Incisor separation	Anterior cranial base length	Anterior cranial base inclination	Anterior maxillary position	Posterior maxillary position	Anterior mandibular position	Posterior mandibular position	Point A position	Point B position	Interalveolar angle	Apex of the maxillary triangle	Apex of the mandibular triangle
1	1	63	17	38	42	73	43	42	65	101	100	64
2	1	64	6	39	36	68	45	43	63	82	106	66
3	2	65	13	40	41	72	38	42	64	96	103	70
4	2	68	3	33	45	62	52	37	57	106	100	68
5	2	67	10	40	40	75	43	42	76	109	101	66
6	2	65	12	43	40	75	42	47	67	81	99	64
7	2	68	12	38	39	68	42	42	62	96	102	70
8	2	63	17	40	44	73	42	44	64	85	96	67
9	2	65	8	37	44	72	45	42	63	99	89	64
10	3	74	0	30	50	55	54	34	51	98	101	70
11	3	68	10	35	46	72	38	38	62	93	100	72
12	3	66	17	40	48	77	39	45	69	100	92	65
13	3	70	13	37	35	73	38	46	66	89	108	71
14	3	67	13	38	42	70	40	44	62	82	100	71
15	4	67	11	37	48	72	42	48	65	98	97	66
16	4	67	9	33	42	65	42	39	58	87	104	72
17	4	68	3	28	50	52	53	31	48	97	102	77
18	4	66	7	39	41	73	38	47	66	72	100	69
19	4	67	8	36	36	69	36	41	61	76	108	75

20	5	67	10	35	43	67	40	39	59	80	102	72
21	5	77	0	32	44	63	50	35	55	100	103	67
22	5	66	5	37	45	70	42	41	60	80	100	71
23	5	64	5	33	41	65	47	38	57	68	108	68
24	5	72	16	41	42	78	39	48	72	100	99	64
25	5	69	4	37	48	73	45	43	63	90	96	63
26	5	66	15	40	42	75	38	43	69	95	96	67
27	6	77	11	87	42	72	42	46	67	95	103	67
28	6	74	10	35	39	65	43	40	59	70	107	72
29	6	67	12	33	42	68	43	37	59	70	104	70
30	6	73	-3	24	46	64	48	28	55	107	111	68
31	6	67	9	37	43	76	37	42	68	110	103	68
32	6	62	11	37	52	71	41	41	64	95	90	63
33	7	69	4	29	35	64	45	34	55	81	117	72
34	7	69	4	34	43	67	46	39	59	106	104	67
35	7	66	12	41	41	73	36	46	65	75	98	70
36	7	68	14	41	38	75	38	46	67	93	100	68
37	8	69	2	30	44	62	47	33	52	83	104	72
38	8	74	16	39	38	80	35	43	71	106	103	66
39	8	68	8	38	43	63	47	43	58	112	100	70
40	8	66	13	40	43	71	41	46	66	94	98	69
41	8	65	18	40	34	78	31	49	67	80	106	72
42	9	74	8	34	42	71	37	40	63	82	104	72
43	9	66	4	36	51	70	45	41	61	82	94	66
44	9	74	6	34	39	65	43	41	59	101	106	71

45	10	66	-3	33	43	64	43	37	56	103	104	74
46	17	70	6	31	45	61	42	33	55	87	103	79
Mean	**5.29**	**68.11**	**8.83**	**37.15**	**42.54**	**69.28**	**42.24**	**41**	**61.96**	**91.13**	**101.54**	**69.02**

Table 32. Cephalometric values - female anterior open bite subjects

Patient number	Incisor separation	Anterior cranial base length	Anterior cranial base inclination	Anterior maxillary position	Posterior maxillary position	Anterior mandibular position	Posterior mandibular position	Point A position	Point B position	Interalveolar angle	Apex of the maxillary triangle	Apex of the mandibular triangle
1	2	73	8	38	40	67	40	41	60	81	103	73
2	2	72	9	34	38	67	37	39	59	85	108	76
3	2	71	14	39	39	72	42	44	63	87	84	68
4	2	61	9	36	43	72	42	40	64	107	100	67
5	2	74	9	36	42	72	39	41	66	102	102	71
6	3	75	7	36	37	68	37	40	60	92	106	73
7	3	80	9	33	39	63	39	38	50	78	108	78
8	3	76	5	36	37	66	43	40	57	78	105	71
9	3	68	5	38	45	70	45	42	63	76	100	67
10	3	69	9	36	44	73	39	42	63	86	100	68
11	3	72	6	35	42	66	40	39	57	75	85	74
12	3	69	9	39	38	70	40	40	62	92	102	70
13	3	68	7	32	38	72	45	39	63	105	108	64
14	3	74	6	34	38	65	43	37	58	93	106	72
15	4	69	7	34	43	65	38	41	59	83	95	77
16	4	67	12	36	36	74	34	38	63	73	108	72
17	4	71	11	38	43	68	40	42	59	90	97	72

18	4	81	11	37	43	65	42	40	58	90	99	73
19	4	61	9	41	47	74	43	45	67	100	93	65
20	4	67	12	37	38	76	41	44	68	115	105	66
21	4	70	11	38	41	65	41	40	59	88	96	70
22	4	62	6	36	47	67	44	39	58	94	97	71
23	4	64	12	34	38	69	40	40	60	86	108	72
24	4	67	14	39	35	73	35	46	67	95	109	73
25	5	60	7	35	47	68	44	37	59	80	100	70
26	5	71	14	36	39	72	36	44	64	85	105	72
27	5	64	8	36	39	71	39	44	63	98	105	70
28	5	67	10	36	44	70	43	42	62	80	100	67
29	5	68	7	35	42	71	43	41	63	87	102	66
30	5	66	4	37	38	72	42	47	64	64	104	67
31	5	69	4	37	44	71	49	43	60	78	100	60
32	6	77	10	40	37	76	36	47	67	90	103	68
33	6	67	8	36	40	72	34	43	65	81	104	74
34	6	72	8	37	40	73	41	44	65	82	105	71
35	6	69	12	34	41	73	41	43	64	75	106	67
36	6	68	12	38	44	75	37	41	66	97	99	67
37	6	76	6	33	41	69	39	39	60	94	106	74
38	6	76	6	27	42	62	37	35	57	82	110	80
39	7	70	10	38	40	72	43	47	65	85	102	64
40	7	67	3	28	46	63	39	32	57	96	106	79
41	7	68	3	43	46	76	42	49	67	78	91	68
42	7	72	10	39	42	71	39	47	64	77	99	70

43	7	73	10	36	43	74	38	44	63	92	101	68
44	7	70	14	41	38	76	37	46	70	108	101	69
45	7	72	13	39	43	74	39	42	65	100	98	69
46	7	75	4	36	46	72	42	38	64	120	100	67
47	8	66	16	37	43	72	38	42	64	100	99	70
48	8	67	9	35	42	67	43	41	61	72	102	71
49	8	67	6	33	41	69	38	41	59	85	105	72
50	8	78	11	38	42	75	39	45	66	93	100	66
51	8	63	12	40	41	76	39	47	70	84	99	69
52	9	70	8	34	42	67	44	37	62	105	103	70
53	9	70	6	34	49	64	52	39	58	109	97	64
54	9	68	9	40	42	70	79	46	70	107	100	64
55	9	72	10	39	40	74	36	47	65	93	101	70
56	9	66	6	34	43	74	43	44	65	93	103	63
57	11	72	8	32	38	63	42	44	67	102	86	66
58	12	68	13	34	42	63	43	37	58	79	103	73
59	13	66	2	32	44	68	41	39	59	74	106	71
Mean	**5.61**	**69.68**	**8.75**	**36.12**	**41.39**	**70.07**	**41.12**	**41.71**	**62.39**	**89.42**	**101.27**	**69.81**

Table 33. Cephalometric values - mild anterior open bite subjects

Patient number	Incisor separation	Anterior cranial base length	Anterior cranial base inclination	Anterior maxillary position	Posterior maxillary position	Anterior mandibular position	Posterior mandibular position	Point A position	Point B position	Interalveolar angle	Apex of the maxillary triangle	Apex of the mandibular triangle
1	1	63	17	38	42	73	43	42	65	101	100	64
2	1	64	6	39	36	68	45	43	63	82	106	66
3	2	65	13	40	41	72	38	42	64	96	103	70
4	2	68	3	33	45	62	52	37	57	106	100	68
5	2	67	10	40	40	75	43	42	76	109	101	66
6	2	65	12	43	40	75	42	47	67	81	99	64
7	2	68	12	38	39	68	42	42	62	96	102	70
8	2	63	17	40	44	73	42	44	64	85	96	67
9	2	65	8	37	44	72	45	42	63	99	89	64
10	2	73	8	38	40	67	40	41	60	81	103	73
11	2	72	9	34	38	67	37	39	59	85	108	76
12	2	71	14	39	39	72	42	44	63	87	84	68
13	2	61	9	36	43	72	42	40	64	107	100	67
14	2	74	9	36	42	72	39	41	66	102	102	71
15	3	75	7	36	37	68	37	40	60	92	106	73
16	3	80	9	33	39	63	39	38	50	78	108	78
17	3	76	5	36	37	66	43	40	57	78	105	71
18	3	68	5	38	45	70	45	42	63	76	100	67
19	3	69	9	36	44	73	39	42	63	86	100	68

20	3	72	6	35	42	66	40	39	57	75	85	74
21	3	69	9	39	38	70	40	40	62	92	102	70
22	3	68	7	32	38	72	45	39	63	105	108	64
23	3	74	6	34	38	65	43	37	58	93	106	72
24	3	74	0	30	50	55	54	34	51	98	101	70
25	3	68	10	35	46	72	38	38	62	93	100	72
26	3	66	17	40	48	77	39	45	69	100	92	65
27	3	70	13	37	35	73	38	46	66	89	108	71
28	3	67	13	38	42	70	40	44	62	82	100	71
Mean	**2.41**	**69.11**	**9.39**	**36.79**	**41.14**	**69.57**	**41.86**	**41.07**	**62**	**91.21**	**100.5**	**69.29**

Table 34. Cephalometric values - mild anterior open bite subjects (males)

Patient number	Incisor separation	Anterior cranial base length	Anterior cranial base inclination	Anterior maxillary position	Posterior maxillary position	Anterior mandibular position	Posterior mandibular position	Point A position	Point B position	Interalveolar angle	Apex of the maxillary triangle	Apex of the mandibular triangle
1	1	63	17	38	42	73	43	42	65	101	100	64
2	1	64	6	39	36	68	45	43	63	82	106	66
3	2	65	13	40	41	72	38	42	64	96	103	70
4	2	68	3	33	45	62	52	37	57	106	100	68
5	2	67	10	40	40	75	43	42	76	109	101	66
6	2	65	12	43	40	75	42	47	67	81	99	64
7	2	68	12	38	39	68	42	42	62	96	102	70
8	2	63	17	40	44	73	42	44	64	85	96	67
9	2	65	8	37	44	72	45	42	63	99	89	64
10	3	74	0	30	50	55	54	34	51	98	101	70
11	3	68	10	35	46	72	38	38	62	93	100	72
12	3	66	17	40	48	77	39	45	69	100	92	65
13	3	70	13	37	35	73	38	46	66	89	108	71
14	3	67	13	38	42	70	40	44	62	82	100	71
Mean	**2.18**	**66.64**	**10.79**	**37.71**	**42.29**	**70.36**	**42.93**	**42**	**63.64**	**94.07**	**99.79**	**67.71**

Table 35. Cephalometric values - mild anterior open bite subjects (females)

Patient number	Incisor separation	Anterior cranial base length	Anterior cranial base inclination	Anterior maxillary position	Posterior maxillary position	Anterior mandibular position	Posterior mandibular position	Point A position	Point B position	Interalveolar angle	Apex of the maxillary triangle	Apex of the mandibular triangle
1	2	73	8	38	40	67	40	41	60	81	103	73
2	2	72	9	34	38	67	37	39	59	85	108	76
3	2	71	14	39	39	72	42	44	63	87	84	68
4	2	61	9	36	43	72	42	40	64	107	100	67
5	2	74	9	36	42	72	39	41	66	102	102	71
6	3	75	7	36	37	68	37	40	60	92	106	73
7	3	80	9	33	39	63	39	38	50	78	108	78
8	3	76	5	36	37	66	43	40	57	78	105	71
9	3	68	5	38	45	70	45	42	63	76	100	67
10	3	69	9	36	44	73	39	42	63	86	100	68
11	3	72	6	35	42	66	40	39	57	75	85	74
12	3	69	9	39	38	70	40	40	62	92	102	70
13	3	68	7	32	38	72	45	39	63	105	108	64
14	3	74	6	34	38	65	43	37	58	93	106	72
Mean	**2.64**	**71.57**	**8**	**35.86**	**40**	**68.79**	**40.79**	**40.14**	**60.36**	**88.36**	**101.21**	**70.86**

Table 36. Cephalometric values - moderate anterior open bite subjects

Patient number	Incisor separation	Anterior cranial base length	Anterior cranial base inclination	Anterior maxillary position	Posterior maxillary position	Anterior mandibular position	Posterior mandibular position	Point A position	Point B position	Interalveolar angle	Apex of the maxillary triangle	Apex of the mandibular triangle
1	4	67	11	37	48	72	42	48	65	98	97	66
2	4	67	9	33	42	65	42	39	58	87	104	72
3	4	68	3	28	50	52	53	31	48	97	102	77
4	4	66	7	39	41	73	38	47	66	72	100	69
5	4	67	8	36	36	69	36	41	61	76	108	75
6	4	69	7	34	43	65	38	41	59	83	95	77
7	4	67	12	36	36	74	34	38	63	73	108	72
8	4	71	11	38	43	68	40	42	59	90	97	72
9	4	81	11	37	43	65	42	40	58	90	99	73
10	4	61	9	41	47	74	43	45	67	100	93	65
11	4	67	12	37	38	76	41	44	68	115	105	66
12	4	70	11	38	41	65	41	40	59	88	96	70
13	4	62	6	36	47	67	44	39	58	94	97	71
14	4	64	12	34	38	69	40	40	60	86	108	72
15	4	67	14	39	35	73	35	46	67	95	109	73
16	5	60	7	35	47	68	44	37	59	80	100	70

17	5	67	10	35	43	67	40	39	59	80	102	72
18	5	77	0	32	44	63	50	35	55	100	103	67
19	5	66	5	37	45	70	42	41	60	80	100	71
20	5	64	5	33	41	65	47	38	57	68	108	68
21	5	72	16	41	42	78	39	48	72	100	99	64
22	5	69	4	37	48	73	45	43	63	90	96	63
23	5	66	15	40	42	75	38	43	69	95	96	67
24	5	71	14	36	39	72	36	44	64	85	105	72
25	5	64	8	36	39	71	39	44	63	98	105	70
26	5	67	10	36	44	70	43	42	62	80	100	67
27	5	68	7	35	42	71	43	41	63	87	102	66
28	5	66	4	37	38	72	42	47	64	64	104	67
29	5	69	4	37	44	71	49	43	60	78	100	60
30	6	77	10	40	37	76	36	47	67	90	103	68
31	6	67	8	36	40	72	34	43	65	81	104	74
32	6	72	8	37	40	73	41	44	65	82	105	71
33	6	69	12	34	41	73	41	43	64	75	106	67
34	6	68	12	38	44	75	37	41	66	97	99	67
35	6	76	6	33	41	69	39	39	60	94	106	74
36	6	76	6	27	42	62	37	35	57	82	110	80
37	6	77	11	87	42	72	42	46	67	95	103	67
38	6	74	10	35	39	65	43	40	59	70	107	72
39	6	67	12	33	42	68	43	37	59	70	104	70
40	6	73	-3	24	46	64	48	28	55	107	111	68
41	6	67	9	37	43	76	37	42	68	110	103	68

42	6	62	11	37	52	71	41	41	64	95	90	63
Mean	**4.95**	**68.69**	**8.67**	**36.86**	**42.26**	**69.74**	**41.07**	**41.24**	**61.95**	**87.55**	**102.12**	**69.6**

Table 37. Cephalometric values - moderate anterior open bite subjects (males)

Patient number	Incisor separation	Anterior cranial base length	Anterior cranial base inclination	Anterior maxillary position	Posterior maxillary position	Anterior mandibular position	Posterior mandibular position	Point A position	Point B position	Interalveolar angle	Apex of the maxillary triangle	Apex of the mandibular triangle
1	4	67	11	37	48	72	42	48	65	98	97	66
2	4	67	9	33	42	65	42	39	58	87	104	72
3	4	68	3	28	50	52	53	31	48	97	102	77
4	4	66	7	39	41	73	38	47	66	72	100	69
5	4	67	8	36	36	69	36	41	61	76	108	75
6	5	67	10	35	43	67	40	39	59	80	102	72
7	5	77	0	32	44	63	50	35	55	100	103	67
8	5	66	5	37	45	70	42	41	60	80	100	71
9	5	64	5	33	41	65	47	38	57	68	108	68
10	5	72	16	41	42	78	39	48	72	100	99	64
11	5	69	4	37	48	73	45	43	63	90	96	63
12	5	66	15	40	42	75	38	43	69	95	96	67
13	6	77	11	87	42	72	42	46	67	95	103	67
14	6	74	10	35	39	65	43	40	59	70	107	72
15	6	67	12	33	42	68	43	37	59	70	104	70
16	6	73	-3	24	46	64	48	28	55	107	111	68
17	6	67	9	37	43	76	37	42	68	110	103	68
18	6	62	11	37	52	71	41	41	64	95	90	63
Mean	**5.06**	**68.67**	**7.94**	**37.83**	**43.67**	**68.78**	**42.56**	**40.39**	**61.39**	**88.33**	**101.83**	**68.83**

Table 38. Cephalometric values - moderate anterior open bite subjects (females)

Patient number	Incisor separation	Anterior cranial base length	Anterior cranial base inclination	Anterior maxillary position	Posterior maxillary position	Anterior mandibular position	Posterior mandibular position	Point A position	Point B position	Interalveolar angle	Apex of the maxillary triangle	Apex of the mandibular triangle
1	4	69	7	34	43	65	38	41	59	83	95	77
2	4	67	12	36	36	74	34	38	63	73	108	72
3	4	71	11	38	43	68	40	42	59	90	97	72
4	4	81	11	37	43	65	42	40	58	90	99	73
5	4	61	9	41	47	74	43	45	67	100	93	65
6	4	67	12	37	38	76	41	44	68	115	105	66
7	4	70	11	38	41	65	41	40	59	88	96	70
8	4	62	6	36	47	67	44	39	58	94	97	71
9	4	64	12	34	38	69	40	40	60	86	108	72
10	4	67	14	39	35	73	35	46	67	95	109	73
11	5	60	7	35	47	68	44	37	59	80	100	70
12	5	71	14	36	39	72	36	44	64	85	105	72
13	5	64	8	36	39	71	39	44	63	98	105	70
14	5	67	10	36	44	70	43	42	62	80	100	67
15	5	68	7	35	42	71	43	41	63	87	102	66
16	5	66	4	37	38	72	42	47	64	64	104	67

17	5	69	4	37	44	71	49	43	60	78	100	60
18	6	77	10	40	37	76	36	47	67	90	103	68
19	6	67	8	36	40	72	34	43	65	81	104	74
20	6	72	8	37	40	73	41	44	65	82	105	71
21	6	69	12	34	41	73	41	43	64	75	106	67
22	6	68	12	38	44	75	37	41	66	97	99	67
23	6	76	6	33	41	69	39	39	60	94	106	74
24	6	76	6	27	42	62	37	35	57	82	110	80
Mean	**4.88**	**68.71**	**9.21**	**36.13**	**41.21**	**70.46**	**39.96**	**41.88**	**62.38**	**86.96**	**102.33**	**70.17**

Table 39. Cephalometric values - severe anterior open bite subjects

Patient number	**Incisor separation**	**Anterior cranial base length**	**Anterior cranial base inclination**	**Anterior maxillary position**	**Posterior maxillary position**	**Anterior mandibular position**	**Posterior mandibular position**	**Point A position**	**Point B position**	**Interalveolar angle**	**Apex of the maxillary triangle**	**Apex of the mandibular triangle**
1	7	69	4	29	35	64	45	34	55	81	117	72
2	7	69	4	34	43	67	46	39	59	106	104	67
3	7	66	12	41	41	73	36	46	65	75	98	70
4	7	68	14	41	38	75	38	46	67	93	100	68
5	7	72	13	39	43	74	39	42	65	100	98	69
6	7	70	10	38	40	72	43	47	65	85	102	64
7	7	67	3	28	46	63	39	32	57	96	106	79
8	7	68	3	43	46	76	42	49	67	78	91	68
9	7	72	10	39	42	71	39	47	64	77	99	70
10	7	73	10	36	43	74	38	44	63	92	101	68
11	7	70	14	41	38	76	37	46	70	108	101	69
12	7	75	4	36	46	72	42	38	64	120	100	67
13	8	66	16	37	43	72	38	42	64	100	99	70
14	9	70	8	34	42	67	44	37	62	105	103	70
15	9	70	6	34	49	64	52	39	58	109	97	64
16	9	68	9	40	42	70	79	46	70	107	100	64
17	12	68	13	34	42	63	43	37	58	79	103	73

18	8	78	11	38	42	75	39	45	66	93	100	66
19	8	63	12	40	41	76	39	47	70	84	99	69
20	9	72	10	39	40	74	36	47	65	93	101	70
21	9	66	6	34	43	74	43	44	65	93	103	63
22	8	67	9	35	42	67	43	41	61	72	102	71
23	8	67	6	33	41	69	38	41	59	85	105	72
24	8	69	2	30	44	62	47	33	52	83	104	72
25	8	74	16	39	38	80	35	43	71	106	103	66
26	8	68	8	38	43	63	47	43	58	112	100	70
27	8	66	13	40	43	71	41	46	66	94	98	69
28	8	65	18	40	34	78	31	49	67	80	106	72
29	9	74	8	34	42	71	37	40	63	82	104	72
30	9	66	4	36	51	70	45	41	61	82	94	66
31	9	74	6	34	39	65	43	41	59	101	106	71
32	10	66	-3	33	43	64	43	37	56	103	104	74
33	11	72	8	32	38	63	42	44	67	102	86	66
34	13	66	2	32	44	68	41	39	59	74	106	71
35	17	70	6	31	45	61	42	33	55	87	103	79
Mean	**8.54**	**69.26**	**8.43**	**36.06**	**42.06**	**69.83**	**42.06**	**41.86**	**62.66**	**92.49**	**101.23**	**69.46**

Table 40. Cephalometric values - severe anterior open bite subjects (males)

Patient number	Incisor separation	Anterior cranial base length	Anterior cranial base inclination	Anterior maxillary position	Posterior maxillary position	Anterior mandibular position	Posterior mandibular position	Point A position	Point B position	Interalveolar angle	Apex of the maxillary triangle	Apex of the mandibular triangle
1	7	69	4	29	35	64	45	34	55	81	117	72
2	7	69	4	34	43	67	46	39	59	106	104	67
3	7	66	12	41	41	73	36	46	65	75	98	70
4	7	68	14	41	38	75	38	46	67	93	100	68
5	8	69	2	30	44	62	47	33	52	83	104	72
6	8	74	16	39	38	80	35	43	71	106	103	66
7	8	68	8	38	43	63	47	43	58	112	100	70
8	8	66	13	40	43	71	41	46	66	94	98	69
9	8	65	18	40	34	78	31	49	67	80	106	72
10	9	74	8	34	42	71	37	40	63	82	104	72
11	9	66	4	36	51	70	45	41	61	82	94	66
12	9	74	6	34	39	65	43	41	59	101	106	71
13	10	66	-3	33	43	64	43	37	56	103	104	74
14	10	70	6	31	45	61	42	33	55	87	103	79
Mean	**8.21**	**68.86**	**8**	**35.71**	**41.36**	**68.86**	**41.14**	**40.79**	**61**	**91.79**	**102.93**	**70.57**

Table 41. Cephalometric values - severe anterior open bite subjects (females)

Patient number	Incisor separation	Anterior cranial base length	Anterior cranial base inclination	Anterior maxillary position	Posterior maxillary position	Anterior mandibular position	Posterior mandibular position	Point A position	Point B position	Interalveolar angle	Apex of the maxillary triangle	Apex of the mandibular triangle
1	7	70	10	38	40	72	43	47	65	85	102	64
2	7	67	3	28	46	63	39	32	57	96	106	79
3	7	68	3	43	46	76	42	49	67	78	91	68
4	7	72	10	39	42	71	39	47	64	77	99	70
5	7	73	10	36	43	74	38	44	63	92	101	68
6	7	70	14	41	38	76	37	46	70	108	101	69
7	7	72	13	39	43	74	39	42	65	100	98	69
8	7	75	4	36	46	72	42	38	64	120	100	67
9	8	66	16	37	43	72	38	42	64	100	99	70
10	8	67	9	35	42	67	43	41	61	72	102	71
11	8	67	6	33	41	69	38	41	59	85	105	72
12	8	78	11	38	42	75	39	45	66	93	100	66
13	8	63	12	40	41	76	39	47	70	84	99	69
14	9	70	8	34	42	67	44	37	62	105	103	70
15	9	70	6	34	49	64	52	39	58	109	97	64
16	9	68	9	40	42	70	79	46	70	107	100	64
17	9	72	10	39	40	74	36	47	65	93	101	70
18	11	66	6	34	43	74	43	44	65	93	103	63

19	12	72	8	32	38	63	42	44	67	102	86	66
20	13	68	13	34	42	63	43	37	58	79	103	73
21	17	66	2	32	44	68	41	39	59	74	106	71
Mean	**8.81**	**69.52**	**8.71**	**36.29**	**42.52**	**70.48**	**42.67**	**42.57**	**63.76**	**92.95**	**100.1**	**68.71**

Statistical analyses

28 Mar 2007, 11:27:03

```
. for var  inc_sep -  mand_trgle: table  sex if  group == 1, c(N X mean X sd X) format(%9.2f) row col

->  table sex if group == 1, c(N inc_sep mean inc_sep sd inc_sep) format(%9.2f) row col

-------------------------------------------------------
      Sex |    N(inc_sep)  mean(inc_sep)    sd(inc_sep)
----------+--------------------------------------------
     Male |             0
   Female |             0
          |
    Total |             0
```

```
->  table sex if group == 1, c(N cran_lnth mean cran_lnth sd cran_lnth) format(%9.2f) row col

----------------------------------------------------------
      Sex |    N(cran_l~h)  mean(cran_l~h)    sd(cran_l~h)
----------+-----------------------------------------------
     Male |             50           69.10            4.21
   Female |             50           69.22            4.18
          |
    Total |            100           69.16            4.17
```

```
->  table sex if group == 1, c(N cran_angle mean cran_angle sd cran_angle) format(%9.2f) row col

----------------------------------------------------------
      Sex |    N(cran_a~e)  mean(cran_a~e)    sd(cran_a~e)
----------+-----------------------------------------------
     Male |             50            7.56            4.19
   Female |             50            6.86            3.88
          |
    Total |            100            7.21            4.03
```

```
->  table sex if group == 1, c(N ant_max mean ant_max sd ant_max) format(%9.2f) row col

-------------------------------------------------------
      Sex |    N(ant_max)  mean(ant_max)    sd(ant_max)
----------+--------------------------------------------
     Male |            50          35.62           4.30
   Female |            50          35.38           3.90
          |
    Total |           100          35.50           4.09
```

```
->  table sex if group == 1, c(N post_max mean post_max sd post_max) format(%9.2f) row col

----------------------------------------------------------
      Sex |    N(post_max)  mean(post_max)    sd(post_max)
----------+-----------------------------------------------
     Male |             50           39.22            3.44
   Female |             50           39.16            4.15
          |
    Total |            100           39.19            3.79
```

```
->  table sex if group == 1, c(N ant_mand mean ant_mand sd ant_mand) format(%9.2f) row col

----------------------------------------------------------
      Sex |    N(ant_mand)  mean(ant_mand)    sd(ant_mand)
----------+-----------------------------------------------
     Male |             50           68.90            5.03
   Female |             50           68.30            5.03
          |
    Total |            100           68.60            5.01
```

```
->  table sex if group == 1, c(N post_mand mean post_mand sd post_mand) format(%9.2f) row col

----------------------------------------------------------
      Sex |    N(post_m~d)  mean(post_m~d)    sd(post_m~d)
----------+-----------------------------------------------
     Male |             50           36.98            4.92
   Female |             50           37.60            4.11
          |
    Total |            100           37.29            4.52
```

```
->  table sex if group == 1, c(N point_a mean point_a sd point_a) format(%9.2f) row col

-------------------------------------------------------
      Sex |    N(point_a)  mean(point_a)    sd(point_a)
----------+--------------------------------------------
     Male |            50          42.34           5.00
   Female |            50          41.70           4.84
          |
    Total |           100          42.02           4.91
```

```
->  table sex if group == 1, c(N point_b mean point_b sd point_b) format(%9.2f) row col

-------------------------------------------------------
      Sex |    N(point_b)  mean(point_b)    sd(point_b)
----------+--------------------------------------------
     Male |            50          60.50           4.69
   Female |            50          60.14           4.25
          |
    Total |           100          60.32           4.46
```

```
->  table sex if group == 1, c(N alv_angle mean alv_angle sd alv_angle) format(%9.2f) row col

----------------------------------------------------------
      Sex |    N(alv_an~e)  mean(alv_an~e)    sd(alv_an~e)
----------+-----------------------------------------------
     Male |             50           79.14            7.99
   Female |             50           78.50            8.42
          |
    Total |            100           78.82            8.17
```

```
->  table sex if group == 1, c(N max_trgle mean max_trgle sd max_trgle) format(%9.2f) row col

----------------------------------------------------------
      Sex |    N(max_tr~e)  mean(max_tr~e)    sd(max_tr~e)
----------+-----------------------------------------------
     Male |             50          105.14            3.34
   Female |             50          105.16            3.58
          |
    Total |            100          105.15            3.44
```

```
->  table sex if group == 1, c(N mand_trgle mean mand_trgle sd mand_trgle) format(%9.2f) row col

----------------------------------------------------------
      Sex |    N(mand_t~e)  mean(mand_t~e)    sd(mand_t~e)
----------+-----------------------------------------------
     Male |             50           74.70            2.83
   Female |             50           74.58            2.91
          |
    Total |            100           74.64            2.86
```

```
. for var  inc_sep -  mand_trgle: table  grade sex if  group == 2, c(N X mean X sd X) format(%9.2f) row col

->  table grade sex if group == 2, c(N inc_sep mean inc_sep sd inc_sep) format(%9.2f) row col

----------------------------------
          |          Sex
    Grade |   Male  Female   Total
----------+-----------------------
     Mild |     14      14      28
          |   2.18    2.64    2.41
          |   0.77    0.50    0.68
          |
 Moderate |     18      24      42
          |   5.06    4.88    4.95
          |   0.80    0.85    0.82
          |
   Severe |     14      21      35
          |   8.21    8.81    8.57
          |   1.05    2.54    2.08
          |
    Total |     46      59     105
          |   5.14    5.75    5.48
          |   2.53    2.93    2.77
```

```
->  table grade sex if group == 2, c(N cran_lnth mean cran_lnth sd cran_lnth) format(%9.2f) row col

----------------------------------
          |          Sex          
    Grade |   Male  Female   Total
----------+-----------------------
     Mild |     14      14      28
          |  66.64   71.57   69.11
          |   2.95    4.54    4.52
          | 
 Moderate |     18      24      42
          |  68.67   68.71   68.69
          |   4.21    5.09    4.68
          | 
   Severe |     14      21      35
          |  68.86   69.52   69.26
          |   3.16    3.50    3.34
          | 
    Total |     46      59     105
          |  68.11   69.68   68.99
          |   3.62    4.52    4.20
```

```
->  table grade sex if group == 2, c(N cran_angle mean cran_angle sd cran_angle) format(%9.2f) row c
> ol

----------------------------------
          |          Sex
    Grade |   Male  Female   Total
----------+-----------------------
     Mild |     14      14      28
          |  10.79    8.00    9.39
          |   5.13    2.32    4.16
          |
 Moderate |     18      24      42
          |   7.94    9.21    8.67
          |   4.92    2.95    3.91
          |
   Severe |     14      21      35
          |   8.00    8.71    8.43
          |   5.91    3.85    4.71
          |
    Total |     46      59     105
          |   8.83    8.75    8.78
          |   5.34    3.16    4.23
```

```
->  table grade sex if group == 2, c(N ant_max mean ant_max sd ant_max) format(%9.2f) row col

----------------------------------
          |           Sex
    Grade |   Male  Female   Total
----------+-----------------------
     Mild |     14      14      28
          |  37.71   35.86   36.79
          |   3.29    2.14    2.88
          |
 Moderate |     18      24      42
          |  37.83   36.13   36.86
          |  12.94    2.72    8.62
          |
   Severe |     14      21      35
          |  35.71   36.29   36.06
          |   4.16    3.62    3.80
          |
    Total |     46      59     105
          |  37.15   36.12   36.57
          |   8.51    2.92    6.03
```

```
->  table grade sex if group == 2, c(N post_max mean post_max sd post_max) format(%9.2f) row col

----------------------------------
          |          Sex
    Grade |   Male  Female   Total
----------+-----------------------
     Mild |     14      14      28
          |  42.29   40.00   41.14
          |   4.25    2.69    3.68
          |
 Moderate |     18      24      42
          |  43.67   41.21   42.26
          |   3.94    3.37    3.79
          |
   Severe |     14      21      35
          |  41.36   42.52   42.06
          |   4.36    2.66    3.43
          |
    Total |     46      59     105
          |  42.54   41.39   41.90
          |   4.19    3.09    3.64
```

```
->  table grade sex if group == 2, c(N ant_mand mean ant_mand sd ant_mand) format(%9.2f) row col
```

Grade	Sex: Male	Female	Total
Mild	14	14	28
	70.36	68.79	69.57
	5.77	3.19	4.65
Moderate	18	24	42
	68.78	70.46	69.74
	6.05	3.75	4.88
Severe	14	21	35
	68.86	70.48	69.83
	6.09	4.53	5.19
Total	46	59	105
	69.28	70.07	69.72
	5.89	3.93	4.88

```
->  table grade sex if group == 2, c(N post_mand mean post_mand sd post_mand) format(%9.2f) row col

----------------------------------
          |          Sex
    Grade |   Male  Female   Total
----------+-----------------------
     Mild |     14      14      28
          |  42.93   40.79   41.86
          |   4.91    2.61    4.01
          |
 Moderate |     18      24      42
          |  42.56   39.96   41.07
          |   4.59    3.64    4.23
          |
   Severe |     14      21      35
          |  41.14   42.67   42.06
          |   4.99    9.01    7.60
          |
    Total |     46      59     105
          |  42.24   41.12   41.61
          |   4.76    6.02    5.51
```

```
->  table grade sex if group == 2, c(N point_a mean point_a sd point_a) format(%9.2f) row col

----------------------------------
          |           Sex         
    Grade |   Male  Female   Total
----------+-----------------------
     Mild |     14      14      28
          |  42.00   40.14   41.07
          |   3.55    1.79    2.92
          | 
 Moderate |     18      24      42
          |  40.39   41.88   41.24
          |   5.42    3.07    4.25
          | 
   Severe |     14      21      35
          |  40.79   42.57   41.86
          |   5.15    4.37    4.70
          | 
    Total |     46      59     105
          |  41.00   41.71   41.40
          |   4.78    3.45    4.08
```

```
->  table grade sex if group == 2, c(N point_b mean point_b sd point_b) format(%9.2f) row col

----------------------------------
          |          Sex
    Grade |   Male  Female   Total
----------+-----------------------
     Mild |     14      14      28
          |  63.64   60.36   62.00
          |   5.64    4.05    5.10
          |
 Moderate |     18      24      42
          |  61.39   62.38   61.95
          |   5.94    3.37    4.61
          |
   Severe |     14      21      35
          |  61.00   63.76   62.66
          |   5.63    3.99    4.83
          |
    Total |     46      59     105
          |  61.96   62.39   62.20
          |   5.74    3.92    4.78
```

```
->  table grade sex if group == 2, c(N alv_angle mean alv_angle sd alv_angle) format(%9.2f) row col

----------------------------------
          |          Sex          
    Grade |   Male  Female   Total
----------+-----------------------
     Mild |     14      14      28
          |  94.07   88.36   91.21
          |   9.06   10.66   10.13
          | 
 Moderate |     18      24      42
          |  88.33   86.96   87.55
          |  13.37   10.47   11.66
          | 
   Severe |     14      21      35
          |  91.79   92.95   92.49
          |  11.96   13.09   12.48
          | 
    Total |     46      59     105
          |  91.13   89.42   90.17
          |  11.77   11.63   11.67
```

```
->  table grade sex if group == 2, c(N max_trgle mean max_trgle sd max_trgle) format(%9.2f) row col

----------------------------------
          |          Sex
    Grade |   Male  Female   Total
----------+-----------------------
     Mild |     14      14      28
          |  99.79  101.21  100.50
          |   4.93    7.68    6.37
          |
 Moderate |     18      24      42
          | 101.83  102.33  102.12
          |   5.12    4.69    4.82
          |
   Severe |     14      21      35
          | 102.93  100.10  101.23
          |   5.31    4.62    5.04
          |
    Total |     46      59     105
          | 101.54  101.27  101.39
          |   5.17    5.50    5.33
```

```
->  table grade sex if group == 2, c(N mand_trgle mean mand_trgle sd mand_trgle) format(%9.2f) row c
> ol

----------------------------------
          |          Sex          
    Grade |   Male  Female   Total
----------+-----------------------
     Mild |     14      14      28
          |  67.71   70.86   69.29
          |   2.92    3.84    3.71
          | 
 Moderate |     18      24      42
          |  68.83   70.17   69.60
          |   3.85    4.24    4.08
          | 
   Severe |     14      21      35
          |  70.57   68.71   69.46
          |   3.46    3.68    3.66
          | 
    Total |     46      59     105
          |  69.02   69.81   69.47
          |   3.58    3.98    3.81
```

```
. for var   cran_lnth -  mand_trgle: anova X   group sex  group*sex  \ table  group sex, c(n X mean X sd X) row col
format(%9.2f)


->  anova cran_lnth group sex group*sex

                           Number of obs =     205     R-squared     =  0.0184
                           Root MSE      = 4.17074     Adj R-squared =  0.0037

                  Source |  Partial SS    df       MS           F     Prob > F
              -----------+----------------------------------------------------
                   Model |  65.4845614     3  21.8281871       1.25     0.2911
                         |
                   group |  3.61489251     1  3.61489251       0.21     0.6490
                     sex |  36.2650517     1  36.2650517       2.08     0.1503
               group*sex |  26.6924726     1  26.6924726       1.53     0.2169
                         |
                Residual |  3496.41788   201  17.3951138
              -----------+----------------------------------------------------
                   Total |  3561.90244   204  17.4603061
```

```
->  table group sex, c(n cran_lnth mean cran_lnth sd cran_lnth) row col format(%9.2f)

----------------------------------
          |          Sex
    Group |   Male  Female   Total
----------+-----------------------
   Normal |     50      50     100
          |  69.10   69.22   69.16
          |   4.21    4.18    4.17
          |
      AOB |     46      59     105
          |  68.11   69.68   68.99
          |   3.62    4.52    4.20
          |
    Total |     96     109     205
          |  68.63   69.47   69.07
          |   3.95    4.35    4.18
```

```
->  anova cran_angle group sex group*sex

                          Number of obs =     205     R-squared     =  0.0386
                          Root MSE      = 4.14785     Adj R-squared =  0.0242

                 Source |  Partial SS    df       MS           F     Prob > F
             -----------+----------------------------------------------------
                  Model |  138.820961     3  46.2736537       2.69     0.0475
                        |
                  group |  126.246958     1  126.246958       7.34     0.0073
                    sex |  7.73820325     1  7.73820325       0.45     0.5032
              group*sex |   4.8799901     1   4.8799901       0.28     0.5949
                        |
               Residual |  3458.13514   201  17.2046524
             -----------+----------------------------------------------------
                  Total |   3596.9561   204  17.6321377
```

```
->  table group sex, c(n cran_angle mean cran_angle sd cran_angle) row col format(%9.2f)

----------------------------------
          |          Sex
    Group |   Male  Female   Total
----------+-----------------------
   Normal |     50      50     100
          |   7.56    6.86    7.21
          |   4.19    3.88    4.03
          |
      AOB |     46      59     105
          |   8.83    8.75    8.78
          |   5.34    3.16    4.23
          |
    Total |     96     109     205
          |   8.17    7.88    8.01
          |   4.79    3.62    4.20
```

```
->  anova ant_max group sex group*sex

                       Number of obs =     205     R-squared     =  0.0160
                       Root MSE      = 5.18497     Adj R-squared =  0.0013

              Source |  Partial SS    df       MS           F     Prob > F
          -----------+----------------------------------------------------
               Model |   87.847921     3  29.2826403       1.09     0.3547
                     |
               group |  65.5321746     1  65.5321746       2.44     0.1200
                 sex |  20.6114329     1  20.6114329       0.77     0.3823
           group*sex |   8.0023301     1   8.0023301       0.30     0.5860
                     |
            Residual |  5403.66427   201  26.8839019
          -----------+----------------------------------------------------
               Total |   5491.5122   204  26.9191774
```

```
->  table group sex, c(n ant_max mean ant_max sd ant_max) row col format(%9.2f)


----------------------------------
          |          Sex
    Group |   Male  Female   Total
----------+-----------------------
   Normal |     50      50     100
          |  35.62   35.38   35.50
          |   4.30    3.90    4.09
          |
      AOB |     46      59     105
          |  37.15   36.12   36.57
          |   8.51    2.92    6.03
          |
    Total |     96     109     205
          |  36.35   35.78   36.05
          |   6.66    3.41    5.19
```

```
->  anova post_max group sex group*sex

                       Number of obs =     205     R-squared     =  0.1290
                       Root MSE      = 3.70743     Adj R-squared =  0.1160

              Source |  Partial SS    df       MS           F     Prob > F
          -----------+----------------------------------------------------
               Model |  409.331107     3  136.443702       9.93     0.0000
                     |
               group |  391.916523     1  391.916523      28.51     0.0000
                 sex |   18.718681     1   18.718681       1.36     0.2446
           group*sex |  15.2000445     1  15.2000445       1.11     0.2942
                     |
            Residual |  2762.74694   201  13.7450097
          -----------+----------------------------------------------------
               Total |  3172.07805   204  15.5494022
```

```
->  table group sex, c(n post_max mean post_max sd post_max) row col format(%9.2f)

----------------------------------
          |           Sex
    Group |   Male  Female   Total
----------+-----------------------
   Normal |     50      50     100
          |  39.22   39.16   39.19
          |   3.44    4.15    3.79
          |
      AOB |     46      59     105
          |  42.54   41.39   41.90
          |   4.19    3.09    3.64
          |
    Total |     96     109     205
          |  40.81   40.37   40.58
          |   4.15    3.76    3.94
```

-

```
>  anova ant_mand group sex group*sex

                        Number of obs =     205     R-squared     =  0.0178
                        Root MSE      = 4.95655     Adj R-squared =  0.0032

                  Source |  Partial SS    df       MS           F     Prob > F
              -----------+----------------------------------------------------
                   Model |  89.6231483     3  29.8743828       1.22     0.3050
                         |
                   group |  58.7666016     1  58.7666016       2.39     0.1235
                     sex |  .435828085     1  .435828085       0.02     0.8942
               group*sex |   24.384133     1   24.384133       0.99     0.3203
                         |
                Residual |   4938.0549   201  24.5674373
              -----------+----------------------------------------------------
                   Total |  5027.67805   204  24.6454806
```

```
->  table group sex, c(n ant_mand mean ant_mand sd ant_mand) row col format(%9.2f)

----------------------------------
          |          Sex
    Group |   Male  Female   Total
----------+-----------------------
   Normal |     50      50     100
          |  68.90   68.30   68.60
          |   5.03    5.03    5.01
          |
      AOB |     46      59     105
          |  69.28   70.07   69.72
          |   5.89    3.93    4.88
          |
    Total |     96     109     205
          |  69.08   69.26   69.18
          |   5.43    4.53    4.96
```

```
->  anova post_mand group sex group*sex

                      Number of obs =     205     R-squared     =  0.1627
                      Root MSE      =  5.0537     Adj R-squared =  0.1502

     Source |  Partial SS    df       MS           F     Prob > F
 -----------+----------------------------------------------------
      Model |  997.729724     3  332.576575      13.02     0.0000
            |
      group |  979.171515     1  979.171515      38.34     0.0000
        sex |  3.18327703     1  3.18327703       0.12     0.7244
  group*sex |  38.4973808     1  38.4973808       1.51     0.2210
            |
   Residual |  5133.51906   201  25.5398958
 -----------+----------------------------------------------------
      Total |  6131.24878   204  30.0551411
```

```
->  table group sex, c(n post_mand mean post_mand sd post_mand) row col format(%9.2f)

----------------------------------
          |          Sex
    Group |   Male  Female   Total
----------+-----------------------
   Normal |     50      50     100
          |  36.98   37.60   37.29
          |   4.92    4.11    4.52
          |
      AOB |     46      59     105
          |  42.24   41.12   41.61
          |   4.76    6.02    5.51
          |
    Total |     96     109     205
          |  39.50   39.50   39.50
          |   5.49    5.50    5.48
```

```
->  anova point_a group sex group*sex

                       Number of obs =     205     R-squared     =  0.0104
                       Root MSE      = 4.51191     Adj R-squared = -0.0044

              Source |  Partial SS    df       MS           F     Prob > F
          -----------+----------------------------------------------------
               Model |  43.0270856     3  14.3423619       0.70     0.5503
                     |
               group |  22.4168591     1  22.4168591       1.10     0.2953
                 sex |    .0656323     1    .0656323       0.00     0.9548
           group*sex |  23.2250254     1  23.2250254       1.14     0.2868
                     |
            Residual |  4091.82169   201  20.3573219
          -----------+----------------------------------------------------
               Total |  4134.84878   204  20.2688666
```

```
->  table group sex, c(n point_a mean point_a sd point_a) row col format(%9.2f)

----------------------------------
          |         Sex
    Group |   Male  Female   Total
----------+-----------------------
   Normal |     50      50     100
          |  42.34   41.70   42.02
          |   5.00    4.84    4.91
          |
      AOB |     46      59     105
          |  41.00   41.71   41.40
          |   4.78    3.45    4.08
          |
    Total |     96     109     205
          |  41.70   41.71   41.70
          |   4.92    4.13    4.50
```

```
->  anova point_b group sex group*sex

                           Number of obs =     205     R-squared     =  0.0418
                           Root MSE      =  4.6459     Adj R-squared =  0.0275

                  Source |  Partial SS    df       MS           F     Prob > F
              -----------+----------------------------------------------------
                   Model |  189.123302     3  63.0411007       2.92     0.0351
                         |
                   group |  174.575508     1  174.575508       8.09     0.0049
                     sex |  .068297025     1  .068297025       0.00     0.9552
               group*sex |  7.99787185     1  7.99787185       0.37     0.5434
                         |
                Residual |  4338.46694   201  21.5844126
              -----------+----------------------------------------------------
                   Total |  4527.59024   204  22.1940698
```

```
->  table group sex, c(n point_b mean point_b sd point_b) row col format(%9.2f)

----------------------------------
          |          Sex
    Group |   Male  Female   Total
----------+-----------------------
   Normal |     50      50     100
          |  60.50   60.14   60.32
          |   4.69    4.25    4.46
          |
      AOB |     46      59     105
          |  61.96   62.39   62.20
          |   5.74    3.92    4.78
          |
    Total |     96     109     205
          |  61.20   61.36   61.28
          |   5.24    4.21    4.71
```

```
->  anova alv_angle group sex group*sex

                       Number of obs =     205     R-squared     =  0.2443
                       Root MSE      = 10.1433     Adj R-squared =  0.2330

              Source |  Partial SS    df       MS           F     Prob > F
          -----------+----------------------------------------------------
               Model |   6685.4168     3  2228.47227      21.66     0.0000
                     |
               group |  6672.64392     1  6672.64392      64.85     0.0000
                 sex |  69.9853739     1  69.9853739       0.68     0.4105
           group*sex |  14.4603692     1  14.4603692       0.14     0.7081
                     |
            Residual |  20680.1442   201  102.886289
          -----------+----------------------------------------------------
               Total |   27365.561   204  134.144907

-
```

```
>  table group sex, c(n alv_angle mean alv_angle sd alv_angle) row col format(%9.2f)
```

Group	Sex: Male	Female	Total
Normal	50	50	100
	79.14	78.50	78.82
	7.99	8.42	8.17
AOB	46	59	105
	91.13	89.42	90.17
	11.77	11.63	11.67
Total	96	109	205
	84.89	84.41	84.63
	11.61	11.61	11.58

```
->  anova max_trgle group sex group*sex

                       Number of obs =     205     R-squared     =  0.1495
                       Root MSE      = 4.53281     Adj R-squared =  0.1368

              Source |  Partial SS    df       MS           F     Prob > F
          -----------+----------------------------------------------------
               Model |  725.863988     3  241.954663      11.78     0.0000
                     |
               group |  712.053211     1  712.053211      34.66     0.0000
                 sex |  .808902674     1  .808902674       0.04     0.8429
           group*sex |  1.08573354     1  1.08573354       0.05     0.8184
                     |
            Residual |  4129.81406   201  20.5463386
          -----------+----------------------------------------------------
               Total |  4855.67805   204  23.8023434
```

```
->  table group sex, c(n max_trgle mean max_trgle sd max_trgle) row col format(%9.2f)

----------------------------------
          |          Sex          
    Group |   Male  Female   Total
----------+-----------------------
   Normal |     50      50     100
          | 105.14  105.16  105.15
          |   3.34    3.58    3.44
          | 
      AOB |     46      59     105
          | 101.54  101.27  101.39
          |   5.17    5.50    5.33
          | 
    Total |     96     109     205
          | 103.42  103.06  103.22
          |   4.65    5.08    4.88
```

```
->  anova mand_trgle group sex group*sex

                          Number of obs =     205     R-squared     =  0.3760
                          Root MSE      = 3.38464     Adj R-squared =  0.3667

                 Source |  Partial SS    df       MS           F     Prob > F
              -----------+----------------------------------------------------
                  Model |  1387.37307     3  462.457691      40.37     0.0000
                        |
                  group |  1386.37909     1  1386.37909     121.02     0.0000
                    sex |   5.7358269     1   5.7358269       0.50     0.4800
              group*sex |  10.5659449     1  10.5659449       0.92     0.3380
                        |
               Residual |  2302.60741   201  11.4557583
              -----------+----------------------------------------------------
                  Total |  3689.98049   204  18.0881396
```

```
->  table group sex, c(n mand_trgle mean mand_trgle sd mand_trgle) row col format(%9.2f)
----------------------------------
          |          Sex
    Group |    Male  Female   Total
----------+-----------------------
   Normal |      50      50     100
          |   74.70   74.58   74.64
          |    2.83    2.91    2.86
          |
      AOB |      46      59     105
          |   69.02   69.81   69.47
          |    3.58    3.98    3.81
          |
    Total |      96     109     205
          |   71.98   72.00   71.99
          |    4.28    4.25    4.25
```

```
.  log close
       log:  C:\DATA_8\dawjee.log
  log type:  text
 closed on:  28 Mar 2007, 11:36:25
```

17 May 2007, 08:43:05

```
.  ttest  inc_sep = 0 if group == 2

One-sample t test

------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
 inc_sep |     105    5.480952    .2701515     2.76823    4.945232    6.016673
------------------------------------------------------------------------------
Degrees of freedom: 104

                            Ho: mean(inc_sep) = 0

     Ha: mean < 0              Ha: mean != 0              Ha: mean > 0
       t =  20.2884              t =  20.2884              t =  20.2884
   P < t =   1.0000          P > |t| =   0.0000          P > t =   0.0000
```

```
. for var  inc_sep -  mand_trgle: anova X  grade sex grade*sex if group == 2 \ test  _coef[grade[1]] = _coef[grade[2]] \ test
_coef[grade[1]] =  _coef[grade[3]] \ test  _coef[grade[2]] =  _coef[grade[3]] \ table  grade sex if group == 2, c(N X mean X sd
X) row col format(%9.2f)


->  anova inc_sep grade sex grade*sex if group == 2

                           Number of obs =     105     R-squared     =  0.7714
                           Root MSE      = 1.35655     Adj R-squared =  0.7599

                  Source |  Partial SS    df       MS           F     Prob > F
              -----------+----------------------------------------------------
                   Model |  614.779365     5  122.955873      66.82     0.0000
                         |
                   grade |  583.273192     2  291.636596     158.48     0.0000
                     sex |  2.15128694     1  2.15128694       1.17     0.2822
               grade*sex |   3.2293333     2  1.61466665       0.88     0.4191
                         |
                Residual |   182.18254    99  1.84022767
              -----------+----------------------------------------------------
                   Total |  796.961905   104  7.66309524
```

```
->  test _coef[grade[1]] = _coef[grade[2]]

 ( 1)  grade[1] - grade[2] = 0

       F(  1,    99) =   23.94
            Prob > F =    0.0000


->  test _coef[grade[1]] = _coef[grade[3]]

 ( 1)  grade[1] - grade[3] = 0

       F(  1,    99) =  173.58
            Prob > F =    0.0000


->  test _coef[grade[2]] = _coef[grade[3]]

 ( 1)  grade[2] - grade[3] = 0

       F(  1,    99) =   94.22
            Prob > F =    0.0000
```

```
->  table grade sex if group == 2, c(N inc_sep mean inc_sep sd inc_sep) row col format(%9.2f)

----------------------------------
          |           Sex
    Grade |   Male  Female   Total
----------+-----------------------
     Mild |     14      14      28
          |   2.18    2.64    2.41
          |   0.77    0.50    0.68
          |
 Moderate |     18      24      42
          |   5.06    4.88    4.95
          |   0.80    0.85    0.82
          |
   Severe |     14      21      35
          |   8.21    8.81    8.57
          |   1.05    2.54    2.08
          |
    Total |     46      59     105
          |   5.14    5.75    5.48
          |   2.53    2.93    2.77
----------------------------------
```

```
->  anova cran_lnth grade sex grade*sex if group == 2

                           Number of obs =     105     R-squared     =  0.0983
                           Root MSE      = 4.08811     Adj R-squared =  0.0528

                  Source |  Partial SS    df       MS           F     Prob > F
              -----------+----------------------------------------------------
                   Model |  180.436905     5   36.087381       2.16     0.0647
                         |
                   grade |  5.44200567     2  2.72100283       0.16     0.8500
                     sex |  88.4776046     1  88.4776046       5.29     0.0235
               grade*sex |  109.838319     2  54.9191595       3.29     0.0415
                         |
                Residual |  1654.55357    99  16.7126623
              -----------+----------------------------------------------------
                   Total |  1834.99048   104  17.6441392
```

```
->  test _coef[grade[1]] = _coef[grade[2]]

 ( 1)  grade[1] - grade[2] = 0

       F(  1,    99) =    4.34
            Prob > F =    0.0399


->  test _coef[grade[1]] = _coef[grade[3]]

 ( 1)  grade[1] - grade[3] = 0

       F(  1,    99) =    2.11
            Prob > F =    0.1498


->  test _coef[grade[2]] = _coef[grade[3]]

 ( 1)  grade[2] - grade[3] = 0

       F(  1,    99) =    0.45
            Prob > F =    0.5060
```

```
->  table grade sex if group == 2, c(N cran_lnth mean cran_lnth sd cran_lnth) row col format(%9.2f)

----------------------------------
          |          Sex
    Grade |   Male  Female   Total
----------+-----------------------
     Mild |     14      14      28
          |  66.64   71.57   69.11
          |   2.95    4.54    4.52
          |
 Moderate |     18      24      42
          |  68.67   68.71   68.69
          |   4.21    5.09    4.68
          |
   Severe |     14      21      35
          |  68.86   69.52   69.26
          |   3.16    3.50    3.34
          |
    Total |     46      59     105
          |  68.11   69.68   68.99
          |   3.62    4.52    4.20
----------------------------------
```

```
->  anova cran_angle grade sex grade*sex if group == 2

                           Number of obs =     105     R-squared     =  0.0485
                           Root MSE      = 4.23256     Adj R-squared =  0.0005

                  Source |  Partial SS    df       MS           F     Prob > F
              -----------+----------------------------------------------------
                   Model |  90.4162698     5   18.083254       1.01     0.4163
                         |
                   grade |  17.9437978     2  8.97189889       0.50     0.6076
                     sex |   1.8158489     1   1.8158489       0.10     0.7509
               grade*sex |  75.0279654     2  37.5139827       2.09     0.1286
                         |
                Residual |  1773.54563    99  17.9146024
              -----------+----------------------------------------------------
                   Total |   1863.9619   104  17.9227106
```

```
->  test _coef[grade[1]] = _coef[grade[2]]

 ( 1)  grade[1] - grade[2] = 0

       F(  1,    99) =    0.72
            Prob > F =    0.3980


->  test _coef[grade[1]] = _coef[grade[3]]

 ( 1)  grade[1] - grade[3] = 0

       F(  1,    99) =    0.24
            Prob > F =    0.6258


->  test _coef[grade[2]] = _coef[grade[3]]

 ( 1)  grade[2] - grade[3] = 0

       F(  1,    99) =    0.15
            Prob > F =    0.6969
```

```
->  table grade sex if group == 2, c(N cran_angle mean cran_angle sd cran_angle) row col format(%9.2f)

----------------------------------
          |          Sex
    Grade |   Male  Female   Total
----------+-----------------------
     Mild |     14      14      28
          |  10.79    8.00    9.39
          |   5.13    2.32    4.16
          |
 Moderate |     18      24      42
          |   7.94    9.21    8.67
          |   4.92    2.95    3.91
          |
   Severe |     14      21      35
          |   8.00    8.71    8.43
          |   5.91    3.85    4.71
          |
    Total |     46      59     105
          |   8.83    8.75    8.78
          |   5.34    3.16    4.23
----------------------------------
```

```
->  anova ant_max grade sex grade*sex if group == 2

                           Number of obs =     105     R-squared     =  0.0188
                           Root MSE      = 6.11905     Adj R-squared = -0.0308

                  Source |  Partial SS    df       MS           F     Prob > F
              -----------+----------------------------------------------------
                   Model |      70.875     5      14.175       0.38     0.8624
                         |
                   grade |  18.9727276     2  9.48636382       0.25     0.7767
                     sex |  24.9614246     1  24.9614246       0.67     0.4162
               grade*sex |  31.0461425     2  15.5230713       0.41     0.6618
                         |
                Residual |  3706.83929    99  37.4428211
              -----------+----------------------------------------------------
                   Total |  3777.71429   104  36.3241758
```

```
->  test _coef[grade[1]] = _coef[grade[2]]

 ( 1)  grade[1] - grade[2] = 0

       F(  1,    99) =    0.02
            Prob > F =    0.8967


->  test _coef[grade[1]] = _coef[grade[3]]

 ( 1)  grade[1] - grade[3] = 0

       F(  1,    99) =    0.04
            Prob > F =    0.8396


->  test _coef[grade[2]] = _coef[grade[3]]

 ( 1)  grade[2] - grade[3] = 0

       F(  1,    99) =    0.01
            Prob > F =    0.9301
```

```
->  table grade sex if group == 2, c(N ant_max mean ant_max sd ant_max) row col format(%9.2f)

----------------------------------
          |          Sex
    Grade |   Male  Female   Total
----------+-----------------------
     Mild |     14      14      28
          |  37.71   35.86   36.79
          |   3.29    2.14    2.88
          |
 Moderate |     18      24      42
          |  37.83   36.13   36.86
          |  12.94    2.72    8.62
          |
   Severe |     14      21      35
          |  35.71   36.29   36.06
          |   4.16    3.62    3.80
          |
    Total |     46      59     105
          |  37.15   36.12   36.57
          |   8.51    2.92    6.03
----------------------------------
```

```
->  anova post_max grade sex grade*sex if group == 2

                    Number of obs =     105     R-squared     =  0.0964
                    Root MSE      = 3.54376     Adj R-squared =  0.0507

      Source |  Partial SS    df       MS           F     Prob > F
  -----------+----------------------------------------------------
       Model |  132.579762     5  26.5159524       2.11     0.0703
             |
       grade |  27.9425618     2  13.9712809       1.11     0.3328
         sex |  35.6354578     1  35.6354578       2.84     0.0952
   grade*sex |  71.5700845     2  35.7850422       2.85     0.0626
             |
    Residual |  1243.26786    99  12.5582612
  -----------+----------------------------------------------------
       Total |  1375.84762   104   13.229304
```

```
->  test _coef[grade[1]] = _coef[grade[2]]

 ( 1)  grade[1] - grade[2] = 0

       F(  1,    99) =    1.03
            Prob > F =    0.3131


->  test _coef[grade[1]] = _coef[grade[3]]

 ( 1)  grade[1] - grade[3] = 0

       F(  1,    99) =    4.26
            Prob > F =    0.0416


->  test _coef[grade[2]] = _coef[grade[3]]

 ( 1)  grade[2] - grade[3] = 0

       F(  1,    99) =    1.54
            Prob > F =    0.2171
```

```
->  table grade sex if group == 2, c(N post_max mean post_max sd post_max) row col format(%9.2f)

----------------------------------
          |          Sex
    Grade |   Male  Female   Total
----------+-----------------------
     Mild |     14      14      28
          |  42.29   40.00   41.14
          |   4.25    2.69    3.68
          |
 Moderate |     18      24      42
          |  43.67   41.21   42.26
          |   3.94    3.37    3.79
          |
   Severe |     14      21      35
          |  41.36   42.52   42.06
          |   4.36    2.66    3.43
          |
    Total |     46      59     105
          |  42.54   41.39   41.90
          |   4.19    3.09    3.64
----------------------------------
```

```
->  anova ant_mand grade sex grade*sex if group == 2

                           Number of obs =     105     R-squared     =  0.0280
                           Root MSE      = 4.92939     Adj R-squared = -0.0210

                  Source |  Partial SS    df       MS           F     Prob > F
              -----------+----------------------------------------------------
                   Model |  69.3972222     5  13.8794444       0.57     0.7219
                         |
                   grade |  .139226566     2  .069613283       0.00     0.9971
                     sex |  8.31624353     1  8.31624353       0.34     0.5599
               grade*sex |  52.9589734     2  26.4794867       1.09     0.3403
                         |
                Residual |  2405.59325    99  24.2989218
              -----------+----------------------------------------------------
                   Total |  2474.99048   104  23.7979853
```

```
->  test _coef[grade[1]] = _coef[grade[2]]


 ( 1)  grade[1] - grade[2] = 0

       F(  1,    99) =    1.02
            Prob > F =    0.3154


->  test _coef[grade[1]] = _coef[grade[3]]

 ( 1)  grade[1] - grade[3] = 0

       F(  1,    99) =    0.99
            Prob > F =    0.3227


->  test _coef[grade[2]] = _coef[grade[3]]

 ( 1)  grade[2] - grade[3] = 0

       F(  1,    99) =    0.00
            Prob > F =    0.9904
```

```
->  table grade sex if group == 2, c(N ant_mand mean ant_mand sd ant_mand) row col format(%9.2f)

----------------------------------
          |          Sex
    Grade |   Male  Female   Total
----------+-----------------------
     Mild |     14      14      28
          |  70.36   68.79   69.57
          |   5.77    3.19    4.65
          |
 Moderate |     18      24      42
          |  68.78   70.46   69.74
          |   6.05    3.75    4.88
          |
   Severe |     14      21      35
          |  68.86   70.48   69.83
          |   6.09    4.53    5.19
          |
    Total |     46      59     105
          |  69.28   70.07   69.72
          |   5.89    3.93    4.88
----------------------------------
```

```
->  anova post_mand grade sex grade*sex if group == 2

                           Number of obs =     105     R-squared     =  0.0450
                           Root MSE      = 5.51497     Adj R-squared = -0.0032

                  Source |  Partial SS    df       MS           F     Prob > F
              -----------+----------------------------------------------------
                   Model |  141.921032     5  28.3842063       0.93     0.4629
                         |
                   grade |  9.70652356     2  4.85326178       0.16     0.8527
                     sex |   28.804273     1   28.804273       0.95     0.3328
               grade*sex |  88.4818824     2  44.2409412       1.45     0.2384
                         |
                Residual |  3011.06944    99  30.4148429
              -----------+----------------------------------------------------
                   Total |  3152.99048   104  30.3172161
```

```
->  test _coef[grade[1]] = _coef[grade[2]]

 ( 1)  grade[1] - grade[2] = 0

       F(  1,    99) =    0.20
            Prob > F =    0.6565


->  test _coef[grade[1]] = _coef[grade[3]]

 ( 1)  grade[1] - grade[3] = 0

       F(  1,    99) =    0.98
            Prob > F =    0.3253


->  test _coef[grade[2]] = _coef[grade[3]]

 ( 1)  grade[2] - grade[3] = 0

       F(  1,    99) =    2.70
            Prob > F =    0.1035
```

```
->  table grade sex if group == 2, c(N post_mand mean post_mand sd post_mand) row col format(%9.2f)

----------------------------------
          |          Sex
    Grade |   Male  Female   Total
----------+-----------------------
     Mild |     14      14      28
          |  42.93   40.79   41.86
          |   4.91    2.61    4.01
          |
 Moderate |     18      24      42
          |  42.56   39.96   41.07
          |   4.59    3.64    4.23
          |
   Severe |     14      21      35
          |  41.14   42.67   42.06
          |   4.99    9.01    7.60
          |
    Total |     46      59     105
          |  42.24   41.12   41.61
          |   4.76    6.02    5.51
----------------------------------
```

```
->  anova point_a grade sex grade*sex if group == 2

                           Number of obs =     105     R-squared     =  0.0491
                           Root MSE      = 4.08015     Adj R-squared =  0.0011

                  Source |  Partial SS    df       MS           F     Prob > F
              -----------+----------------------------------------------------
                   Model |  85.0829365     5  17.0165873       1.02     0.4088
                         |
                   grade |  7.43683237     2  3.71841619       0.22     0.8002
                     sex |  5.57275498     1  5.57275498       0.33     0.5642
               grade*sex |  62.0120747     2  31.0060374       1.86     0.1607
                         |
                Residual |  1648.11706    99  16.6476471
              -----------+----------------------------------------------------
                   Total |      1733.2   104  16.6653846
```

```
->  test _coef[grade[1]] = _coef[grade[2]]

 ( 1)  grade[1] - grade[2] = 0

       F(  1,    99) =    1.59
            Prob > F =    0.2098


->  test _coef[grade[1]] = _coef[grade[3]]

 ( 1)  grade[1] - grade[3] = 0

       F(  1,    99) =    2.98
            Prob > F =    0.0876


->  test _coef[grade[2]] = _coef[grade[3]]

 ( 1)  grade[2] - grade[3] = 0

       F(  1,    99) =    0.33
            Prob > F =    0.5691
```

```
->  table grade sex if group == 2, c(N point_a mean point_a sd point_a) row col format(%9.2f)

----------------------------------
          |          Sex
    Grade |   Male  Female   Total
----------+-----------------------
     Mild |     14      14      28
          |  42.00   40.14   41.07
          |   3.55    1.79    2.92
          |
 Moderate |     18      24      42
          |  40.39   41.88   41.24
          |   5.42    3.07    4.25
          |
   Severe |     14      21      35
          |  40.79   42.57   41.86
          |   5.15    4.37    4.70
          |
    Total |     46      59     105
          |  41.00   41.71   41.40
          |   4.78    3.45    4.08
----------------------------------
```

```
->  anova point_b grade sex grade*sex if group == 2

                           Number of obs =     105     R-squared     =  0.0675
                           Root MSE      = 4.73344     Adj R-squared =  0.0204

                  Source |  Partial SS    df       MS           F     Prob > F
              -----------+----------------------------------------------------
                   Model |  160.659127     5  32.1318254       1.43     0.2187
                         |
                   grade |  4.83555582     2  2.41777791       0.11     0.8978
                     sex |  .595117513     1  .595117513       0.03     0.8709
               grade*sex |  145.484849     2  72.7424243       3.25     0.0431
                         |
                Residual |  2218.14087    99  22.4054634
              -----------+----------------------------------------------------
                   Total |      2378.8   104  22.8730769
```

```
->  test _coef[grade[1]] = _coef[grade[2]]

 ( 1)  grade[1] - grade[2] = 0

       F(  1,    99) =    1.61
            Prob > F =    0.2079


->  test _coef[grade[1]] = _coef[grade[3]]

 ( 1)  grade[1] - grade[3] = 0

       F(  1,    99) =    4.35
            Prob > F =    0.0397


->  test _coef[grade[2]] = _coef[grade[3]]

 ( 1)  grade[2] - grade[3] = 0

       F(  1,    99) =    0.96
            Prob > F =    0.3292
```

```
->  table grade sex if group == 2, c(N point_b mean point_b sd point_b) row col format(%9.2f)

----------------------------------
          |          Sex
    Grade |   Male  Female   Total
----------+-----------------------
     Mild |     14      14      28
          |  63.64   60.36   62.00
          |   5.64    4.05    5.10
          |
 Moderate |     18      24      42
          |  61.39   62.38   61.95
          |   5.94    3.37    4.61
          |
   Severe |     14      21      35
          |  61.00   63.76   62.66
          |   5.63    3.99    4.83
          |
    Total |     46      59     105
          |  61.96   62.39   62.20
          |   5.74    3.92    4.78
----------------------------------
```

```
->  anova alv_angle grade sex grade*sex if group == 2

                           Number of obs =     105     R-squared     =  0.0542
                           Root MSE      = 11.6291     Adj R-squared =  0.0064

                  Source |  Partial SS    df       MS           F     Prob > F
              -----------+----------------------------------------------------
                   Model |  766.503571     5  153.300714       1.13     0.3477
                         |
                   grade |  455.151365     2  227.575683       1.68     0.1911
                     sex |  97.6741318     1  97.6741318       0.72     0.3975
               grade*sex |  182.899339     2  91.4496696       0.68     0.5109
                         |
                Residual |  13388.4107    99  135.236472
              -----------+----------------------------------------------------
                   Total |  14154.9143   104  136.104945
```

```
->  test _coef[grade[1]] = _coef[grade[2]]

 ( 1)  grade[1] - grade[2] = 0

       F(  1,    99) =    0.13
            Prob > F =    0.7213


->  test _coef[grade[1]] = _coef[grade[3]]

 ( 1)  grade[1] - grade[3] = 0

       F(  1,    99) =    1.31
            Prob > F =    0.2549


->  test _coef[grade[2]] = _coef[grade[3]]

 ( 1)  grade[2] - grade[3] = 0

       F(  1,    99) =    2.98
            Prob > F =    0.0877
```

```
->  table grade sex if group == 2, c(N alv_angle mean alv_angle sd alv_angle) row col format(%9.2f)

----------------------------------
          |          Sex
    Grade |   Male  Female   Total
----------+-----------------------
     Mild |     14      14      28
          |  94.07   88.36   91.21
          |   9.06   10.66   10.13
          |
 Moderate |     18      24      42
          |  88.33   86.96   87.55
          |  13.37   10.47   11.66
          |
   Severe |     14      21      35
          |  91.79   92.95   92.49
          |  11.96   13.09   12.48
          |
    Total |     46      59     105
          |  91.13   89.42   90.17
          |  11.77   11.63   11.67
----------------------------------
```

```
->  anova max_trgle grade sex grade*sex if group == 2

                          Number of obs =     105     R-squared     =  0.0438
                          Root MSE      =  5.3459     Adj R-squared = -0.0045

                  Source |  Partial SS    df       MS           F     Prob > F
              -----------+----------------------------------------------------
                   Model |  129.704762     5  25.9409524       0.91     0.4793
                         |
                   grade |  41.8786217     2  20.9393109       0.73     0.4832
                     sex |  2.27940016     1  2.27940016       0.08     0.7782
               grade*sex |  81.3726627     2  40.6863314       1.42     0.2457
                         |
                Residual |  2829.28571    99  28.5786436
              -----------+----------------------------------------------------
                   Total |  2958.99048   104  28.4518315
```

```
->  test _coef[grade[1]] = _coef[grade[2]]

 ( 1)  grade[1] - grade[2] = 0

       F(  1,    99) =    0.39
            Prob > F =    0.5351


->  test _coef[grade[1]] = _coef[grade[3]]

 ( 1)  grade[1] - grade[3] = 0

       F(  1,    99) =    0.37
            Prob > F =    0.5454


->  test _coef[grade[2]] = _coef[grade[3]]

 ( 1)  grade[2] - grade[3] = 0

       F(  1,    99) =    1.96
            Prob > F =    0.1643
```

```
->  table grade sex if group == 2, c(N max_trgle mean max_trgle sd max_trgle) row col format(%9.2f)

----------------------------------
          |          Sex
    Grade |   Male  Female   Total
----------+-----------------------
     Mild |     14      14      28
          |  99.79  101.21  100.50
          |   4.93    7.68    6.37
          |
 Moderate |     18      24      42
          | 101.83  102.33  102.12
          |   5.12    4.69    4.82
          |
   Severe |     14      21      35
          | 102.93  100.10  101.23
          |   5.31    4.62    5.04
          |
    Total |     46      59     105
          | 101.54  101.27  101.39
          |   5.17    5.50    5.33
----------------------------------
```

```
->  anova mand_trgle grade sex grade*sex if group == 2

                       Number of obs =     105     R-squared     =  0.0780
                       Root MSE      =  3.7526     Adj R-squared =  0.0315

              Source |  Partial SS    df       MS           F     Prob > F
          -----------+----------------------------------------------------
               Model |  118.014286     5  23.6028571       1.68     0.1474
                     |
               grade |    1.957413     2  .978706499       0.07     0.9329
                 sex |  19.1002368     1  19.1002368       1.36     0.2470
           grade*sex |  100.648657     2  50.3243286       3.57     0.0317
                     |
            Residual |  1394.11905    99  14.0820106
          -----------+----------------------------------------------------
               Total |  1512.13333   104  14.5397436
```

```
->  test _coef[grade[1]] = _coef[grade[2]]

 ( 1)  grade[1] - grade[2] = 0

       F(  1,    99) =    0.30
            Prob > F =    0.5855


->  test _coef[grade[1]] = _coef[grade[3]]

 ( 1)  grade[1] - grade[3] = 0

       F(  1,    99) =    2.74
            Prob > F =    0.1011


->  test _coef[grade[2]] = _coef[grade[3]]

 ( 1)  grade[2] - grade[3] = 0

       F(  1,    99) =    1.68
            Prob > F =    0.1982
```

```
->  table grade sex if group == 2, c(N mand_trgle mean mand_trgle sd mand_trgle) row col format(%9.2f)

----------------------------------
          |          Sex
    Grade |   Male  Female   Total
----------+-----------------------
     Mild |     14      14      28
          |  67.71   70.86   69.29
          |   2.92    3.84    3.71
          |
 Moderate |     18      24      42
          |  68.83   70.17   69.60
          |   3.85    4.24    4.08
          |
   Severe |     14      21      35
          |  70.57   68.71   69.46
          |   3.46    3.68    3.66
          |
    Total |     46      59     105
          |  69.02   69.81   69.47
          |   3.58    3.98    3.81
----------------------------------
```

17 May 2007, 09:25:06
Repeat for Ant_Max & Post Mand

```
. for var    ant_max post_mand: anova X   group sex group*sex   \ table   group sex , c(N X mean X sd X) row col
format(%9.2f)

->  anova ant_max group sex group*sex

                           Number of obs =     204     R-squared     =  0.0066
                           Root MSE      = 3.78394     Adj R-squared = -0.0083

                  Source |  Partial SS    df       MS           F     Prob > F
              -----------+----------------------------------------------------
                   Model |  19.1192013     3   6.3730671       0.45     0.7210
                         |
                   group |  17.0866666     1  17.0866666       1.19     0.2760
                     sex |  .347218486     1  .347218486       0.02     0.8764
               group*sex |  1.24693304     1  1.24693304       0.09     0.7682
                         |
                Residual |   2863.6406   200   14.318203
              -----------+----------------------------------------------------
                   Total |   2882.7598   203  14.2007872
```

```
->  table group sex , c(N ant_max mean ant_max sd ant_max) row col format(%9.2f)

----------------------------------
          |          Sex
    Group |   Male  Female   Total
----------+-----------------------
   Normal |     50      50     100
          |  35.62   35.38   35.50
          |   4.30    3.90    4.09
          |
      AOB |     45      59     104
          |  36.04   36.12   36.09
          |   4.03    2.92    3.43
          |
    Total |     95     109     204
          |  35.82   35.78   35.80
          |   4.16    3.41    3.77
----------------------------------
```

```
->  anova post_mand group sex group*sex

                       Number of obs =     204     R-squared     =  0.1950
                       Root MSE      =  4.2859     Adj R-squared =  0.1829

              Source |  Partial SS    df       MS           F     Prob > F
          -----------+----------------------------------------------------
               Model |  889.763518     3  296.587839      16.15     0.0000
                     |
               group |  835.774548     1  835.774548      45.50     0.0000
                 sex |  16.8500229     1  16.8500229       0.92     0.3393
           group*sex |  72.5417465     1  72.5417465       3.95     0.0483
                     |
            Residual |   3673.7806   200   18.368903
          -----------+----------------------------------------------------
               Total |  4563.54412   203  22.4805129
```

```
->  table group sex , c(N post_mand mean post_mand sd post_mand) row col format(%9.2f)

----------------------------------
          |          Sex
    Group |   Male  Female   Total
----------+-----------------------
   Normal |     50      50     100
          |  36.98   37.60   37.29
          |   4.92    4.11    4.52
          |
      AOB |     46      58     104
          |  42.24   40.47   41.25
          |   4.76    3.35    4.11
          |
    Total |     96     108     204
          |  39.50   39.14   39.31
          |   5.49    3.97    4.74
----------------------------------
```

```
. for var   ant_max post_mand: anova X  grade sex grade*sex if group == 2 \ test  _coef[grade[1]] =  _co
> ef[grade[2]] \ test  _coef[grade[1]] =  _coef[grade[3]] \ test  _coef[grade[2]] =  _coef[grade[3]] \ t
> able  grade sex if group == 2, c(N X mean X sd X) row col format(%9.2f)

->  anova ant_max grade sex grade*sex if group == 2

                           Number of obs =     104     R-squared     =  0.0520
                           Root MSE      = 3.42154     Adj R-squared =  0.0036

                  Source |  Partial SS    df       MS           F     Prob > F
              -----------+----------------------------------------------------
                   Model |  62.9406917     5  12.5881383       1.08     0.3788
                         |
                   grade |  25.8484583     2  12.9242292       1.10     0.3356
                     sex |  .028647546     1  .028647546       0.00     0.9606
               grade*sex |  40.3260416     2  20.1630208       1.72     0.1840
                         |
                Residual |  1147.28046    98  11.7069435
              -----------+----------------------------------------------------
                   Total |  1210.22115   103  11.7497199
```

```
->  test _coef[grade[1]] = _coef[grade[2]]

 ( 1)  grade[1] - grade[2] = 0

       F(  1,    98) =    0.05
            Prob > F =    0.8164


->  test _coef[grade[1]] = _coef[grade[3]]

 ( 1)  grade[1] - grade[3] = 0

       F(  1,    98) =    0.13
            Prob > F =    0.7174


->  test _coef[grade[2]] = _coef[grade[3]]

 ( 1)  grade[2] - grade[3] = 0

       F(  1,    98) =    0.02
            Prob > F =    0.8754
```

```
->  table grade sex if group == 2, c(N ant_max mean ant_max sd ant_max) row col format(%9.2f)

----------------------------------
          |          Sex
    Grade |   Male  Female   Total
----------+-----------------------
     Mild |     14      14      28
          |  37.71   35.86   36.79
          |   3.29    2.14    2.88
          |
 Moderate |     17      24      41
          |  34.94   36.13   35.63
          |   4.25    2.72    3.44
          |
   Severe |     14      21      35
          |  35.71   36.29   36.06
          |   4.16    3.62    3.80
          |
    Total |     45      59     104
          |  36.04   36.12   36.09
          |   4.03    2.92    3.43
----------------------------------
```

```
->  anova post_mand grade sex grade*sex if group == 2

                       Number of obs =     104     R-squared     =  0.0669
                       Root MSE      =   4.072     Adj R-squared =  0.0193

              Source |  Partial SS    df       MS           F     Prob > F
          -----------+----------------------------------------------------
               Model |  116.547222     5  23.3094444       1.41     0.2289
                     |
               grade |  11.6598255     2  5.82991276       0.35     0.7044
                 sex |  70.0688625     1  70.0688625       4.23     0.0425
           grade*sex |  25.9377627     2  12.9688813       0.78     0.4603
                     |
            Residual |  1624.95278    98  16.5811508
          -----------+----------------------------------------------------
               Total |      1741.5   103   16.907767
```

```
->  test _coef[grade[1]] = _coef[grade[2]]

 ( 1)  grade[1] - grade[2] = 0

       F(  1,    98) =    0.37
            Prob > F =    0.5471


->  test _coef[grade[1]] = _coef[grade[3]]

 ( 1)  grade[1] - grade[3] = 0

       F(  1,    98) =    0.00
            Prob > F =    0.9640


->  test _coef[grade[2]] = _coef[grade[3]]

 ( 1)  grade[2] - grade[3] = 0

       F(  1,    98) =    0.52
            Prob > F =    0.4712
```

```
->  table grade sex if group == 2, c(N post_mand mean post_mand sd post_mand) row col format(%9.2f)

----------------------------------
          |          Sex
    Grade |   Male  Female   Total
----------+-----------------------
     Mild |     14      14      28
          |  42.93   40.79   41.86
          |   4.91    2.61    4.01
          |
 Moderate |     18      24      42
          |  42.56   39.96   41.07
          |   4.59    3.64    4.23
          |
   Severe |     14      20      34
          |  41.14   40.85   40.97
          |   4.99    3.53    4.12
          |
    Total |     46      58     104
          |  42.24   40.47   41.25
          |   4.76    3.35    4.11
----------------------------------
```

13 Feb 2008, 14:40:31

Standard deviations for the pilot study

```
. by group: summm  inc_sep -  var11

----------------------------------------------------------------------------------------------------
-> group = AOB

    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+--------------------------------------------------------
     inc_sep |        20         5.4     2.18608          2          9
        var1 |        20        70.4    4.783744         63         80
        var2 |        20        8.85    2.560325          3         14
        var3 |        20       36.95    2.502104         33         43
        var4 |        20        40.3      2.7549         36         46
-------------+--------------------------------------------------------
        var5 |        20       71.25    3.931988         63         76
        var6 |        20       38.45    2.762055         34         43
        var7 |        20        43.4    3.315038         38         49
        var8 |        20        62.8    4.372161         50         70
        var9 |        20        83.5    7.458658         72         98
-------------+--------------------------------------------------------
       var10 |        20       102.3    4.461531         91        108
       var11 |        20        70.8    3.860733         63         78
```

```
----------
```

-> group = Normal

Variable	Obs	Mean	Std. Dev.	Min	Max
inc_sep	0				
var1	20	69.05	4.058454	62	78
var2	20	7.25	4.228662	0	15
var3	20	35.5	3.940345	30	44
var4	20	39.5	3.284733	33	46
var5	20	68.7	5.222421	59	79
var6	20	37.4	4.604346	28	45
var7	20	42.1	4.940701	31	54
var8	20	60.35	4.625729	51	72
var9	20	78.75	8.340611	60	90
var10	20	105	3.464102	100	111
var11	20	74.55	2.946452	69	79

t test analyses for the pilot study

```
. for var  var1 -  var11: ttest X, by(group)

->  ttest var1, by(group)

Two-sample t test with equal variances
------------------------------------------------------------------------------
   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
     AOB |      20        70.4    1.069678    4.783744    68.16114    72.63886
  Normal |      20       69.05     .907498    4.058454    67.15058    70.94942
---------+--------------------------------------------------------------------
combined |      40      69.725    .7007208    4.431747    68.30766    71.14234
---------+--------------------------------------------------------------------
    diff |                1.35     1.40277               -1.489759    4.189759
------------------------------------------------------------------------------
    diff = mean(AOB) - mean(Normal)                               t =   0.9624
Ho: diff = 0                                     degrees of freedom =       38

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.8290         Pr(|T| > |t|) = 0.3419          Pr(T > t) = 0.1710
```

```
->  ttest var2, by(group)

Two-sample t test with equal variances
------------------------------------------------------------------------------
   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
     AOB |      20        8.85     .572506    2.560325    7.651731    10.04827
  Normal |      20        7.25    .9455575    4.228662    5.270925    9.229075
---------+--------------------------------------------------------------------
combined |      40        8.05    .5603913    3.544226    6.916502    9.183498
---------+--------------------------------------------------------------------
    diff |                 1.6     1.10537               -.6377039    3.837704
------------------------------------------------------------------------------
    diff = mean(AOB) - mean(Normal)                               t =   1.4475
Ho: diff = 0                                     degrees of freedom =       38

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.9220         Pr(|T| > |t|) = 0.1560          Pr(T > t) = 0.0780
```

```
->  ttest var3, by(group)

Two-sample t test with equal variances
------------------------------------------------------------------------------
   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
     AOB |      20       36.95    .5594875    2.502104    35.77898    38.12102
  Normal |      20        35.5    .8810878    3.940345    33.65586    37.34414
---------+--------------------------------------------------------------------
combined |      40      36.225    .5280437    3.339641    35.15693    37.29307
---------+--------------------------------------------------------------------
    diff |                1.45    1.043716               -.6628916    3.562892
------------------------------------------------------------------------------
    diff = mean(AOB) - mean(Normal)                               t =   1.3893
Ho: diff = 0                                     degrees of freedom =       38

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.9136         Pr(|T| > |t|) = 0.1728          Pr(T > t) = 0.0864
```

```
->  ttest var4, by(group)

Two-sample t test with equal variances
------------------------------------------------------------------------------
   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
     AOB |      20        40.3    .6160144      2.7549    39.01067    41.58933
  Normal |      20        39.5    .7344887    3.284733     37.9627     41.0373
---------+--------------------------------------------------------------------
combined |      40        39.9    .4774398    3.019594    38.93429    40.86571
---------+--------------------------------------------------------------------
    diff |                  .8    .9586174               -1.14062     2.74062
------------------------------------------------------------------------------
    diff = mean(AOB) - mean(Normal)                               t =   0.8345
Ho: diff = 0                                     degrees of freedom =       38

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.7954         Pr(|T| > |t|) = 0.4092          Pr(T > t) = 0.2046
```

```
->  ttest var5, by(group)

Two-sample t test with equal variances
------------------------------------------------------------------------------
   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
     AOB |      20       71.25    .8792192    3.931988    69.40977    73.09023
  Normal |      20        68.7    1.167769    5.222421    66.25583    71.14417
---------+--------------------------------------------------------------------
combined |      40      69.975    .7497756    4.741997    68.45844    71.49156
---------+--------------------------------------------------------------------
    diff |                2.55    1.461749               -.4091564    5.509156
------------------------------------------------------------------------------
    diff = mean(AOB) - mean(Normal)                               t =   1.7445
Ho: diff = 0                                     degrees of freedom =       38

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.9554         Pr(|T| > |t|) = 0.0892          Pr(T > t) = 0.0446
```

```
->  ttest var6, by(group)

Two-sample t test with equal variances
------------------------------------------------------------------------------
   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
     AOB |      20       38.45    .6176143    2.762055    37.15732    39.74268
  Normal |      20        37.4    1.029563    4.604346     35.2451     39.5549
---------+--------------------------------------------------------------------
combined |      40      37.925     .598489    3.785177    36.71444    39.13556
---------+--------------------------------------------------------------------
    diff |                1.05    1.200603               -1.380494    3.480494
------------------------------------------------------------------------------
    diff = mean(AOB) - mean(Normal)                               t =   0.8746
Ho: diff = 0                                     degrees of freedom =       38

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.8063         Pr(|T| > |t|) = 0.3873          Pr(T > t) = 0.1937
```

```
->  ttest var7, by(group)

Two-sample t test with equal variances
------------------------------------------------------------------------------
   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
     AOB |      20        43.4    .7412649    3.315038    41.84851    44.95149
  Normal |      20        42.1    1.104774    4.940701    39.78768    44.41232
---------+--------------------------------------------------------------------
combined |      40       42.75    .6648212    4.204698    41.40527    44.09473
---------+--------------------------------------------------------------------
    diff |                 1.3    1.330413               -1.393281    3.993281
------------------------------------------------------------------------------
    diff = mean(AOB) - mean(Normal)                               t =   0.9771
Ho: diff = 0                                     degrees of freedom =       38

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.8327         Pr(|T| > |t|) = 0.3347          Pr(T > t) = 0.1673
```

```
->  ttest var8, by(group)

Two-sample t test with equal variances
------------------------------------------------------------------------------
   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
     AOB |      20        62.8    .9776449    4.372161    60.75377    64.84623
  Normal |      20       60.35    1.034344    4.625729    58.18509    62.51491
---------+--------------------------------------------------------------------
combined |      40      61.575    .7293196    4.612622    60.09981    63.05019
---------+--------------------------------------------------------------------
    diff |                2.45    1.423256               -.4312313    5.331231
------------------------------------------------------------------------------
    diff = mean(AOB) - mean(Normal)                               t =   1.7214
Ho: diff = 0                                     degrees of freedom =       38

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.9533         Pr(|T| > |t|) = 0.0933          Pr(T > t) = 0.0467
```

```
->  ttest var9, by(group)

Two-sample t test with equal variances
------------------------------------------------------------------------------
   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
     AOB |      20        83.5    1.667807    7.458658    80.00924    86.99076
  Normal |      20       78.75    1.865017    8.340611    74.84647    82.65353
---------+--------------------------------------------------------------------
combined |      40      81.125     1.29208    8.171832    78.51152    83.73848
---------+--------------------------------------------------------------------
    diff |                4.75    2.501973               -.3149793    9.814979
------------------------------------------------------------------------------
    diff = mean(AOB) - mean(Normal)                               t =   1.8985
Ho: diff = 0                                     degrees of freedom =       38

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.9674         Pr(|T| > |t|) = 0.0652          Pr(T > t) = 0.0326
```

```
->  ttest var10, by(group)

Two-sample t test with equal variances
------------------------------------------------------------------------------
   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
     AOB |      20       102.3    .9976288    4.461531    100.2119    104.3881
  Normal |      20         105    .7745967    3.464102    103.3788    106.6212
---------+--------------------------------------------------------------------
combined |      40      103.65    .6597882    4.172867    102.3155    104.9845
---------+--------------------------------------------------------------------
    diff |                -2.7    1.263037               -5.256885   -.1431147
------------------------------------------------------------------------------
    diff = mean(AOB) - mean(Normal)                              t =  -2.1377
Ho: diff = 0                                     degrees of freedom =       38

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.0195         Pr(|T| > |t|) = 0.0390          Pr(T > t) = 0.9805
```

```
->  ttest var11, by(group)
Two-sample t test with equal variances
------------------------------------------------------------------------------
   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
     AOB |      20        70.8    .8632863    3.860733    68.99312    72.60688
  Normal |      20       74.55    .6588467    2.946452    73.17102    75.92898
---------+--------------------------------------------------------------------
combined |      40      72.675    .6143451    3.885459    71.43237    73.91763
---------+--------------------------------------------------------------------
    diff |               -3.75    1.085975               -5.948442   -1.551558
------------------------------------------------------------------------------
    diff = mean(AOB) - mean(Normal)                               t =  -3.4531
Ho: diff = 0                                     degrees of freedom =       38

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.0007         Pr(|T| > |t|) = 0.0014          Pr(T > t) = 0.9993
```

20 May 2008, 12:58:23

Statistical analysis for other cephalometric analyses

```
. for var  pfh -  inter_1: ttest X, by(group) welch unequal \ ranksum X, by(group)

->  ttest pfh, by(group) welch unequal

Two-sample t test with unequal variances
------------------------------------------------------------------------------
   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
  Normal |      20        75.3    1.509793    6.751998    72.13997    78.46003
     AOB |      20        76.8    1.990239    8.900621    72.63438    80.96562
---------+--------------------------------------------------------------------
combined |      40       76.05     1.23877     7.83467    73.54435    78.55565
---------+--------------------------------------------------------------------
    diff |                -1.5    2.498105               -6.560919    3.560919
------------------------------------------------------------------------------
    diff = mean(Normal) - mean(AOB)                               t =  -0.6005
Ho: diff = 0                                 Welch's degrees of freedom =  37.1568

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.2759         Pr(|T| > |t|) = 0.5518          Pr(T > t) = 0.7241
```

```
->  ranksum pfh, by(group)

Two-sample Wilcoxon rank-sum (Mann-Whitney) test

       group |      obs    rank sum    expected
-------------+---------------------------------
      Normal |       20         386         410
         AOB |       20         434         410
-------------+---------------------------------
    combined |       40         820         820

unadjusted variance     1366.67
adjustment for ties       -6.79
                     ----------
adjusted variance       1359.87

Ho: pfh(group==Normal) = pfh(group==AOB)
             z =  -0.651
    Prob > |z| =   0.5152
```

```
->  ttest afh, by(group) welch unequal

Two-sample t test with unequal variances
------------------------------------------------------------------------------
   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
  Normal |      20       121.8    1.394727    6.237408    118.8808    124.7192
     AOB |      20       127.6    2.022765    9.046081    123.3663    131.8337
---------+--------------------------------------------------------------------
combined |      40       124.7     1.29852    8.212561    122.0735    127.3265
---------+--------------------------------------------------------------------
    diff |                -5.8    2.456999               -10.78652   -.8134761
------------------------------------------------------------------------------
    diff = mean(Normal) - mean(AOB)                              t =  -2.3606
Ho: diff = 0                              Welch's degrees of freedom =  35.2867

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.0119         Pr(|T| > |t|) = 0.0239          Pr(T > t) = 0.9881
```

```
->  ranksum afh, by(group)

Two-sample Wilcoxon rank-sum (Mann-Whitney) test

       group |      obs    rank sum    expected
-------------+---------------------------------
      Normal |       20         337         410
         AOB |       20         483         410
-------------+---------------------------------
    combined |       40         820         820

unadjusted variance     1366.67
adjustment for ties       -6.79
                     ----------
adjusted variance       1359.87

Ho: afh(group==Normal) = afh(group==AOB)
             z =  -1.980
    Prob > |z| =   0.0478
```

```
->  ttest pfh_afh, by(group) welch unequal

Two-sample t test with unequal variances
------------------------------------------------------------------------------
   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
  Normal |      20       61.93    1.315457    5.882901    59.17672    64.68328
     AOB |      20        60.2    1.280378    5.726026    57.52014    62.87986
---------+--------------------------------------------------------------------
combined |      40      61.065     .916533    5.796663    59.21114    62.91886
---------+--------------------------------------------------------------------
    diff |                1.73      1.8357               -1.980176    5.440177
------------------------------------------------------------------------------
    diff = mean(Normal) - mean(AOB)                               t =   0.9424
Ho: diff = 0                             Welch's degrees of freedom =  39.9694

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.8242         Pr(|T| > |t|) = 0.3516          Pr(T > t) = 0.1758
```

```
->  ranksum pfh_afh, by(group)

Two-sample Wilcoxon rank-sum (Mann-Whitney) test

       group |      obs    rank sum    expected
-------------+---------------------------------
      Normal |       20       432.5         410
         AOB |       20       387.5         410
-------------+---------------------------------
    combined |       40         820         820

unadjusted variance     1366.67
adjustment for ties       -1.41
                      ----------
adjusted variance       1365.26

Ho: pfh_afh(group==Normal) = pfh_afh(group==AOB)
             z =   0.609
    Prob > |z| =   0.5426
```

```
->  ttest ufh, by(group) welch unequal

Two-sample t test with unequal variances
------------------------------------------------------------------------------
   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
  Normal |      20       50.25    .7393988    3.306692    48.70242    51.79758
     AOB |      20        50.8     1.20874     5.40565    48.27008    53.32992
---------+--------------------------------------------------------------------
combined |      40      50.525    .7007208    4.431747    49.10766    51.94234
---------+--------------------------------------------------------------------
    diff |                -.55    1.416956               -3.433534    2.333534
------------------------------------------------------------------------------
    diff = mean(Normal) - mean(AOB)                              t =  -0.3882
Ho: diff = 0                              Welch's degrees of freedom =  32.7857

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.3502         Pr(|T| > |t|) = 0.7004          Pr(T > t) = 0.6498
```

```
->  ranksum ufh, by(group)

Two-sample Wilcoxon rank-sum (Mann-Whitney) test

       group |      obs    rank sum    expected
-------------+---------------------------------
      Normal |       20         395         410
         AOB |       20         425         410
-------------+---------------------------------
    combined |       40         820         820

unadjusted variance     1366.67
adjustment for ties       -9.87
                     ----------
adjusted variance       1356.79

Ho: ufh(group==Normal) = ufh(group==AOB)
             z =  -0.407
    Prob > |z| =   0.6838
```

```
->  ttest lfh, by(group) welch unequal

Two-sample t test with unequal variances
------------------------------------------------------------------------------
   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
  Normal |      20       72.35    1.418441    6.343459    69.38117    75.31883
     AOB |      20       76.55    1.394491    6.236354     73.6313     79.4687
---------+--------------------------------------------------------------------
combined |      40       74.45    1.037718    6.563106    72.35102    76.54898
---------+--------------------------------------------------------------------
    diff |                -4.2    1.989115               -8.22019   -.1798103
------------------------------------------------------------------------------
    diff = mean(Normal) - mean(AOB)                              t =  -2.1115
Ho: diff = 0                            Welch's degrees of freedom =  39.9878

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.0205         Pr(|T| > |t|) = 0.0410          Pr(T > t) = 0.9795
```

```
->  ranksum lfh, by(group)

Two-sample Wilcoxon rank-sum (Mann-Whitney) test

       group |      obs    rank sum    expected
-------------+---------------------------------
      Normal |       20         340         410
         AOB |       20         480         410
-------------+---------------------------------
    combined |       40         820         820

unadjusted variance     1366.67
adjustment for ties       -4.87
                     ----------
adjusted variance       1361.79

Ho: lfh(group==Normal) = lfh(group==AOB)
             z =  -1.897
    Prob > |z| =   0.0578
```

```
->  ttest ufh_lfh, by(group) welch unequal

Two-sample t test with unequal variances
------------------------------------------------------------------------------
   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
  Normal |      20      70.075    1.968019    8.801249    65.95589    74.19411
     AOB |      20      66.515    1.479692    6.617384    63.41797    69.61203
---------+--------------------------------------------------------------------
combined |      40      68.295    1.248209    7.894365    65.77026    70.81974
---------+--------------------------------------------------------------------
    diff |                3.56    2.462232               -1.428989    8.548989
------------------------------------------------------------------------------
    diff = mean(Normal) - mean(AOB)                               t =   1.4458
Ho: diff = 0                                 Welch's degrees of freedom =  36.9929

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.9217         Pr(|T| > |t|) = 0.1566          Pr(T > t) = 0.0783
```

```
->  ranksum ufh_lfh, by(group)

Two-sample Wilcoxon rank-sum (Mann-Whitney) test

       group |      obs    rank sum    expected
-------------+---------------------------------
      Normal |       20         459         410
         AOB |       20         361         410
-------------+---------------------------------
    combined |       40         820         820

unadjusted variance     1366.67
adjustment for ties       -1.03
                     ----------
adjusted variance       1365.64

Ho: ufh_lfh(group==Normal) = ufh_lfh(group==AOB)
             z =   1.326
    Prob > |z| =   0.1849
```

```
->  ttest sn_fh, by(group) welch unequal

Two-sample t test with unequal variances
------------------------------------------------------------------------------
   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
  Normal |      20        7.25    .9455575    4.228662    5.270925    9.229075
     AOB |      20        8.85     .572506    2.560325    7.651731    10.04827
---------+--------------------------------------------------------------------
combined |      40        8.05    .5603913    3.544226    6.916502    9.183498
---------+--------------------------------------------------------------------
    diff |                -1.6     1.10537               -3.850012    .6500124
------------------------------------------------------------------------------
    diff = mean(Normal) - mean(AOB)                               t =  -1.4475
Ho: diff = 0                              Welch's degrees of freedom =  32.5728

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.0787         Pr(|T| > |t|) = 0.1573          Pr(T > t) = 0.9213
```

```
->  ranksum sn_fh, by(group)

Two-sample Wilcoxon rank-sum (Mann-Whitney) test

       group |      obs    rank sum    expected
-------------+---------------------------------
      Normal |       20         357         410
         AOB |       20         463         410
-------------+---------------------------------
    combined |       40         820         820

unadjusted variance     1366.67
adjustment for ties      -13.33
                     ----------
adjusted variance       1353.33

Ho: sn_fh(group==Normal) = sn_fh(group==AOB)
             z =  -1.441
    Prob > |z| =   0.1497
```

```
->  ttest fh_pp, by(group) welch unequal

Two-sample t test with unequal variances
------------------------------------------------------------------------------
   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
  Normal |      20        -2.8    .7595012    3.396593   -4.389654   -1.210346
     AOB |      20       -3.85    1.105667    4.944694   -6.164188   -1.535812
---------+--------------------------------------------------------------------
combined |      40      -3.325    .6673594    4.220752   -4.674862   -1.975138
---------+--------------------------------------------------------------------
    diff |                1.05    1.341396               -1.6726      3.7726
------------------------------------------------------------------------------
    diff = mean(Normal) - mean(AOB)                               t =   0.7828
Ho: diff = 0                              Welch's degrees of freedom =   35.209

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.7805         Pr(|T| > |t|) = 0.4390          Pr(T > t) = 0.2195
```

```
->  ranksum fh_pp, by(group)

Two-sample Wilcoxon rank-sum (Mann-Whitney) test

       group |      obs    rank sum    expected
-------------+---------------------------------
      Normal |       20         442         410
         AOB |       20         378         410
-------------+---------------------------------
    combined |       40         820         820

unadjusted variance     1366.67
adjustment for ties      -16.67
                     ----------
adjusted variance       1350.00

Ho: fh_pp(group==Normal) = fh_pp(group==AOB)
             z =   0.871
    Prob > |z| =   0.3838
```

```
->  ttest pp_op, by(group) welch unequal

Two-sample t test with unequal variances
------------------------------------------------------------------------------
   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
  Normal |      20        8.45    1.179819    5.276313     5.98061    10.91939
     AOB |      20       13.25    1.654142    7.397546    9.787842    16.71216
---------+--------------------------------------------------------------------
combined |      40       10.85    1.073904    6.791964    8.677825    13.02218
---------+--------------------------------------------------------------------
    diff |                -4.8    2.031787               -8.920759   -.6792407
------------------------------------------------------------------------------
    diff = mean(Normal) - mean(AOB)                               t =  -2.3625
Ho: diff = 0                          Welch's degrees of freedom =  35.9737

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.0118         Pr(|T| > |t|) = 0.0237          Pr(T > t) = 0.9882
```

```
->  ranksum pp_op, by(group)

Two-sample Wilcoxon rank-sum (Mann-Whitney) test

       group |      obs    rank sum    expected
-------------+---------------------------------
      Normal |       20       335.5         410
         AOB |       20       484.5         410
-------------+---------------------------------
    combined |       40         820         820

unadjusted variance     1366.67
adjustment for ties       -9.62
                     ----------
adjusted variance       1357.05

Ho: pp_op(group==Normal) = pp_op(group==AOB)
             z =  -2.022
    Prob > |z| =   0.0431
```

```
->  ttest op_mp, by(group) welch unequal

Two-sample t test with unequal variances
------------------------------------------------------------------------------
   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
  Normal |      20        23.1     1.30767    5.848077    20.36302    25.83698
     AOB |      20       22.95    1.249158    5.586403    20.33548    25.56452
---------+--------------------------------------------------------------------
combined |      40      23.025    .8926247    5.645454     21.2195     24.8305
---------+--------------------------------------------------------------------
    diff |                 .15    1.808423               -3.50521     3.80521
------------------------------------------------------------------------------
    diff = mean(Normal) - mean(AOB)                               t =   0.0829
Ho: diff = 0                            Welch's degrees of freedom =  39.9123

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.5328         Pr(|T| > |t|) = 0.9343          Pr(T > t) = 0.4672
```

```
->  ranksum op_mp, by(group)

Two-sample Wilcoxon rank-sum (Mann-Whitney) test

       group |      obs    rank sum    expected
-------------+---------------------------------
      Normal |       20         415         410
         AOB |       20         405         410
-------------+---------------------------------
    combined |       40         820         820

unadjusted variance     1366.67
adjustment for ties       -6.92
                     ----------
adjusted variance       1359.74

Ho: op_mp(group==Normal) = op_mp(group==AOB)
             z =   0.136
    Prob > |z| =   0.8921
```

```
->  ttest mp_ab, by(group) welch unequal

Two-sample t test with unequal variances
------------------------------------------------------------------------------
   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
  Normal |      20        69.8    .9640922    4.311551    67.78213    71.81787
     AOB |      20       66.95    1.471617    6.581273    63.86987    70.03013
---------+--------------------------------------------------------------------
combined |      40      68.375    .8977804    5.678062    66.55907    70.19093
---------+--------------------------------------------------------------------
    diff |                2.85    1.759299               -.724471    6.424471
------------------------------------------------------------------------------
    diff = mean(Normal) - mean(AOB)                               t =   1.6200
Ho: diff = 0                             Welch's degrees of freedom =   34.222

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.9428         Pr(|T| > |t|) = 0.1144          Pr(T > t) = 0.0572
```

```
->  ranksum mp_ab, by(group)

Two-sample Wilcoxon rank-sum (Mann-Whitney) test

       group |      obs    rank sum    expected
-------------+---------------------------------
      Normal |       20         455         410
         AOB |       20         365         410
-------------+---------------------------------
    combined |       40         820         820

unadjusted variance     1366.67
adjustment for ties      -14.74
                     ----------
adjusted variance       1351.92

Ho: mp_ab(group==Normal) = mp_ab(group==AOB)
             z =   1.224
    Prob > |z| =   0.2210
```

```
->  ttest odi_values, by(group) welch unequal

Two-sample t test with unequal variances
------------------------------------------------------------------------------
   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
  Normal |      20          67    .8914801     3.98682    65.13411    68.86589
     AOB |      20        63.1     1.98799    8.890563    58.93909    67.26091
---------+--------------------------------------------------------------------
combined |      40       65.05    1.119724    7.081757    62.78514    67.31486
---------+--------------------------------------------------------------------
    diff |                 3.9    2.178725               -.5694672    8.369467
------------------------------------------------------------------------------
    diff = mean(Normal) - mean(AOB)                               t =   1.7900
Ho: diff = 0                             Welch's degrees of freedom =  27.1176

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.9577         Pr(|T| > |t|) = 0.0846          Pr(T > t) = 0.0423
```

```
->  ranksum odi_values, by(group)

Two-sample Wilcoxon rank-sum (Mann-Whitney) test

       group |      obs    rank sum    expected
-------------+---------------------------------
      Normal |       20         478         410
         AOB |       20         342         410
-------------+---------------------------------
    combined |       40         820         820

unadjusted variance     1366.67
adjustment for ties       -6.67
                     ----------
adjusted variance       1360.00

Ho: odi_va~s(group==Normal) = odi_va~s(group==AOB)
             z =   1.844
    Prob > |z| =   0.0652
```

```
->  ttest sna, by(group) welch unequal

Two-sample t test with unequal variances
------------------------------------------------------------------------------
   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
  Normal |      20       87.85    1.328384    5.940716    85.06966    90.63034
     AOB |      20       86.65    .8280446    3.703128    84.91688    88.38312
---------+--------------------------------------------------------------------
combined |      40       87.25    .7785177    4.923778     85.6753     88.8247
---------+--------------------------------------------------------------------
    diff |                 1.2    1.565332               -1.984039    4.384039
------------------------------------------------------------------------------
    diff = mean(Normal) - mean(AOB)                               t =   0.7666
Ho: diff = 0                              Welch's degrees of freedom =  33.1789

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.7756         Pr(|T| > |t|) = 0.4487          Pr(T > t) = 0.2244
```

```
->  ranksum sna, by(group)

Two-sample Wilcoxon rank-sum (Mann-Whitney) test

       group |      obs    rank sum    expected
-------------+---------------------------------
      Normal |       20       449.5         410
         AOB |       20       370.5         410
-------------+---------------------------------
    combined |       40         820         820

unadjusted variance     1366.67
adjustment for ties      -15.13
                     ----------
adjusted variance       1351.54

Ho: sna(group==Normal) = sna(group==AOB)
             z =   1.074
    Prob > |z| =   0.2826
```

```
->  ttest snb, by(group) welch unequal

Two-sample t test with unequal variances
------------------------------------------------------------------------------
   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
  Normal |      20       82.95    1.122673    5.020746    80.60022    85.29978
     AOB |      20       80.45    .7555932    3.379115    78.86853    82.03147
---------+--------------------------------------------------------------------
combined |      40        81.7    .6972473    4.409779    80.28968    83.11032
---------+--------------------------------------------------------------------
    diff |                 2.5    1.353261               -.2478711    5.247871
------------------------------------------------------------------------------
    diff = mean(Normal) - mean(AOB)                               t =   1.8474
Ho: diff = 0                             Welch's degrees of freedom =  34.7858

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.9634         Pr(|T| > |t|) = 0.0732          Pr(T > t) = 0.0366
```

```
->  ranksum snb, by(group)

Two-sample Wilcoxon rank-sum (Mann-Whitney) test

       group |      obs    rank sum    expected
-------------+---------------------------------
      Normal |       20         466         410
         AOB |       20         354         410
-------------+---------------------------------
    combined |       40         820         820

unadjusted variance     1366.67
adjustment for ties      -10.38
                     ----------
adjusted variance       1356.28

Ho: snb(group==Normal) = snb(group==AOB)
             z =   1.521
    Prob > |z| =   0.1284
```

```
->  ttest anb, by(group) welch unequal

Two-sample t test with unequal variances
------------------------------------------------------------------------------
   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
  Normal |      20         5.9    .5520297    2.468752    4.744588    7.055412
     AOB |      20        6.35    .5245299    2.345769    5.252146    7.447854
---------+--------------------------------------------------------------------
combined |      40       6.125    .3775554     2.38787    5.361322    6.888678
---------+--------------------------------------------------------------------
    diff |                -.45    .7614909               -1.989162    1.089162
------------------------------------------------------------------------------
    diff = mean(Normal) - mean(AOB)                               t =  -0.5909
Ho: diff = 0                             Welch's degrees of freedom =  39.8908

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.2789         Pr(|T| > |t|) = 0.5579          Pr(T > t) = 0.7211
```

```
->  ranksum anb, by(group)

Two-sample Wilcoxon rank-sum (Mann-Whitney) test

       group |      obs    rank sum    expected
-------------+---------------------------------
      Normal |       20       409.5         410
         AOB |       20       410.5         410
-------------+---------------------------------
    combined |       40         820         820

unadjusted variance     1366.67
adjustment for ties      -27.82
                     ----------
adjusted variance       1338.85

Ho: anb(group==Normal) = anb(group==AOB)
             z =  -0.014
    Prob > |z| =   0.9891
```

```
->  ttest upp_1, by(group) welch unequal

Two-sample t test with unequal variances
------------------------------------------------------------------------------
   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
  Normal |      20        19.5    1.683511    7.528892    15.97637    23.02363
     AOB |      20       30.05    1.675638    7.493682    26.54285    33.55715
---------+--------------------------------------------------------------------
combined |      40      24.775    1.444924      9.1385    21.85237    27.69763
---------+--------------------------------------------------------------------
    diff |              -10.55    2.375284               -15.35063   -5.749369
------------------------------------------------------------------------------
    diff = mean(Normal) - mean(AOB)                               t =  -4.4416
Ho: diff = 0                             Welch's degrees of freedom =  39.9991

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.0000         Pr(|T| > |t|) = 0.0001          Pr(T > t) = 1.0000
```

```
->  ranksum upp_1, by(group)

Two-sample Wilcoxon rank-sum (Mann-Whitney) test

       group |      obs    rank sum    expected
-------------+---------------------------------
      Normal |       20         274         410
         AOB |       20         546         410
-------------+---------------------------------
    combined |       40         820         820

unadjusted variance     1366.67
adjustment for ties       -3.72
                     ----------
adjusted variance       1362.95

Ho: upp_1(group==Normal) = upp_1(group==AOB)
             z =  -3.684
    Prob > |z| =   0.0002
```

```
->  ttest low_1, by(group) welch unequal

Two-sample t test with unequal variances
------------------------------------------------------------------------------
   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
  Normal |      20       33.95    .9388543    4.198684    31.98496    35.91504
     AOB |      20       39.35    1.431369    6.401275    36.35411    42.34589
---------+--------------------------------------------------------------------
combined |      40       36.65    .9490549     6.00235    34.73036    38.56964
---------+--------------------------------------------------------------------
    diff |                -5.4    1.711801               -8.877874   -1.922126
------------------------------------------------------------------------------
    diff = mean(Normal) - mean(AOB)                              t =  -3.1546
Ho: diff = 0                         Welch's degrees of freedom =  34.2472

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.0017         Pr(|T| > |t|) = 0.0033          Pr(T > t) = 0.9983
```

```
->  ranksum low_1, by(group)

Two-sample Wilcoxon rank-sum (Mann-Whitney) test

       group |      obs    rank sum    expected
-------------+---------------------------------
      Normal |       20         292         410
         AOB |       20         528         410
-------------+---------------------------------
    combined |       40         820         820

unadjusted variance     1366.67
adjustment for ties      -11.15
                     ----------
adjusted variance       1355.51

Ho: low_1(group==Normal) = low_1(group==AOB)
             z =  -3.205
    Prob > |z| =   0.0014
```

```
->  ttest inter_1, by(group) welch unequal

Two-sample t test with unequal variances
------------------------------------------------------------------------------
   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
  Normal |      20      120.65    1.749098    7.822202    116.9891    124.3109
     AOB |      20      104.15    2.423867    10.83986    99.07679    109.2232
---------+--------------------------------------------------------------------
combined |      40       112.4    1.980287    12.52444    108.3945    116.4055
---------+--------------------------------------------------------------------
    diff |                16.5    2.989059                 10.4391     22.5609
------------------------------------------------------------------------------
    diff = mean(Normal) - mean(AOB)                               t =   5.5201
Ho: diff = 0                              Welch's degrees of freedom =  36.2052

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 1.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 0.0000
```

```
->  ranksum inter_1, by(group)

Two-sample Wilcoxon rank-sum (Mann-Whitney) test

       group |      obs    rank sum    expected
-------------+---------------------------------
      Normal |       20       570.5         410
         AOB |       20       249.5         410
-------------+---------------------------------
    combined |       40         820         820

unadjusted variance     1366.67
adjustment for ties       -2.44
                     ----------
adjusted variance       1364.23

Ho: inter_1(group==Normal) = inter_1(group==AOB)
             z =   4.345
    Prob > |z| =   0.0000

. log close
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  log type:  text
 closed on:  20 May 2008, 12:59:37
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```