

The Contemporary Coben Analysis

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ABSTRACT

As orthodontics integrates more digital imagery it has become necessary to reconfigure and adapt the Coben analysis. In its original paper-based form, it is exceedingly time consuming. The objective of this project was to: 1.) Create a novel method for analyzing radiographic cephalometric images in a digital manner using the Coben analysis. 2.) Compare the original norms and standard deviations to the measurements taken on today's patients. 3.) Address any changes in the norms due to secular trends.

In the present study 279 digital cephalometric radiographs were separated into 3 age groups by sex. The breakdown is as follows: 53 males age 7-10 with a median age of 8.17 years, 43 females age 7-10 with a median age of 8.67 years, 45 males age 11-14 with a median age of 11.58 years, 50 females age 11-14 with a median age of 11.52 years, 41 males age 15-18 with a median age of 16.08 years and 47 females with a median age of 16.33 years. The cephalometric radiographs were digitally traced using Coben analysis standards to compare to the original Coben analysis norms and assess any differences in secular trends.

Based on the results collected, the following conclusions were drawn:

1. As evidenced by the larger standard deviations in the current study compared to the original study, more individual variation exists among the facial skeletal components that form a Class I occlusion than previously thought.

2. We recommend 3.8° should be used for the S-N angle mean in males age 11-14 and 2.9° for females age 11-14 as opposed to the 7° suggested by the original study
3. The hand tracing method previously employed uses graph paper with the coordinate system enlarged 8% to compensate for the 8% enlargement of the radiographic film. This is no longer necessary when tracing a digital cephalometric radiograph.
4. The distance from basion to articulare in this study is consistently within one standard deviation of the original study's measurements for males and females. This distance appears stable for research purposes.
5. The Coben analysis linear and proportional measurements need not be adjusted due to the vast array of variables present in any population which include, but are not limited to, variation in comparative sample populations, genetics, polymorphisms, or endocrine disrupting chemicals.

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CHAPTER 1

INTRODUCTION

Diagnosis and orthodontic treatment depends greatly upon growth and development of the face. This subject is not only of didactic interest to the orthodontist, but also of great clinical importance. Various studies have described growth and development in humans (Brodie, 1946; Wylie, 1947; Downs, 1948). Unfortunately, due to the great variation from one individual face to another, limited clinical usefulness can come of these studies. Though generalization of growth and development are vital to clinical understanding, the variations from the norm in individual to individual are more important (Coben, 1961). The Coben analysis offers the ability to assess the integration of skeletal variants that result in different facial types, the growth behavior and adjustments of cranial and facial structures within the individual face, and the manner in which growth may modify the facial form.

As orthodontics becomes more reliant on paperless work stations and digital imagery it has become necessary to assess the methodology of the Coben analysis. Currently, the Coben analysis employs complex hand measurements and time consuming calculations. In today's busy practice world it has become difficult for the everyday clinician to use the analysis in its current form.

In order for the Coben analysis to be used by the everyday clinician, a method needs to be developed for quick analysis of digital lateral cephalometric radiographs. With this new methodology, there is also a need to evaluate the original norms and

assess any secular trends between today's patient and those patients used for the original analysis.

In the present study, 279 subjects were examined via lateral cephalometric radiographs to determine the variation of the relative size and growth of cranial and facial structures. The incorporation of these variants on the facial profile helped obtain knowledge of the changes in growth of the individual face. The results were then compared to the original study, with the same goals, completed by Coben.

The following text reviews the literature pertaining to the history of growth, development, cephalometric analysis and the origin of the Coben analysis.

CHAPTER 2

REVIEW OF THE LITERATURE

2.1 Early Growth Studies

The 18th century marked a renaissance in growth studies. Histologists of the day popularized an organic dye, called madder, which had a high affinity for growing bone (Belchier, 1736; Duhamel 1739). Using madder to study mandibular growth in swine established the sites of growth in the bone and the alveolar process (Hunter, 1771). General conclusions on the directional resorption and apposition of different parts of the mandible were reaffirmed by later research (Humphrey, 1864; Brash, 1924).

2.2 Anthropometry

Early studies of dried crania signified the beginning of modern day cephalometrics. The first recorded attempt to interpret human cranial growth involved the use of bone from dried skulls. The crania of three different ages were compared. While Campion measured the amount of growth which takes place at succeeding age periods, Keith attempted to determine the sites where the growth occurs. Both concluded that the entire face is essentially part of the apparatus of mastication and that irregularities of the jaws, in size, shape and position, can be

explained only when a study is made of the ingenious and elaborate mechanism which underlies growth of the face as a whole (Keith and Campion, 1922).

The invention of the craniostat in 1924 by Thomas Todd offered a more accurate means of recording anthropometric measurements. The craniostat eventually afforded the ability to hold the skull in a fixed position. Birdsall Holly Broadbent later developed a radiographic film holding apparatus that along with the craniostat, led to the design of the first cephalometer in 1931.

Advanced studies eventually provided greater insight. An investigation of a large series of Indian skulls followed by serial anthropometric measurements on living individuals reasoned that growth is present in all dimensions. Through analysis of facial height, depth, width and changes in proportions the judgment was assumed, “Faces with excellent occlusion show variability in overall skeletal growth and development” (Hellman, 1927).

2.3 Longitudinal Research

In the late 19th century the use of longitudinal studies to obtain an accurate knowledge of human growth mechanisms was employed (Boas, 1892). Soon thereafter, Shuttleworth and Davenport used similar methods. Appalled that longitudinal data were being analyzed in a cross-sectional manner, Shuttleworth used data amassed from the Harvard Growth Study to illustrate growth should be understood in terms of increments. In a longitudinal study of several hundred

individuals, Davenport provided evidence that variability in the growth curves of head dimensions included accelerated growth in children. Other researchers concluded that previous longitudinal studies pertaining to craniofacial growth were not adequate for interpretation of individual variation (Tanner, 1955) and the need for longitudinal studies extending beyond 20 years of age (Nanda, 1955).

Subsequently, a longitudinal investigation to study the growth patterns of the craniofacial complex was employed. This study conducted by Ferrer in 1964 evaluated group data as a central tendency through the utilization of annual means. Conclusions found males demonstrate greater variability than females in general growth rhythm. Males have a higher growth rate in both the anterior cranial base and frontal bone area. It was also found face height accelerated between the ages of one to four in males, followed by a leveling until age nine. In females a constant continued increase was observed from age one to nine.

2.4 Early Radiography

In 1895, Roentgen discovered the x-ray through experimentation with light emissions from the discharge of electrical currents through evacuated glass tubes. When the glass tubes were electrically charged, glowing light radiated from a proximate barium platinocyanide-coated screen. The first radiograph was created when Roentgen placed his wife's hand between the evacuated tubes and screen. He realized bones could be visualized when a body part was placed between the electron

source and screen. The application of this technique allowed for the study of living subjects in addition to dried crania. The use of x-rays for orthodontic diagnosis and treatment planning was later pioneered by Broadbent (Broadbent, 1931).

2.5 Origin of Cephalometrics and Cephalometric Analysis

Prior to Broadbent creating a method for standardization of serial cephalometric radiographs in a growing person, it was impossible to determine changes due to developmental growth or orthodontic treatment. The research previous to Broadbent was imprecise. Orthodontists began realizing the benefits Broadbent's method possessed after he presented his first diagrams that demonstrated a systematic growth pattern of a normal child's face. Following Broadbent, Brodie published, "On the Growth Pattern of The Human Head", a quantitative study on the growth of the human head from the third month to the eighth year of life. He concluded the developmental pattern of the human skull is established at an early age and very little change occurs from that point (Brodie, 1941).

Other cephalometric radiographic examinations followed. A comparison of males 12 years old and 20 to 22 years old found that in older subjects the face increases not only in vertical height but also in a more prognathic manner (Bjork, 1947).

Facial profile analyses were introduced. In 1948, Downs developed his analysis of facial form that evaluated the balance and harmony of individual facial profiles.

During the same time, the Wylie analysis examined anteroposterior dysplasia. While Downs evaluated the profile, Wylie focused on segmenting the face according to anatomic landmarks in an attempt to determine the variation of the internal facial morphology related to a particular facial type. It was discovered that a discrepancy in a certain part of the skull could be negated by a deviation in another part in the opposite direction. When deviations balanced each other out, it resulted in acceptable facial harmony. On the other hand, discrepancy in the opposite direction could lead to gross facial disharmony (Wylie, 1947). In 1946, Brodie had come to similar conclusions of Wylie.

2.6 Cranial Growth and Orthodontics

Cranial growth in orthodontics has been studied thoroughly in order to determine the primary etiological factors of dental malocclusion. Early orthodontists suggested dental occlusion and function as the primary determinants of facial development (Angle, 1907). Through examination of the etiological factors that influence the occlusion the leading philosophy on the subject changed. It is now accepted that facial growth and development are the main factors used to determine dental occlusion, adding validity to Hellman's claim, "faces with excellent occlusion display great variation in their development."

2.6.1 Etiological Factors of Dental Malocclusion

A study on mandibular form was constructed to determine if anatomical variations are associated with specific malocclusions. The following findings were made: 1.) a Class II mandible is similar to a Class I mandible, 2.) the body and ramus of the mandible do not differ from the norm and 3.) an underdeveloped mandible could not be the cause for the malocclusion examined (Adams, 1939). To eliminate the possibility that the teeth may be in a posterior relationship to the bone, evaluation of the first molars was assessed. It was found the relationship between the first molar and the mandible is similar in at least two planes of space and remains before and after the molars come into occlusion. This relationship appears to be identical in both Class I and Class II cases (Elman, 1940). Similar conditions of stability were assessed in the maxilla. The examination of the relation of the cranium and the molars proved stability of the maxillary teeth. It was decided the molars can be used as a basis for classification in Class I and Class II cases according to the Angle Classification system (Baldrige, 1941).

Soon, others confirmed the aforementioned research and revealed that Class II malocclusions of both div 1 and div 2 do not lack any development of the mandible. In addition to this, the maxillary first molar may be in a more posterior position than previously thought in Class II malocclusions. Due to the more horizontal position of the mandibular plane, the chin button is as far forward in Class II patients as it is in Class I patients (Renfroe, 1941).

The morphology of retrognathic mandibles was also of concern. Examination of a sample population showed that patients exhibit significant differences in craniofacial anatomy. Class II, div 1 males are larger than Class I males in terms of overall maxillary length but not in overall mandibular length. The maxillary first molar is further forward and the maxillary central incisor and anterior nasal spine are farther forward in relation to Sella in Class II, div 1 males (Elsasser, 1948).

While attention was being given to Class II malocclusions, the necessity arose to examine Class III malocclusions in a similar manner. Through similar methodology, the etiological factors of Class III malocclusion were systematically examined. Compared to Class I malocclusions, Class III malocclusions show the molars are further forward in the cranial base and the position assumed by the upper first molar is distinct in all cases. The height of the mandible in the molar region of Class III malocclusions is shorter but, the height of the symphysis is higher than compared to Class I and Class II patients. The angle formed by the occlusal plane to the inferior border of the mandible is also larger in Class III as compared to Class I and Class II patients (Shoenwetter, 1940). Expanding upon previous works, other conclusions included Class III malocclusions are an alteration in pattern, they are more likely the continuation of growth beyond the norm, and all Class III malocclusions have a distinguishing facial pattern, the main feature being elongation of the face (Stapf, 1948).

The assessment of the skeletal pattern of Class III patients and normal occlusion patients afforded the ability to examine previous Class III research in a new light. Evidence shows Class III malocclusions do not imply typical facial skeletal patterns. Various types of skeletal profiles are associated with Class III malocclusions. The maxilla of Class III patients tends to be less prognathic than normal patients, with the mandible being more prognathic than normal patients. Angular measurements show the lower border of the mandible has a steeper incline, the upper incisors are inclined further to the labial relative to the palatal occlusal plane, and the lower incisors are inclined further to the lingual relative to the lower mandibular border and occlusal plane. There is no significance between Class III and normal patients in the length of the body of the mandible from gonion to gnathion and on the ramus between articulare and gonion (Sanborn, 1955).

Examinations of different malocclusions on the facial pattern were also assessed. The comparison of the characteristics of untreated patients with excellent occlusions and patients who had Class II malocclusions showed Class II patient's facial patterns exhibited variability within the group (Drelich, 1948). Through examination of the relationship of maxillary structures to the cranium in malocclusion and in normal occlusion, evidence lead toward the use of cephalometrics to record the relationship the upper incisors form with the planes of the head (Riedel, 1948). Further examination of the skeletal pattern characteristics of Class I and Class II, div 1 malocclusions revealed the two groups to be similar except for that the body of the

mandible appears shorter, and the mandibular first molar appears more posterior in the Class II, div 1 patients (Craig, 1950). Skeletal morphological comparisons between Class I, Class II, div 1 and Class II, div 2 malocclusions show a high degree of variability exists between facial patterns of the different malocclusions examined. Class I and Class II, div 1 malocclusions appear similar (Blair, 1952). Still other morphological studies of the adult mandible in Class II malocclusion and normal occlusion show mandibles in Class II, div 1 patients are smaller than patients with excellent occlusions. The position of the mandibular first molar is not constant in its relation to the mandible. Also noteworthy is no significant difference in the size of the anterior cranial base between the two groups exists (Gilmore, 1950).

From knowledge gained through the analysis of etiological factors that affect dental malocclusion facial growth and development and orthodontics evolved past the idea that if the occlusion was guided in place form and function would follow.

2.6.2 Facial Growth and Development

Early developmental studies noted a generalized decrease in facial convexity as well as increases in vertical height in comparisons between boys and men (Bjork, 1947; Lande, 1952). It was inferred, growth of the crania and maxilla occurs harmoniously, whereas the mandible tends to be more prognathic (Lande, 1952). In a separate study Bjork, suggests changes in the cranial base are common during the

growth period. Any change of the cranial base will displace the maxilla and mandible in the opposite direction.

Later, more specific craniofacial examination revealed no variation in the craniofacial profile and denture patterns between 12.8 year old males and females. Also, it was shown as a result of changes which occur in the craniofacial proportions, the 12.8 year old child has a more retrognathic, convex skeletal profile, steeper mandibular plane, and a more protrusive denture compared to the 16 year old (Prosterman, 1960).

Other studies used linear and angular measurements to investigate individual variations in the growth pattern of the cranial base. Growth patterns of the components of the cranial base display rhythmic alterations, periods of acceleration, deceleration, and plateaus in growth are evident. Not only are changes in the cranial base common during the growth period, no two individuals possess the same growth pattern rhythms. The spheno-occipital synchondrosis shows fluctuations at various rhythmic patterns giving the appearance it is adjustable. Only slight increase in depth of the anterior fossa occurs after seven years of age and frontal bone thickness is approximately three times greater in males. The anterior cranial fossa has a neural growth rate while the posterior cranial base and frontal bone thickness approximate the rate of general skeletal growth (Pederson, 1962).

Viewing previous cross-sectional studies as inadequate for a complete understanding of individual variation, Jensen concerned himself with accurate

interpretation of growth response and its clinical application. The substantiation of Pederson's earlier claim that, "growth of the anterior cranial fossa follows the neural growth curve, which contributes little to growth after age seven", was paramount to Jensen's work. He also found growth due to apposition and changes in the frontal bone and the increase in size of the posterior cranial base follow the general growth described by Scammon. Other important discoveries included, individual rhythmic variation in the posterior cranial base coincides with a change in flexure of the overall cranial base. Growth in males is more vertical than females, as males have a greater increase in cranial base flexion. In females the sella angle is more obtuse contributing to upper face depth. The analysis of flexural changes needs to be done on an individual basis rather than on a central tendency which creates an erroneous depiction of the data. The general growth rhythms differ between sexes and intra-sex variability is greater in males. Females show their greatest growth between ages 7 and 14 with the greatest circumpubertal increment between ages 11 and 13. In males circumpubertal growth spurt is between 13 and 15 followed by a post-adolescent spurt between 16 and 17. Middle face depth increases slightly more than cranial base depth in females compared to males. Lower face depth increases greater than middle or cranial base depth in both sexes. Increase in height of the anterior face is continuous, with minor fluctuations in both sexes. The greatest increase in posterior face height occurs between ages 12-17 in males and ages 11-13 in females (Jensen, 1964).

2.7 Clinical Cephalometric Analyses

Clinical cephalometric analyses may be divided into two general categories. Analyses such as the Downs, Tweed and Steiner describe the facial form of an individual and evaluate the parameters of the functional esthetic balance of the dentition with a particular profile. The second type of analyses consists of those which define the total morphologic pattern and its growth, the Coben Analysis is in this category.

Both the Coben and Downs analyses employ a common reference plane – Frankfort Horizontal. Therefore, the analyses complement each other. The Downs analysis assesses the proportional dimensions of the profile through angular measurements, while the Coben analysis explains the same structural associations in terms of linear measurements and ratios within the total craniofacial blueprint (Coben, 1986).

2.7.1 Downs Analysis

Downs based his analysis on a sample of 20 children aged 12 to 17 years all with excellent occlusion. The analysis includes the lines Nasion to Pogonion, Nasion to “A” point, “A” point to “B” point, “A” point to Pogonion, Sell to Gnathion, the occlusal plane, mandibular plane, the long axis of the upper and lower incisors, and the Frankfort horizontal plane. The Downs analysis is concerned with the profile, as

the primary reference plane is Frankfort horizontal. The only vertical assessment is with the mandibular plane and y-axis (Enlow, 1975).

2.7.2 Steiner Analysis

The Steiner analysis is profile oriented and provides visualization of incisor position and anterior facial profile detail. Steiner related the maxillary and mandibular central incisors to the skeletal profile plane and established standards. The mean position for the maxillary incisor is 4 millimeters in front of the Nasion – “A” point Plane, and the axial inclination is 22 degrees. The mandibular incisor occupied a position 4 millimeters anterior to the Nasion – “B” point Plane, and the axial inclination is 25 degrees. The Steiner analysis is based on a single reference plane, that being Sella to Nasion, and does not take into account variations in length or cant of this reference plane (Enlow, 1975).

2.7.3 Tweed Analysis

Tweed, based on clinical observation, believed that the most stable and esthetic results are obtained when the lower incisor teeth are positioned upright over the basal bone of the mandible. He later related the positions and inclinations of the mandibular incisors to their dental base by using sectioned models. Normal occlusion was impossible without a normal facial pattern according to Tweed. The original maxillofacial triangle was introduced by Margolis for use with a lateral cephalometric

radiograph. Tweed modified the triangle, which consists of the Frankfort horizontal plane, the mandibular plane, and the long axis of the lower incisors. The angles formed by the triangle are the Frankfort-mandibular plane (FMA), the lower incisors to mandibular plane (IMPA), and the lower incisors to Frankfort horizontal (FMIA). The foundation is the FMA angle, and treatment is dictated by this angle. An FMA of 16 to 28 degrees indicates a good prognosis. An FMA between 28 and 35 degrees indicates a fair prognosis. The Tweed analysis is used for clinical treatment planning by establishing the position where the lower incisors should be located (Enlow, 1975).

2.7.4 Wylie Analysis

The Wylie analysis derived from a sample of males and females with an average age of 11 years, 6 months. All of the measurements except mandibular length are made parallel to the Frankfort horizontal plane from projections to the following points: posterior border of the condyle, sella, PTM, upper first molar, and the anterior nasal spine. The mandibular plane is drawn and perpendicular projections made to the posterior border of the condyle and pogonion for mandibular length.

The analysis provides a means of evaluation anteroposterior size and position of the maxilla and mandible. For maxillary measurements below the norm, the difference is placed in the prognathic column, and values above the norm in the orthognathic column. For mandibular measurements above the norm, the difference

is put in the prognathic column and in the orthognathic column when the measurements are below normal (Enlow, 1975).

2.7.5 Coben Analysis

Previous studies directed toward the analysis of the variation of facial profiles focused only on depth dimensions, particularly those of Downs, Steiner and Wylie. Little attention was placed on variation of facial height, the influence of the cranial base, and integration of all the variants in the overall facial pattern. The previous studies were of a “static” nature based upon morphology of faces at a single age period, and were of limited clinical usefulness. More important was to understand the growth behavior of the individual face and the changes of the facial profile over time (Coben, 1955).

The need arose to analyze the integration of skeletal variants that resulted in different facial types, the growth behavior and adjustments of cranial and facial structures within the individual face, and the manner in which growth might modify facial form. The coordinate method of analysis capable of orienting the head relative to the Frankfort Horizontal plane became known as the Coben Analysis. The Coben analysis offers the opportunity to quantify the contributions from the various craniofacial components to the entire craniofacial complex. Along with this method of analysis, a longitudinal cephalometric radiographic study of 47 Caucasians, 25 males and 22 females was presented. Two radiographs taken at ages 8 and 16 years were

used for each child. The findings were divided into two phases. The first phase included the statistical analysis of the morphology and growth of the total sample. The second phase included the analysis of individual patterns, or the characteristics of the total sample serving as a basis for comparison. Upon analysis of growth between 8 and 16 years of age males were found to exceed females in facial depth measurements. More significant was that males exceeded females in vertical growth measurements. Both sexes were found to show the most growth in lower face depths, with an equal increase in the middle face and cranial base. In males, anterior face height exceeded posterior face height and lower face depth. In the female, anterior and posterior face height were equal to lower face depth. Males showed more variability in growth than females. The relative height of the posterior face increased in both male and female subjects. Slight differences in proportion of the component segments of anterior face height occurred in both sexes (Coben, 1955).

The advantage presented by the Coben analysis is in the ability to understand the skeletal variation among faces. The relation of the head to the Frankfort Horizontal plane allows for the patient to be visualized in his/her postural position. This aids in the ability to understand variations in treatment response of different growth patterns (Coben, 1955).

Although morphologic assessment is a major application of the Coben Analysis, the primary contribution lies in the application to growth and tooth movement. The same system used for the morphologic analysis quantifies growth of

craniofacial structures and their combined effect on facial form, the position of the teeth and the pattern of the profile.

Curves that portray measures of central tendency do not offer a keen insight of growth processes and their interrelations. Curves meant to portray a central tendency must be compared with individual trends in order to have a true biological definition (Hixon, 1960). This validates the idea, more importantly than the description of growth and development in generalized terms is how an individual face differs from the average, and the factors that lead to the difference (Coben 1955).

2.8 Basion Horizontal Plane of Orientation

The Coben analysis employs basion as point (0,0) on the coordinate plane. Basion Horizontal is defined as a cephalometric horizontal plane parallel to Frankfort Horizontal, whose point of origin is Basion (Coben, 1961). It represents the foramen magnum plane of orientation and depicts a philosophy of growth which holds that craniofacial growth is reflected away from the foramen magnum. Growth of the cranial base translates the upper face and maxillary dentition upward and forward away from the foramen magnum. Growth of the mandible translates the lower dentition downward and forward. The two diverging vectors create space for vertical facial development and tooth eruption (Coben, 1961).

2.9 Sutural Growth and the Cranial Base

The Coben analysis is based upon the philosophy that the anterior half of the craniomaxillary complex is carried in a general upward and forward direction by growth of the sphenoid-occipital synchondrosis until the synchondrosis closes after puberty (Brodie, 1963; Coben 1966). Expansion of the cranial base is a result of cartilaginous growth between bones and expansive forces originating from the growing brain, as suggested by Moss. These forces displace the bones at the suture lines. The synchondroses, through interstitial growth separate adjacent bones as appositional bone growth adds to the edge of the sutures. Through this method growth of bones within the ventral midline, cribriform plate of the ethmoid, presphenoid, basisphenoid and basoccipital bones contribute to the growth of the cranial base. The cartilage between these bones contributes variably to cranial elongation and lateral expansion. The sphenofrontal, frontoethmoidal and sphenoid-ethmoidal sutures contribute growth in the anteroposterior length of the anterior cranial fossa. The frontoethmoidal and sphenoid-ethmoidal sutures stop adding to sagittal plane growth after 7 years of age (Sperber, 2001).

Two distinct phases of craniofacial growth exist due to a change in upper facial development after the approximate age of seven. Before age seven, growth of the upper face is dominated by the nasal septum, the eyes and the sphenoid-ethmoidal/circum-maxillary suture system. At this age, growth of the suture system produces space for the eruption of the maxillary first molars. Longitudinal cephalometric studies that suggest a continuous increase in the Sella-Frontal

dimension with little increase in the thickness of the frontal bone before age seven support the concept that bone apposition and remodeling resorption are minor factors in the early years of life (Pederson, 1962).

At approximately age seven, growth of the upper face changes with the closure of the speno-ethmoidal suture. The Sella-Frontale dimension stabilizes, while the thickness of the frontal bone begins to increase by surface apposition and remodels until maturity. After age seven, the initial primary system of speno-ethmoidal/circum-maxillary sutural growth of the upper face is replaced by surface apposition and remodeling resorption. In later examination, Scott, reasoned that the speno-ethmoidal suture must be viewed as part of the major circum-maxillary suture system, and that once part of the suture closes, there is no further growth in that suture system.

The above description of growth is utilized in the Coben analysis. The Coben philosophy emphasizes that the speno-occipital synchondrosis is the key to comprehension of craniofacial growth in its true form.

2.9.1 Speno-occipital synchondrosis and cranial growth

Postnatal growth in the speno-occipital synchondrosis is the major contributor to growth of the cranial base, persisting into early adulthood. This prolonged growth period allows for continued posterior expansion of the maxilla to accommodate later erupting molar teeth and provides space for the growing

nasopharynx. The spheno-occipital suture is the last synchondroses to fuse, beginning on its cerebral surface at 12 to 13 years in girls and 14 to 15 years in boys and completing ossification of the external aspect by 20 years of age (Sperber, 2001).

The role of the spheno-occipital synchondrosis in craniofacial growth, as it affects the spatial position of the upper face and maxillary dentition, is masked by the traditional method of superimposing cephalometric tracings on the anterior cranial base. Furthermore, the erroneous assumption that the overall direction of growth of the face is demonstrated by superimposing stable areas of the anterior cranial base has led to gross misrepresentation of treatment results throughout orthodontic literature. Problems arise, not when studies quantify changes within the face relative to the anterior cranial base but, when the anterior cranial base is superimposed to demonstrate the directional expression of growth of the entire face in order to interpret the skeletal effects of orthodontic treatment (Coben, 1998).

Further analysis reveals the sagittal relationship of articulare to the anterior border of the foramen magnum, basion, does not change postnatal (Coben, 1955; Ferrer, 1964; Jensen, 1964). This claim was further verified. Between ages 5 and 20 the distance between basion and articulare remains essentially constant (Seward, 1981).

CHAPTER 3

AIM OF THE INVESTIGATION

The purpose of this thesis is threefold: 1.) to compare the original norms and standard deviations of the original Coben study to the measurements taken on today's patients, 2.) to address any changes in the norms due to secular trends, and 3.) to create a method so the Coben analysis can be calculated using digital cephalometric radiographs.

Currently, the Coben Analysis requires complex hand measurements and difficult calculations. As more orthodontic offices and clinics become dependent on new technology it has become necessary to update the Coben analysis to fit this new trend. Along with a novel method for analyzing digital cephalometric radiographs using the Coben analysis it is also necessary to evaluate the original normal values and assess any secular trends in the data between today's patient and those in the original study.

CHAPTER 4

MATERIALS AND METHODS

4.1 Introduction

All data presented in this thesis were based upon orthodontic treatment records at the subjects' initial or pretreatment records appointment. The following report includes a description of the hardware and software systems needed for data collection. The subject selection, data collection, and data manipulation are also described.

4.2 Subject Selection

The following inclusion criteria were observed in order to standardize data collection. Patients included in the sample were between the ages of seven and eighteen years, the subjects were seeking orthodontic treatment from a local orthodontist. Subjects were limited to those who had pretreatment digital lateral cephalometric radiograph with the nasion support and millimeter ruler visible in the image. All patients were Caucasian and diagnosed as Angle Class I. Subjects were of three age groups 7-10, 11-14 and 15-18. Of the 1,100 pretreatment records reviewed 279 subjects were selected upon the above criteria. The 279 subjects were separated as follows: 53 males age seven to ten, 43 females age seven to ten, 45 males age eleven

to fourteen, 50 females age eleven to fourteen, 41 males age fifteen to eighteen and 47 females age fifteen to eighteen.

4.3 Diagnostic Records

Pretreatment digital lateral cephalometric radiographs with the Nasion support and millimeter ruler visible in the radiograph were collected for this study (figure 4.1). Orthodontic models, clinical examination forms, medical and family histories were not included.

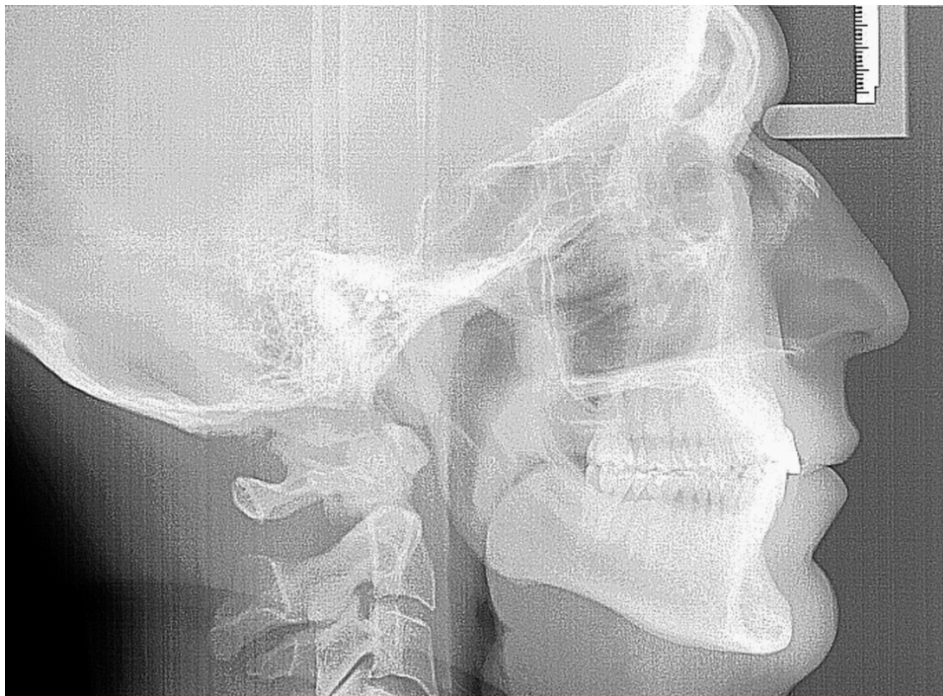


Figure 4.1 – Lateral Cephalometric Radiograph with Nasion support and millimeter ruler

4.4 Data Collection

Facial form and postural head position were correlated by using The Frankfort Horizontal Plane as the plane of orientation. Qualifying subjects' pretreatment lateral

cephalometric radiographs were initially analyzed using Dolphin 11.0 digital imaging software; cephalometric points were plotted according to Coben analysis standards (figures 4.2). The cephalometric points, planes and angles used for the Coben Analysis are defined in the glossary (appendix A). To ensure accuracy of cephalometric points, all digital cephalometric images were replotted using ImageJ software made available by NIH (figure 4.3). The millimeter ruler in the nasion support was plotted at zero and the highest viewable millimeter measurement possible after the digital Cephalometric radiograph was oriented parallel to the Frankfort horizontal plane. The millimeter measurement was then recorded in the excel spreadsheet for each individual radiograph as to ensure each radiograph was scaled properly. The use of the Frankfort Horizontal Plane as the plane of orientation combined with the ImageJ program allowed each digital tracing to essentially be divided into a coordinate system of lines in the same method described by Coben. Basion (Ba) is designated as the point of registration, with lines parallel to Frankfort Horizontal as the abscissas (x-coordinate) and lines perpendicular to Frankfort Horizontal as ordinates (y-coordinate). The abscissa parallel to Frankfort Horizontal whose point of origin is Basion (Ba) is designated Basion Horizontal (BaH) and represents the foramen magnum plane of orientation. Facial depth can then be measured as millimeters depth from Basion (Ba) along abscissas parallel to Basion Horizontal (fig. 4.7). Facial height is measured superiorly and inferiorly from Basion Horizontal along the ordinates (y-coordinates) termed Basion verticals (BaV) (fig. 4.6).

All data plotted using the ImageJ software was then imported to microsoft excel (figure 4.4 and 4.5) to express the linear and proportional measurements described by Coben (Coben, 1955).

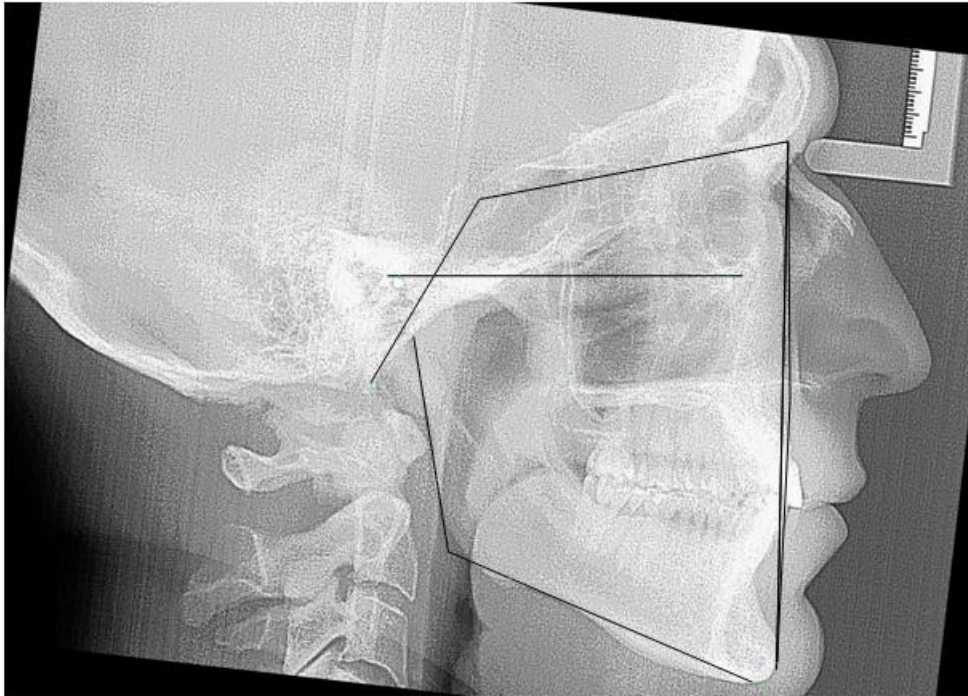


Figure 4.2 Dolphin Imaging 11.0 traced lateral cephalometric radiograph

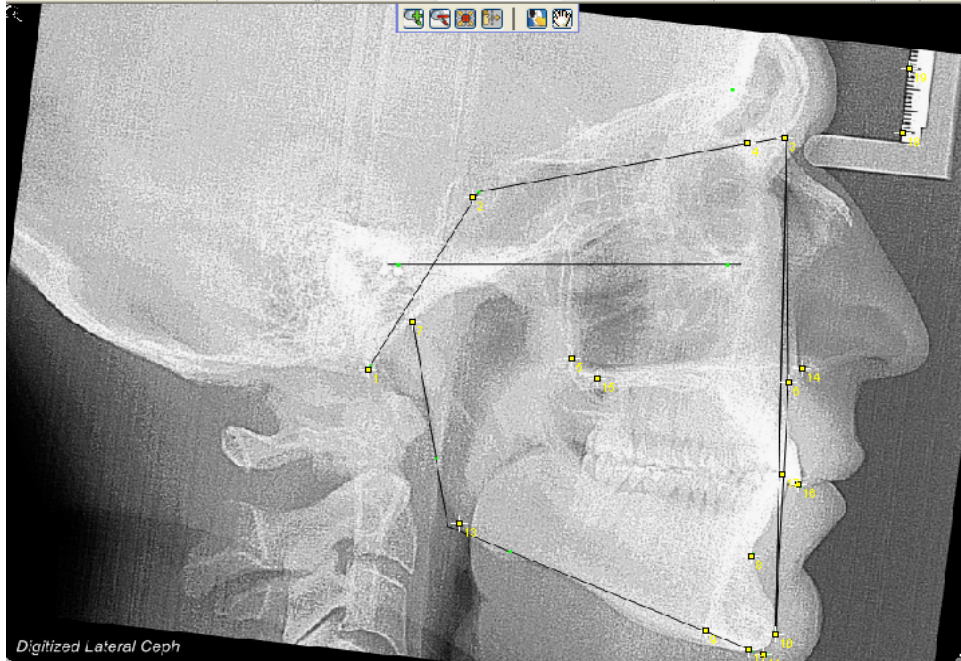


Figure 4.3 ImageJ traced lateral cephalometric radiograph

					x	y			x'	y'	x''	y''	x'''	y'''
Basion	1	0	201	201	201	816	1124	1	816	10876	0	0	0	0
Sella	2	0	213	213	213	1008	536	1	1008	11464	192	588	15.11366	46.28559
Nasion	3	0	48	48	48	1884	284	1	1884	11716	1068	840	84.06975	66.12227
Frontale	4	0	184	184	184	1732	320	1	1732	11680	916	804	72.10476	63.28846
Ptm	5	0	231	231	231	1340	936	1	1340	11064	524	188	41.2477	14.79879
A point	6	0	184	184	184	1924	1024	1	1924	10976	1108	100	87.21843	7.871699
Articulare	7	0	247	247	247	900	944	1	900	11056	84	180	6.612227	14.16906
B point	8	0	160	160	160	1952	1500	1	1952	10500	1136	-376	89.4225	-29.5976
B' point	9	0	192	192	192	1844	1764	1	1844	10236	1028	-640	80.92107	-50.3789
Po	10	0	174	174	174	2024	1764	1	2024	10236	1208	-640	95.09012	-50.3789
Po'	11	0	77	77	77	1976	1808	1	1976	10192	1160	-684	91.31171	-53.8424
Menton	12	0	160	160	160	1952	1796	1	1952	10204	1136	-672	89.4225	-52.8978
Gonion	13	0	159	159	159	1204	1552	1	1204	10448	388	-428	30.54219	-33.6909
ANS	14	0	144	144	144	1988	936	1	1988	11064	1172	188	92.25631	14.79879
PNS	15	0	197	197	197	1384	1072	1	1384	10928	568	52	44.71125	4.093283
Max 1	16	0	159	159	159	2044	1280	1	2044	10720	1228	-156	96.66446	-12.2799
Man 1	17	0	173	173	173	1992	1248	1	1992	10752	1176	-124	92.57118	-9.76091
Ruler 1	18	0	105	105	105	2464	956	1	2464	11044	1648	168	129.7256	13.22445
Ruler 2	19	0	23	23	23	2452	16	1	2452	11984	1636	1108	128.781	87.21843
mm	74													

Figure 4.4 ImageJ excel spreadsheet data entry form

Standard Deviation Conventions		BASION HORIZONTAL							
Within 1 standard deviation (clear)		COBEN COORDINATE CRANIOFACIAL ANALYSIS							
Greater than 1 standard deviations (Yellow)		Name: XXXXXXXXXX		AGE 16 YRS +/- 1 YR MALE					
Greater than 2 standard deviations (Red)		ID: XXXX							
Measurement Descriptions		Birth: XX/XX/XXXX		LINEAR	MEAN	S.D.	PROPORTIONS	MEAN	S.D.
		Age: Xxy.XXm							
CRANIAL BASE	Post cranial base	Ba.S (a.l.)	46.3 mm	45.1	1.53				
	Increment & direction of spheno-occipital synchondrosis	Ba.S angle (S.Ba.BaH)	60.2 °	58.9	3.92				
	Effective depth of post cranial base	Ba.S	23.0 mm	23.1	3.08				
	Ant cranial base	S.N (a.l.)	69.7 mm	70.3	1.04				
	S to constructed F (closely represents true ant cranial base)	S.F (a.l.)	61.5 mm	58.7	2.50				
	Constructed F to N (thickness of frontal bone)	F.N (a.l.)	8.2 mm	11.6	2.28				
	Inclination of ant cranial base	S.N angle (N.S.BaH)	11.5 °	6.3	3.19				
	Effective depth of ant cranial base	S.N	68.3 mm	69.7	1.18				
	Cranial base angle	S angle (180° + S.N angle - Ba.S angle)	131.3 °	127.4	4.70				
	Total effective depth of cranial base	Ba.N	91.3 mm	92.8	3.90				
FACIAL DEPTH	Effective depth of post cranial base	Ba.S	23.0 mm	23.1	3.08	25.2 % Ba.N	24.8	2.58	
	Spatial Relation to Max (pterygoid region)	S.Ptm	21.8 mm	19.2	2.12	23.8 % Ba.N	20.7	2.66	
	Effective depth of max	Ptm.A	47.6 mm	48.1	2.22	52.1 % Ba.N	51.9	2.98	
	Total effective depth of midface	Ba.A	92.3 mm	90.4	3.81	101.1 % Ba.N	97.4	3.81	
	Ant-post position of the mandible relative to Ba	Ba.Ar	9.9 mm	8.1	2.57	10.8 % Ba.N	8.7	2.67	
	Effective depth of the mandible itself	Ar.Po	79.4 mm	79.9	6.86	87.0 % Ba.N	86.2	8.81	
	Effective depth of mandibular apical base	Ba.B (Ba.Po - B.Po)	84.0 mm	84.8	5.80	92.0 % Ba.N	91.5	6.55	
	Total effective depth of lower face	Ba.Po	89.3 mm	88.0	7.17	97.8 % Ba.N	95.0	8.92	
	Absolute length of ramus	Ar.Go (a.l.)	47.9 mm	49.5	4.27	52.4 % Ba.N	53.3	4.82	
	Angle of ramus plane from perp to Ba-H (+ = forward)	RI angle	12.2 °	8.1	4.69				
	Effective depth of ramus	Ar.Go	10.1 mm	7.0	4.31	11.1 % Ba.N	7.5	4.67	
	Absolute length of the mandibular body	Go.Po' (a.l.)	73.5 mm	76.7	4.38	80.4 % Ba.N	82.8	5.79	
	Mandibular plane angle	MPI angle	24.8 °	23.9	4.94				
	Anatomic chin	B'.Po' (a.l.)	13.8 mm	9.1	2.60	15.1 % Ba.N	9.9	2.87	
	Effective depth of chin	B.Po	5.3 mm	3.2	3.24	5.8 % Ba.N	3.5	3.58	
	Effective depth of mandibular body	Go.Po	69.3 mm	72.9	4.99	75.9 % Ba.N	78.7	6.46	
	Gonial angle	Go angle (90° + RI angle + MPI angle)	127.0 °	122.0	6.38				
	FACIAL HEIGHT	Total ant facial height	N.M	119.1 mm	116.3	5.74	130.5 % Ba.N	125.4	6.18
Effective height of post cranial base		Ba.S	40.2 mm	38.3	2.54	33.8 % NM	33.0	2.40	
Effective height of ant cranial base		S.N	13.9 mm	7.5	3.76	11.7 % NM	6.4	3.15	
Total effective height of cranial base		Ba.N	54.1 mm	45.8	4.03	45.4 % NM	39.4	3.11	
Effective height of lower post face		Ba.Go	35.7 mm	41.4	4.74	29.9 % NM	35.7	4.27	
Effective height of ramus		Ar.Go	46.8 mm	48.8	4.42	39.3 % NM	42.1	4.07	
Superior position of Ar relative to Ba		Ba.Ar	11.1 mm	7.4	1.83	9.3 % NM	6.4	1.58	
Effective height of mandibular corpus		Go.M	29.3 mm	29.1	5.60	24.6 % NM	24.9	4.28	
Total effective height of lower face		Ba.M	65.0 mm	70.5	5.36	54.6 % NM	60.6	3.11	
Effective height of the midface		S.Go (Ba.S + Ba.Go)	75.9 mm	79.7	4.39	63.7 % NM	68.7	4.51	
Vertical Position of posterior palate		Ba.Pns	-2.0 mm	-5.0	2.81	-1.7 % NM	-4.4	2.18	
Vertical Position of anterior palate		Ba.Ans	0.3 mm	-7.8	5.09	0.2 % NM	-6.8	4.41	
Palatal plane inclination		Pal angle	-2.9 °	-3.2	5.83				
Effective anterior mid-face height		N.Ans	53.9 mm	53.6	3.16	45.2 % NM	46.2	2.47	
Effective maxillary dental height (ANS to incisal edge)		Ans_1	26.8 mm	26.9	3.08	22.5 % NM	23.1	2.22	
Effective mandibular dental height (M to incisal edge)		M_1	40.7 mm	39.5	2.78	34.2 % NM	34.0	1.53	
Over bite		1/1	-2.3 mm	-3.7	2.14	-1.9 % NM	-3.3	1.90	
Effective anterior lower face height		Ans.M	65.3 mm	62.7	4.87	54.8 % NM	53.8	2.47	

Figure 4.5 - Coben analysis excel spreadsheet measurements

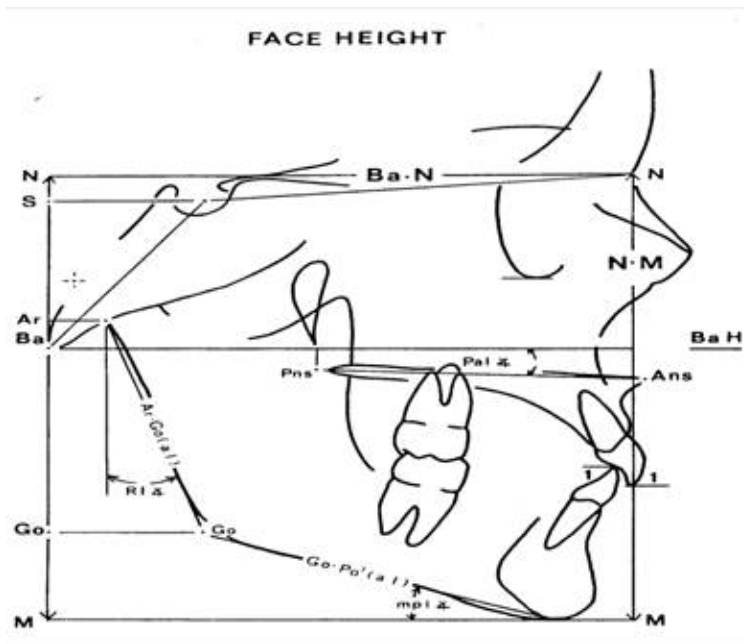


Figure 4.6 – Coben Analysis Facial Height points, planes and angles

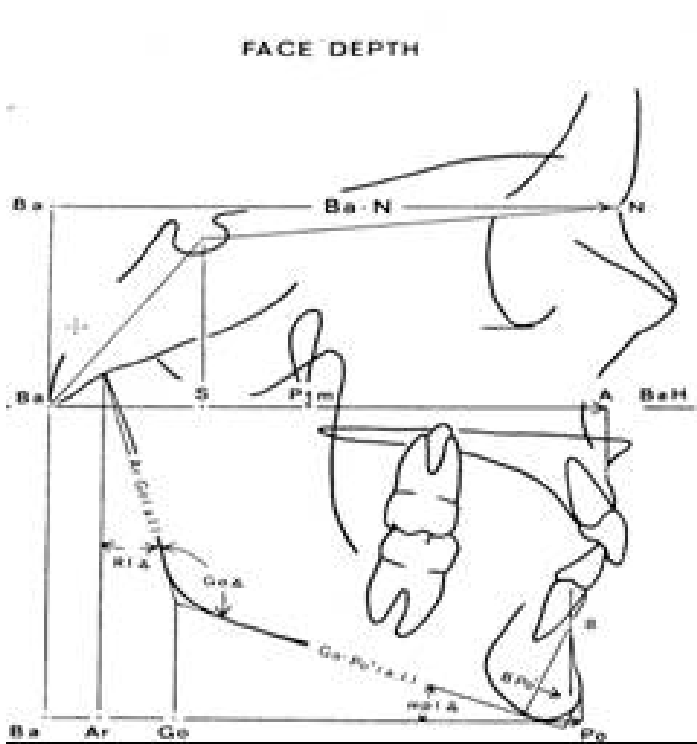


Figure 4.7 – Coben Analysis Facial Depth points, planes and angles

4.5 Hardware

Table 4.1 - Hardware

Component	Platform	Manufacturer
Computer	Microsoft	Dell
Digital Cephalometer	Orthopantomograph OP-100D	Instrumentarium

Hardware employed to analyze data is found in table 4.1. Data were obtained using a Dell Optiplex 760 computer. Lateral cephalometric radiographs were captured with the Instrumentarium OP-100D. The lateral cephalometric radiographs were digitally traced using a Dell Optiplex 760 computer.

4.6 Software

Table 4.2 - Software

Component	Platform	Manufacturer
Operating System	Windows XP	Microsoft
Digital Radiographs	Dolphin Imaging 11.0	Instrumentarium, Dolphin Imaging
Radiographic Tracings	Dolphin Imaging 11.0	Dolphin Imaging
Radiographic Tracings	ImageJ	NIH
Data Analysis	Excel	Microsoft

Software used to analyze data is found in table 4.2. Digital lateral cephalometric radiographs were taken with the OP-100D and stored via Dolphin Imaging 11.0. The radiographs were enhanced for optimum landmark visibility by gamma and blur/sharpen adjustments and were subsequently traced using Dolphin Imaging 11.0 software (fig. 4.1). All traced images were then retraced using ImageJ,

Java-based image processing program developed by NIH (fig. 4.2). ImageJ raw data was imported into Microsoft excel and converted to express Coben analysis measurements (fig. 4.4) as defined by Coben.

4.7 Data Analysis

Cephalometric points were measured using the ImageJ program and subsequently converted to millimeter measurements with Microsoft excel for all qualified digital lateral cephalometric radiographs. The averages and standard deviations were then acquired via Microsoft excel and compiled into 1 set of data points for each of the 6 groups previously described. The 6 new sets of data points were then compared to the original data sets compiled by Coben from his original study. Analysis includes mean averages, standard deviations and ranges of cranial base, facial height and facial depth linear and proportional measurements for the appropriate groups.

CHAPTER 5

RESULTS

5.1 Introduction

The procedures in data acquisition using Microsoft Excel were described in detail in the Materials and Methods section (Chapter 4). The aforementioned methods allowed for the production of Microsoft excel data for 279 Coben Analyses which were grouped by age and sex as previously described. The following includes the compilation of the data from this study in comparison to Coben's original data.

5.2 Males and Females 7 – 10 Years of Age Proportional Means

A total of 95 digitized lateral cephalometric radiographs of males and females between the ages of 7 and 10 with a median age of 8.35 years measured according to Coben analysis standards were compared to the original study. The following charts compare the facial depth (Table 3) and facial height (Table 4) measurements. Measurements as a percentage of the distance basion to nasion (%Ba-N) are recorded for facial depth. Measurements as a percentage of the distance nasion to menton (%N-M) are recorded for facial height. Both proportional measurements, with standard deviations and ranges are compared to the original study. Any measurements highlighted in yellow are one standard deviation outside the original norms.

Facial Depth (Table – 3)	Current Study (%Ba-N or °)	S.D.	Range	Original Study (%Ba-N or °)	S.D.	Range
Ba-N	83.2mm	5.10	70.1/99.1	83.1mm	3.75	75.0/92.5
Ba-S	25.6	2.98	18.5/31.6	24.9	2.19	19.9/29.7
S-Ptm	20.5	3.44	12.2/29.1	20.7	2.82	15.6/26.8
Ptm-A	50.8	3.43	42.2/58.3	51.4	2.59	44.8/57.0
Ba-A	96.9	3.95	87.9/105.9	97.0	3.24	90.7/105.1
Ba-Ar	10.0	2.58	3.03/19.3	9.9	2.63	5.2/15.4
Ar-Po	76.9	7.16	61.5/91.7	80.2	6.48	63.2/94.3
Ba-Po	86.9	6.95	71.8/105.0	90.1	6.38	73.6/107.0
Ar-Go (a.l.)	46.3	4.14	32.6/55.8	45.2	3.20	37.5/52.5
RI Angle	14.0	5.43	-1.8/24.3	9.8	4.98	-2.0/19.0
Ar-Go	11.2	4.60	-1.7/22.2	7.6	3.95	-1.1/14.5
Go-Po' (a.l.)	72.0	4.20	61.0/84.9	76.9	3.99	67.4/84.6
MPI Angle	29.4	5.33	18.7/43.5	26.4	4.07	18.0/36.0
Go-Po	65.7	5.30	54.6/79.9	72.6	4.44	62.8/81.5
Go Angle	133.3	6.19	121.5/147.9	126.2	5.41	114.0/138.0

Facial Height (Table – 4)	Current Study (%N-M or °)	S.D.	Range	Original Study (%N-M or °)	S.D.	Range
N-S	5.8	4.92	-1.21/16.5	7.1	3.69	-0.5/15.4
Ar-Go	39.0	3.58	28.9/46.1	38.5	2.76	32.0/44.8
S-Go	65.1	4.18	53.9/73.6	65.0	3.79	58.2/73.0
N-Ans	45.4	2.10	39.3/50.4	45.8	2.18	41.3/50.5
Ans-U1	23.4	2.90	11.3/28.7	23.8	2.18	18.7/27.4
M-L1	32.5	1.90	27.9/37.3	33.4	1.76	29.5/36.8
U1-L1	-1.3	3.32	-6.2/12.3	3.0	2.45	-4.5/8.8
Ans-M	54.6	2.10	49.6/60.7	54.2	2.18	49.5/58.7
N-M	114.8%Ba-N	7.54	99.7/135.7	115.3%Ba-N	6.56	95.1/127.3

5.3 Males 7 – 10 Years of Age

A total of 53 digitized lateral cephalometric radiographs of males between the ages of 7 and 10 with a median age of 8.17 years measured according to Coben analysis standards were compared to the original study. The following charts compare the cranial base (Table 5), facial depth (Table 6) and facial height (Table 7) measurements. Measurements in millimeters (mm) and angles in degrees (°) are compared along with standard deviations for both studies. For facial depth and facial height the proportional measurements are also included. Any measurements highlighted in yellow are one standard deviation outside the norm.

Cranial Base (Table – 5)	Current Study (mm or °)	S.D. (±)	Original Study (mm or °)	S.D. (±)
Posterior Cranial Base (Ba-S a.l.)	40.2	3.22	38.9	2.25
Increment and Direction of Spheno-occipital Synchondrosis (Ba-S angle)	57.4	5.35	57.5	3.61
Effective Depth of the Posterior Cranial Base (Ba-S)	21.6	3.62	20.7	2.42
Anterior Cranial Base (S-N a.l.)	62.7	3.06	63.0	2.44
S to Constructed F (S-F a.l.)	57.9	3.19	57.8	2.54
Thickness of Frontal Bone (F-N a.l.)	4.9	1.31	5.2	1.74
Inclination of Anterior Cranial Base (S-N angle)	5.2	4.85	6.3	3.19
Effective Depth of Anterior Cranial Base (S-N)	62.3	3.09	62.4	2.51
Cranial Base Angle (S angle)	127.8	5.35	128.8	4.56
Total Effective Depth of Cranial Base (Ba-N)	83.8	5.01	83.1	3.75

Facial Depth (Table – 6)	Current Study (mm or °)	S.D. (±)	Original Study (mm or °)	S.D. (±)	Proportions (%Ba-N)	Mean	S.D.
Effective depth of post cranial base (Ba-S)	21.6	3.62	20.7	2.42	25.7	24.9	2.16
Spatial Relation to Max (S-Ptm)	17.2	2.96	17.2	1.90	20.5	20.7	2.47
Effective depth of maxilla (Ptm-A)	43.0	2.65	42.7	1.96	51.2	51.4	2.59
Total effective depth of the midface (Ba-A)	81.7	4.71	80.6	3.50	97.5	97.0	3.24
Ant-post position of the mandible relative to Basion (Ba-Ar)	8.6	2.54	8.3	2.31	10.2	9.9	2.60
Effective depth of the mandible itself (Ar-Po)	64.6	6.62	66.7	4.86	77.1	80.2	6.48
Effective depth of mandibular apical base (Ba-B)	74.4	5.84	74.9	4.49	88.8	90.1	5.50
Total effective depth of lower face (Ba-Po)	73.2	6.98	74.9	5.33	87.3	90.1	6.38
Absolute length of ramus (Ar-Go a.l.)	38.9	3.73	37.6	2.97	46.4	45.2	3.20
Ramal Inclination (RI angle)	14.2	5.19	9.8	4.98			
Effective depth of the ramus (Ar-Go)	9.6	3.75	6.3	3.26	11.5	7.6	3.95
Absolute length of the mandibular body (Go-Po' a.l.)	60.1	4.28	64.1	2.87	71.7	76.9	3.99
Mandibular plane angle	29.2	5.48	26.4	4.07			
Anatomic chin (B'-Po' a.l.)	7.3	1.53	5.1	1.76	8.7	6.1	2.09
Effective depth of chin (B-Po)	-1.2	1.65	0.0	1.47	-1.5	0.0	1.78
Effective depth of mandibular body (Go-Po)	55.0	5.14	60.3	3.50	65.6	72.6	4.44
Gonial angle	133.4	6.35	126.2	5.41			

Facial Height (Table – 7)	Current Study (mm or °)	S.D. (±)	Original Study (mm or °)	S.D. (±)	Proportions	Mean	S.D.
Total ant facial height (N-M)	97.0	5.43	95.7	4.46	115.7	115.3	6.56
Effective height of post cranial base (Ba-S)	33.7	3.31	32.6	2.26	34.7	34.1	2.28
Effective height of ant cranial base (S-N)	5.7	5.24	6.8	3.49	5.9	7.1	3.68
Total effective height of cranial base (Ba-N)	39.4	6.48	39.4	3.86	40.6	41.2	3.80
Effective height of lower post face (Ba-Go)	29.5	4.41	29.6	3.52	30.4	30.9	3.27
Effective height of ramus (Ar-Go)	37.5	3.46	36.9	2.94	38.7	38.5	2.76
Superior position of Ar relative to Ba (Ba-Ar)	8.0	3.43	7.3	1.80	8.3	7.6	1.96
Effective height of mandibular corpus (Go-M)	28.1	4.73	26.7	3.56	29.0	27.9	3.35
Total effective height of lower face (Ba-M)	57.6	5.84	56.3	4.80	59.4	58.8	3.81
Effective height of the midface (S-Go)	63.2	4.12	62.3	4.19	65.2	65.0	3.79
Vertical Position of posterior palate (Ba-Pns)	-2.9	4.48	-2.1	2.84	-3.0	-2.2	2.83
Vertical Position of anterior palate (Ba-Ans)	-4.7	5.81	-4.4	4.52	-4.8	-4.6	4.68
Palatal plane inclination (Pal angle)	2.5	3.54	2.7	3.88			
Effective anterior mid-face height (N-Ans)	44.1	3.07	43.8	2.73	45.4	45.8	2.18
Effective maxillary dental height (ANS to incisal edge)	22.0	3.83	22.8	2.27	22.7	23.8	2.18
Effective mandibular dental height (M to incisal edge)	31.7	2.61	32.1	2.28	32.7	33.4	1.76
Overbite	-0.8	3.90	-3.0	2.37	-0.8	-3.0	2.45
Effective anterior lower face height (Ans-M)	52.9	3.62	51.9	3.22	54.6	54.2	2.18

5.4 Females 7 – 10 Years of Age

A total of 43 digitized lateral cephalometric radiographs of females between the ages of 7 and 10 with a median age of 8.67 years measured according to Coben analysis standards were compared to the original study. The following charts compare the cranial base (Table 8), facial depth (Table 9) and facial height (Table 10) measurements. Measurements in millimeters (mm) and angles in degrees (°) are compared along with standard deviations for both studies. For facial depth and facial height the proportional measurements are also included. Any measurements highlighted in yellow are one standard deviation outside the norm.

Cranial Base (Table – 8)	Current Study (mm or °)	S.D. (±)	Original Study (mm or °)	S.D. (±)
Posterior Cranial Base (Ba-S (a.l.))	37.6	3.52	38.9	2.25
Increment and Direction of Spheno-occipital Synchondrosis (Ba-S angle)	55.4	4.82	57.5	3.61
Effective Depth of the Posterior Cranial Base (Ba-S)	21.2	2.75	20.7	2.42
Anterior Cranial Base (S-N (a.l.))	61.7	4.19	63.0	2.44
S to Constructed F (S-F(a.l.))	56.1	4.45	57.8	2.54
Thickness of Frontal Bone (F-N (a.l.))	5.6	1.83	5.2	1.74
Inclination of Anterior Cranial Base (S-N angle)	5.2	3.75	6.3	3.19
Effective Depth of Anterior Cranial Base (S-N)	61.3	4.19	62.4	2.51
Cranial Base Angle (S angle)	129.7	5.99	128.8	4.56
Total Effective Depth of Cranial Base (Ba-N)	82.5	5.12	83.1	3.75

Facial Depth (Table – 9)	Current Study (mm or °)	S.D. (±)	Original Study (mm or °)	S.D. (±)	Proportions (%Ba-N)	Mean	S.D.
Effective depth of post cranial base (Ba-S)	21.2	2.75	20.7	2.42	25.7	24.9	2.16
Spatial Relation to Max (S-Ptm)	16.8	2.56	17.2	1.90	20.4	20.7	2.47
Effective depth of maxilla (Ptm-A)	41.5	3.33	42.7	1.96	50.3	51.4	2.59
Total effective depth of the midface (Ba-A)	79.4	5.25	80.6	3.50	96.3	97.0	3.24
Ant-post position of the mandible relative to Basion (Ba-Ar)	8.2	2.08	8.3	2.31	9.9	9.9	2.60
Effective depth of the mandible itself (Ar-Po)	63.4	6.18	66.7	4.86	76.9	80.2	6.48
Effective depth of mandibular apical base (Ba-B)	73.3	5.83	74.9	4.49	88.8	90.1	5.50
Total effective depth of lower face (Ba-Po)	71.6	6.32	74.9	5.33	86.8	90.1	6.38
Absolute length of ramus (Ar-Go a.l.)	38.1	3.71	37.6	2.97	46.2	45.2	3.20
Ramal Inclination (RI angle)	13.7	5.72	9.8	4.98			
Effective depth of the ramus (Ar-Go)	8.9	3.86	6.3	3.26	10.8	7.6	3.95
Absolute length of the mandibular body (Go-Po' a.l.)	59.8	5.06	64.1	2.87	72.5	76.9	3.99
Mandibular plane angle	29.6	5.15	26.4	4.07			
Anatomic chin (B'-Po' a.l.)	5.9	0.72	5.1	1.76	7.2	6.1	2.09
Effective depth of chin (B-Po)	-1.7	1.46	0.0	1.47	-2.1	0.0	1.78
Effective depth of mandibular body (Go-Po)	54.5	5.18	60.3	3.50	66.0	72.6	4.44
Gonial angle	133.3	6.00	126.2	5.41			

Facial Height (Table - 10)	Current Study (mm or °)	S.D. (±)	Original Study (mm or °)	S.D. (±)	Proportions	Mean	S.D.
Total ant facial height (N-M)	93.9	6.90	95.7	4.46	113.9	115.3	6.56
Effective height of post cranial base (Ba-S)	30.9	3.92	32.6	2.26	32.9	31.1	2.28
Effective height of ant cranial base (S-N)	5.5	4.06	6.8	3.49	5.9	7.1	3.68
Total effective height of cranial base (Ba-N)	36.5	4.92	39.4	3.86	38.8	41.2	3.80
Effective height of lower post face (Ba-Go)	29.9	4.15	29.6	3.52	31.8	30.9	3.27
Effective height of ramus (Ar-Go)	36.8	3.71	36.9	2.94	39.2	38.5	2.76
Superior position of Ar relative to Ba (Ba-Ar)	7.0	2.99	7.3	1.80	7.4	7.6	1.96
Effective height of mandibular corpus (Go-M)	27.6	5.24	26.7	3.56	29.4	27.9	3.35
Total effective height of lower face (Ba-M)	57.5	6.10	56.3	4.80	61.2	58.8	3.81
Effective height of the midface (S-Go)	60.8	5.16	62.3	4.19	64.7	65.0	3.79
Vertical Position of posterior palate (Ba-Pns)	-4.6	3.42	-2.1	2.84	-4.9	-2.2	2.83
Vertical Position of anterior palate (Ba-Ans)	-6.2	4.62	-4.4	4.52	-6.5	-4.6	4.68
Palatal plane inclination (Pal angle)	2.4	3.77	2.7	3.88			
Effective anterior mid-face height (N-Ans)	42.6	3.63	43.8	2.73	45.4	45.8	2.18
Effective maxillary dental height (ANS to incisal edge)	22.5	2.74	22.8	2.27	24.0	23.8	2.18
Effective mandibular dental height (M to incisal edge)	30.3	2.56	32.1	2.28	32.2	33.4	1.76
Overbite	-1.5	2.43	-3.0	2.37	-1.6	-3.0	2.45
Effective anterior lower face height (Ans-M)	51.3	51.9	3.22		54.6	54.2	2.18

5.5 Males 11 – 14 Years of Age

A total of 45 digitized lateral cephalometric radiographs of males between the ages of 11 and 14 with a median age of 11.58 years measured according to Coben analysis standards and compared to the original study. The following charts compare the cranial base (Table 11), facial depth (Table 12) and facial height (Table 13) measurements. Measurements in millimeters (mm) and angles in degrees (°) are compared along with standard deviations for both studies. For facial depth and facial height the proportional measurements are also included. Any measurements highlighted in yellow are one standard deviation outside the original norm.

Cranial Base (Table -11)	Current Study (mm or °)	S.D. (±)	Original Study (mm or °)	S.D. (±)
Posterior Cranial Base (Ba-S (a.l.))	43.1	3.98	42.3	2.24
Increment and Direction of Spheno-occipital Synchondrosis (Ba-S angle)	55.8	4.23	56.2	3.98
Effective Depth of the Posterior Cranial Base (Ba-S)	24.2	3.84	23.5	2.48
Anterior Cranial Base (S-N (a.l.))	67.5	4.22	65.9	2.82
S to Constructed F (S-F(a.l.))	60.5	4.03	59.7	2.35
Thickness of Frontal Bone (F-N (a.l.))	6.9	1.86	6.2	1.95
Inclination of Anterior Cranial Base (S-N angle)	3.8	3.68	7.0	3.17
Effective Depth of Anterior Cranial Base (S-N)	67.2	4.24	65.1	2.81
Cranial Base Angle (S angle)	128.0	4.83	130.8	4.09
Total Effective Depth of Cranial Base (Ba-N)	91.4	6.99	88.6	3.55

Facial Depth (Table - 12)	Current Study (mm or °)	S.D. (±)	Original Study (mm or °)	S.D. (±)	Proportions (%Ba-N)	Mean	S.D.
Effective depth of post cranial base (Ba-S)	24.2	3.84	23.5	2.48	26.5	26.4	2.29
Spatial Relation to Max (S-Ptm)	16.9	3.09	17.9	2.69	18.5	20.4	3.23
Effective depth of maxilla (Ptm-A)	45.8	3.51	44.7	2.24	50.1	50.4	2.56
Total effective depth of the midface (Ba-A)	86.9	5.74	86.1	3.36	95.1	97.2	3.37
Ant-post position of the mandible relative to Basion (Ba-Ar)	8.9	2.43	8.6	1.86	9.7	9.7	2.03
Effective depth of the mandible itself (Ar-Po)	70.6	5.70	73.7	5.30	77.3	83.2	6.58
Effective depth of mandibular apical base (Ba-B)	79.6	5.82	81.1	4.97	87.1	91.5	6.03
Total effective depth of lower face (Ba-Po)	79.4	6.02	82.3	5.32	87.0	92.9	6.50
Absolute length of ramus (Ar-Go a.l.)	41.1	4.25	42.2	3.80	45.0	47.6	4.34
Ramal Inclination (RI angle)	11.8	5.36	10.8	4.80			
Effective depth of the ramus (Ar-Go)	8.3	3.69	7.9	3.61	9.1	8.9	4.08
Absolute length of the mandibular body (Go-Po' a.l.)	68.4	4.47	69.6	3.76	74.9	78.6	4.61
Mandibular plane angle	29.6	4.76	26.0	4.21			
Anatomic chin (B'-Po' a.l.)	8.2	1.31	5.6	1.40	9.0	6.3	1.62
Effective depth of chin (B-Po)	-0.1	1.50	1.2	1.07	-0.2	1.4	1.23
Effective depth of mandibular body (Go-Po)	62.3	4.62	65.8	4.31	68.2	74.3	5.43
Gonial angle	131.4	5.52	126.8	5.30			

Facial Height (Table - 13)	Current Study (mm or °)	S.D. (±)	Original Study (mm or °)	S.D. (±)	Proportions	Mean	S.D.
Total ant facial height (N-M)	104.9	9.43	106.3	4.70	114.9	120.0	5.89
Effective height of post cranial base (Ba-S)	35.5	3.30	35.0	2.74	33.8	33.0	2.54
Effective height of ant cranial base (S-N)	4.5	4.26	7.9	3.60	4.3	7.4	3.38
Total effective height of cranial base (Ba-N)	40.0	5.29	42.9	4.98	38.1	40.4	4.38
Effective height of lower post face (Ba-Go)	32.5	4.87	34.0	4.29	30.9	32.0	3.85
Effective height of ramus (Ar-Go)	40.1	4.41	41.3	3.76	38.2	38.9	3.35
Superior position of Ar relative to Ba (Ba-Ar)	7.6	2.06	7.3	1.91	7.3	6.9	1.82
Effective height of mandibular corpus (Go-M)	32.5	5.37	29.4	4.55	30.9	27.6	4.04
Total effective height of lower face (Ba-M)	64.9	8.33	63.4	5.41	61.9	59.6	4.39
Effective height of the midface (S-Go)	68.0	6.46	69.0	4.44	64.8	65.0	3.78
Vertical Position of posterior palate (Ba-Pns)	-5.5	3.45	-4.5	3.29	-5.2	-4.2	3.10
Vertical Position of anterior palate (Ba-Ans)	-8.4	5.29	-5.2	4.99	-8.0	-4.9	4.81
Palatal plane inclination (Pal angle)	4.0	3.84	1.0	3.68			
Effective anterior mid-face height (N-Ans)	48.4	4.75	48.1	2.15	46.2	45.3	1.75
Effective maxillary dental height (ANS to incisal edge)	25.1	3.28	25.8	2.18	23.9	24.2	1.56
Effective mandibular dental height (M to incisal edge)	34.7	3.48	35.7	2.14	33.1	33.6	1.16
Overbite	-3.4	1.64	-3.3	1.01	-3.2	-3.1	0.98
Effective anterior lower face height (Ans-M)	56.6	5.85	58.2	3.76	53.8	54.7	1.75

5.6 Females Age 11-14

A total of 50 digitized lateral cephalometric radiographs of females between the ages of 11 and 14 with a median age of 11.92 years measured according to Coben analysis standards were compared to the original study. The following charts compare the cranial base (Table 14), facial depth (Table 15) and facial height (Table-16) measurements. Measurements in millimeters (mm) and angles in degrees (°) are compared along with standard deviations for both studies. For facial depth and facial height the proportional measurements are also included. Any measurements highlighted in yellow are one standard deviation outside the original norm.

Cranial Base (Table – 14)	Current Study (mm or °)	S.D. (±)	Original Study (mm or °)	S.D. (±)
Posterior Cranial Base (Ba-S (a.l.))	40.8	3.36	42.3	2.24
Increment and Direction of Spheno-occipital Synchondrosis (Ba-S angle)	54.1	3.79	56.2	3.98
Effective Depth of the Posterior Cranial Base (Ba-S)	23.8	2.69	23.5	2.48
Anterior Cranial Base (S-N (a.l.))	64.5	3.00	65.9	2.82
S to Constructed F (S-F(a.l.))	57.8	3.29	59.7	2.35
Thickness of Frontal Bone (F-N (a.l.))	6.7	2.07	6.2	1.95
Inclination of Anterior Cranial Base (S-N angle)	2.9	4.13	7.0	3.17
Effective Depth of Anterior Cranial Base (S-N)	64.2	3.04	65.1	2.81
Cranial Base Angle (S angle)	128.8	5.67	130.8	4.09
Total Effective Depth of Cranial Base (Ba-N)	88.1	4.28	88.6	3.55

Facial Depth (Table – 15)	Current Study (mm or °)	S.D. (±)	Original Study (mm or °)	S.D. (±)	Proportions (%Ba-N)	Mean	S.D.
Effective depth of post cranial base (Ba-S)	23.8	2.69	23.5	2.48	27.1	26.4	2.29
Spatial Relation to Max (S-Ptm)	16.9	2.91	17.9	2.69	19.2	20.4	3.23
Effective depth of maxilla (Ptm-A)	43.5	2.97	44.7	2.24	49.4	50.4	2.56
Total effective depth of the midface (Ba-A)	84.2	4.83	86.1	3.36	95.7	97.2	3.37
Ant-post position of the mandible relative to Basion (Ba-Ar)	8.6	2.03	8.6	1.86	9.8	9.7	2.03
Effective depth of the mandible itself (Ar-Po)	68.9	6.82	73.7	5.30	78.2	83.2	6.58
Effective depth of mandibular apical base (Ba-B)	77.6	6.16	81.1	4.97	88.1	91.5	6.03
Total effective depth of lower face (Ba-Po)	77.5	7.23	82.3	5.32	88.0	92.9	6.50
Absolute length of ramus (Ar-Go a.l.)	41.9	4.60	42.2	3.80	47.6	47.6	4.34
Ramal Inclination (RI angle)	11.1	4.74	10.8	4.80			
Effective depth of the ramus (Ar-Go)	8.0	3.58	7.9	3.61	9.1	8.9	4.08
Absolute length of the mandibular body (Go-Po' a.l.)	65.8	4.62	69.6	3.76	74.7	78.6	4.61
Mandibular plane angle	28.6	6.26	26.0	4.21			
Anatomic chin (B'-Po' a.l.)	6.5	1.11	5.6	1.40	7.4	6.3	1.62
Effective depth of chin (B-Po)	-0.1	2.00	1.2	1.07	-0.1	1.4	1.23
Effective depth of mandibular body (Go-Po)	60.9	5.72	65.8	4.31	69.1	74.3	5.43
Gonial angle	129.7	6.56	126.8	5.30			

Facial Height (Table – 16)	Current Study (mm or °)	S.D. (±)	Original Study (mm or °)	S.D. (±)	Proportions	Mean	S.D.
Total ant facial height (N-M)	100.0	5.90	106.3	4.70	113.6	120.0	5.89
Effective height of post cranial base (Ba-S)	33.0	3.33	35.0	2.74	33.0	33.0	2.54
Effective height of ant cranial base (S-N)	3.3	4.59	7.9	3.60	3.3	7.4	3.38
Total effective height of cranial base (Ba-N)	36.3	5.03	42.9	4.98	36.3	40.4	4.38
Effective height of lower post face (Ba-Go)	33.9	4.89	34.0	4.29	33.9	32.0	3.85
Effective height of ramus (Ar-Go)	41.0	4.56	41.3	3.76	41.0	38.9	3.35
Superior position of Ar relative to Ba (Ba-Ar)	7.1	2.54	7.3	1.91	7.1	6.9	1.82
Effective height of mandibular corpus (Go-M)	29.8	5.78	29.4	4.55	29.8	27.6	4.04
Total effective height of lower face (Ba-M)	63.7	5.70	63.4	5.41	63.7	59.6	4.39
Effective height of the midface (S-Go)	66.9	5.10	69.0	4.44	66.9	65.0	3.78
Vertical Position of posterior palate (Ba-Pns)	-6.7	3.03	-4.5	3.29	-6.7	-4.2	3.10
Vertical Position of anterior palate (Ba-Ans)	-9.5	4.53	-5.2	4.99	-9.5	-4.9	4.81
Palatal plane inclination (Pal angle)	4.1	3.54	1.0	3.68			
Effective anterior mid-face height (N-Ans)	45.8	3.52	48.1	2.15	45.8	45.3	1.75
Effective maxillary dental height (ANS to incisal edge)	24.3	2.12	25.8	2.18	24.3	24.2	1.56
Effective mandibular dental height (M to incisal edge)	33.5	2.49	35.7	2.14	33.5	33.6	1.16
Overbite	-3.6	1.55	-3.3	1.01	-3.6	-3.1	0.98
Effective anterior lower face height (Ans-M)	54.2	3.85	58.2	3.76	54.2	54.7	1.75

5.7 Male Age 15-18

A total of 41 digitized lateral cephalometric radiographs of males between the ages of 15 and 18 with a median age of 16.08 years measured according to Coben analysis standards were compared to the original study. The following charts compare the cranial base (Table 17), facial depth (Table 18) and facial height (Table 19) measurements. Measurements in millimeters (mm) and angles in degrees (°) are compared along with standard deviations for both studies. For facial depth and facial height the proportional measurements are also included. Any measurements highlighted in yellow are one standard deviation outside the original norm.

Cranial Base (Table – 17)	Current Study (mm or °)	S.D. (±)	Original Study (mm or °)	S.D. (±)
Posterior Cranial Base (Ba-S (a.l.))	44.2	3.41	45.1	1.53
Increment and Direction of Spheno-occipital Synchondrosis (Ba-S angle)	54.9	3.22	58.9	3.92
Effective Depth of the Posterior Cranial Base (Ba-S)	25.3	2.42	23.1	3.08
Anterior Cranial Base (S-N (a.l.))	68.7	3.78	70.3	1.04
S to Constructed F (S-F(a.l.))	59.9	4.33	58.7	2.50
Thickness of Frontal Bone (F-N (a.l.))	8.8	2.03	11.6	2.28
Inclination of Anterior Cranial Base (S-N angle)	2.6	4.39	6.3	3.19
Effective Depth of Anterior Cranial Base (S-N)	68.5	3.85	69.1	1.18
Cranial Base Angle (S angle)	127.8	5.89	127.4	4.70
Total Effective Depth of Cranial Base (Ba-N)	93.8	4.74	92.8	3.90

Facial Depth (Table – 18)	Current Study (mm or °)	S.D. (±)	Original Study (mm or °)	S.D. (±)	Proportions (%Ba-N)	Mean	S.D.
Effective depth of post cranial base (Ba-S)	25.3	2.42	23.1	3.08	27.0	24.4	2.58
Spatial Relation to Max (S-Ptm)	17.4	3.10	19.2	2.12	18.6	20.7	2.66
Effective depth of maxilla (Ptm-A)	46.8	3.30	48.1	2.22	49.9	51.9	2.98
Total effective depth of the midface (Ba-A)	89.6	4.90	90.4	3.81	95.5	97.4	3.81
Ant-post position of the mandible relative to Basion (Ba-Ar)	9.2	2.71	8.1	2.57	9.8	8.7	2.67
Effective depth of the mandible itself (Ar-Po)	73.0	8.00	79.9	6.86	77.8	86.2	8.81
Effective depth of mandibular apical base (Ba-B)	82.5	7.03	84.8	5.80	88.0	91.5	6.55
Total effective depth of lower face (Ba-Po)	82.2	8.22	88.0	7.17	87.7	95.0	8.92
Absolute length of ramus (Ar-Go a.l.)	48.9	4.92	49.5	4.27	52.2	53.3	4.82
Ramal Inclination (RI angle)	9.8	4.86	8.1	4.69			
Effective depth of the ramus (Ar-Go)	8.4	4.44	7.0	4.31	9.0	7.5	4.76
Absolute length of the mandibular body (Go-Po' a.l.)	70.8	4.41	76.7	4.38	75.5	82.8	5.79
Mandibular plane angle	29.1	5.55	23.9	4.94			
Anatomic chin (B'-Po' a.l.)	12.0	3.27	9.1	2.60	12.8	9.9	2.87
Effective depth of chin (B-Po)	-0.3	2.22	3.2	3.24	-0.3	3.5	3.58
Effective depth of mandibular body (Go-Po)	64.6	5.84	72.9	4.99	68.9	78.7	6.46
Gonial angle	128.9	5.66	122.0	6.38			

Facial Height (Table - 19)	Current Study (mm or °)	S.D. (±)	Original Study (mm or °)	S.D. (±)	Proportions	Mean	S.D.
Total ant facial height (N-M)	112.5	5.18	116.3	5.74	120.0	125.4	6.18
Effective height of post cranial base (Ba-S)	36.1	3.48	38.3	2.54	32.1	33.0	2.40
Effective height of ant cranial base (S-N)	3.1	5.17	7.5	3.76	2.8	6.4	3.15
Total effective height of cranial base (Ba-N)	39.3	4.52	45.8	4.03	34.9	39.4	3.11
Effective height of lower post face (Ba-Go)	40.7	4.86	41.4	4.74	36.2	35.7	4.27
Effective height of ramus (Ar-Go)	48.0	4.67	48.8	4.42	42.7	42.1	4.07
Superior position of Ar relative to Ba (Ba-Ar)	7.3	2.67	7.4	1.83	6.5	6.4	1.58
Effective height of mandibular corpus (Go-M)	32.6	5.30	29.1	5.60	29.0	24.9	4.28
Total effective height of lower face (Ba-M)	73.3	4.98	70.5	5.36	65.1	60.6	3.11
Effective height of the midface (S-Go)	76.8	6.09	79.7	4.39	68.2	68.7	4.51
Vertical Position of posterior palate (Ba-Pns)	-7.8	3.20	-5.0	2.81	-6.9	-4.4	2.18
Vertical Position of anterior palate (Ba-Ans)	-10.8	4.56	-7.8	5.09	-9.6	-6.8	4.41
Palatal plane inclination (Pal angle)	4.1	3.61	3.2	5.83			
Effective anterior mid-face height (N-Ans)	50.0	3.96	53.6	3.16	44.5	46.2	2.47
Effective maxillary dental height (ANS to incisal edge)	27.2	2.33	26.9	3.08	24.2	23.1	2.22
Effective mandibular dental height (M to incisal edge)	38.5	2.57	39.5	2.78	34.2	34.0	1.53
Overbite	-3.2	1.97	-3.7	2.14	-2.8	-3.3	1.90
Effective anterior lower face height (Ans-M)	62.5	4.03	62.7	4.87	55.5	53.8	2.47

5.8 Female Age 15-18

A total of 47 digitized lateral cephalometric radiographs of females between the ages of 15 and 18 with a median age of 16.33 years measured according to Coben analysis standards were compared to the original study. The following charts compare the cranial base (Table 20), facial depth (Table 21) and facial height Table 22) measurements. Measurements in millimeters (mm) and angles in degrees (°) are compared along with standard deviations for both studies. For facial depth and facial height the proportional measurements are also included. Any measurements highlighted in yellow are one standard deviation outside the original norm.

Cranial Base (Table - 20)	Current Study (mm or °)	S.D. (±)	Original Study (mm or °)	S.D. (±)
Posterior Cranial Base (Ba-S (a.l.))	41.7	3.45	42.4	2.03
Increment and Direction of Spheno-occipital Synchronosis (Ba-S angle)	56.2	3.97	54.9	3.03
Effective Depth of the Posterior Cranial Base (Ba-S)	23.1	2.88	24.2	2.64
Anterior Cranial Base (S-N (a.l.))	65.9	3.38	67.1	2.46
S to Constructed F (S-F(a.l.))	57.2	3.49	57.8	2.75
Thickness of Frontal Bone (F-N (a.l.))	8.7	2.88	9.3	2.41
Inclination of Anterior Cranial Base (S-N angle)	3.5	3.84	6.3	3.19
Effective Depth of Anterior Cranial Base (S-N)	65.7	3.39	66.2	2.65
Cranial Base Angle (S angle)	127.3	4.68	131.4	5.19
Total Effective Depth of Cranial Base (Ba-N)	88.8	5.00	90.4	4.39

Facial Depth (Table - 21)	Current Study (mm or °)	S.D. (±)	Original Study (mm or °)	S.D. (±)	Proportions (%Ba-N)	Mean	S.D.
Effective depth of post cranial base (Ba-S)	23.1	2.88	24.2	2.64	26.0	26.7	2.04
Spatial Relation to Max (S-Ptm)	17.6	3.02	17.9	2.22	19.8	19.8	2.43
Effective depth of maxilla (Ptm-A)	45.1	2.65	46.8	2.71	50.8	51.8	2.97
Total effective depth of the midface (Ba-A)	85.8	4.16	88.9	4.87	96.7	98.3	3.52
Ant-post position of the mandible relative to Basion (Ba-Ar)	8.5	2.50	8.4	2.49	9.6	9.2	2.52
Effective depth of the mandible itself (Ar-Po)	71.3	7.17	78.7	5.73	80.4	87.2	6.77
Effective depth of mandibular apical base (Ba-B)	79.8	5.53	84.6	5.63	89.9	93.6	5.58
Total effective depth of lower face (Ba-Po)	79.9	6.64	87.1	6.34	90.0	96.4	6.73
Absolute length of ramus (Ar-Go a.l.)	46.3	4.59	46.4	3.49	52.2	51.3	4.47
Ramal Inclination (RI angle)	9.1	4.75	9.7	5.12			
Effective depth of the ramus (Ar-Go)	7.3	4.00	7.7	4.01	8.3	8.6	4.44
Absolute length of the mandibular body (Go-Po' a.l.)	69.0	3.59	73.5	3.43	77.7	80.1	6.44
Mandibular plane angle	25.9	6.86	21.3	4.97			
Anatomic chin (B'-Po' a.l.)	9.0	1.38	7.3	2.04	10.1	8.1	2.38
Effective depth of chin (B-Po)	0.0	2.06	2.4	1.99	0.0	2.8	2.10
Effective depth of mandibular body (Go-Po)	64.0	4.59	71.0	4.71	72.1	78.6	4.78
Gonial angle	125.0	5.45	120.3	7.25			

Facial Height (Table – 22)	Current Study (mm or °)	S.D. (±)	Original Study (mm or °)	S.D. (±)	Proportions	Mean	S.D.
Total ant facial height (N-M)	105.2	5.30	105.5	4.16	118.5	116.7	4.61
Effective height of post cranial base (Ba-S)	34.6	3.45	34.6	2.03	32.9	32.8	2.04
Effective height of ant cranial base (S-N)	4.0	4.46	7.5	4.11	3.8	7.1	3.85
Total effective height of cranial base (Ba-N)	38.5	5.04	42.1	4.01	36.6	39.9	3.67
Effective height of lower post face (Ba-Go)	38.2	5.03	38.6	4.17	36.3	36.6	4.14
Effective height of ramus (Ar-Go)	45.6	4.44	45.6	3.51	43.3	43.2	3.52
Superior position of Ar relative to Ba (Ba-Ar)	7.4	3.20	7.0	1.50	7.0	6.6	1.40
Effective height of mandibular corpus (Go-M)	28.5	7.21	24.8	5.11	27.1	23.5	4.40
Total effective height of lower face (Ba-M)	66.7	6.15	63.4	4.85	63.4	60.1	3.67
Effective height of the midface (S-Go)	72.8	4.85	73.2	4.60	69.1	69.4	4.75
Vertical Position of posterior palate (Ba-Pns)	-7.0	3.28	-4.2	2.69	-6.7	-4.0	2.55
Vertical Position of anterior palate (Ba-Ans)	-9.5	4.70	-6.5	4.08	-9.1	-6.2	3.94
Palatal plane inclination (Pal angle)	3.5	4.61	2.8	3.05			
Effective anterior mid-face height (N-Ans)	48.1	3.20	48.6	2.21	45.7	46.1	2.10
Effective maxillary dental height (ANS to incisal edge)	25.1	2.22	25.1	2.73	23.9	24.0	2.32
Effective mandibular dental height (M to incisal edge)	35.4	2.24	36.1	2.14	33.6	34.0	1.38
Overbite	-3.3	1.89	-4.3	1.78	-3.2	-4.1	1.79
Effective anterior lower face height (Ans-M)	57.1	3.97	56.9	3.84	54.3	53.9	2.10

CHAPTER 6

DISCUSSION

6.1 Introduction

The growth and form of the human face consists of any number of variations in size, shape and growth of the individual structures. To understand how various facial types and differences in growth effect individual faces, the variations of the determinants must be studied as a whole. It is difficult to distinguish a particular characteristic as normal or abnormal without an understanding of the effect it has on the entire facial morphology. Two people may have the same size mandible or maxilla and still have different appearances.

Variations in the mandible and maxilla exist from individual to individual, for this reason it is of utmost importance to assess the influence of the cranial base on the overall craniofacial morphology. Variations in growth of the cranial base may have profound effects on the dentofacial complex. A severe flexure of the cranial base without a corresponding reduction in the mandible can lead to mandibular prognathism (Coben, 1955). Using the same rationale, an obtuse cranial base may increase the depth of the upper face and result in a retrognathic mandible. A horizontal anterior cranial base can position the entire posterior face at such a superior position affecting a steep mandibular plane angle and also causing a retrognathic mandible.

Appraising the effects of the mandible on the overall growth of the face must entail more than just the growth of the body or ramus of the mandible. The change in position of the lower border of the mandible, the change in directional growth of the condyle and the inclination of the ramus all may affect changes from individual to individual. Facial growth must not only include the absolute increments of the parts involved, but also the directional growth of the structures which may determine the effectiveness of their contributions (Coben, 1955).

Small or large mandibles cannot explain every Class II or Class III malocclusion. Oftentimes one or more areas is identified as the “abnormality”, in reality an individual may present with one, two, three or any number of almost infinite patterns that could lead to a malocclusion. Upon examining the variations in the cranial base and the structures that form the dentofacial complex it is evident that no one factor or factors is responsible for a particular malocclusion, rather the problem is expressed in any number of infinite variables.

Though generalities in growth behavior exist and may be used as guides during a patient’s facial development, many patients deviate from these generalities. No characteristic, or combination of characteristics, yields an infallible formula to the growth potential of the individual face (Coben, 1955).

6.2 General Observations from the Sample

In comparison, males exceed females in growth of facial height. In the depth dimension males also show more growth than females. Males and females show more vertical growth in the anterior as opposed to the posterior face and also show increases in lower face prognathism (Ba-Po) and posterior face height (S-Go). Both males and females showed relative stability in the basion to articulare (Ba-Ar) measurement.

6.2.1 Comparison of Ranges of 7-10 Year Olds

A comparison of the individual measurement ranges between 7-10 year olds in the current study and 8 ± 1 year olds in the original study show the current study population to have generally larger standard deviations for the individual measurements along with a wider range among the measurements. Since all patients included in both studies are Class I occlusion, this trend adds validity to the vast array of variation that exists among the individual parts that form the occlusion.

6.2.2 Contributions of the Cranial Base to Facial Form

The effect of the cranial base on facial growth is of great importance. The Coben analysis affords the ability to illustrate a mechanism through which growth of the cranial base carries the upper face upward and forward away from the vertebral column, as Coben has shown, differences not only appear in the absolute increment

of the posterior cranial base, but also in its directional growth; this can contribute to facial depth in one person and facial height in another.

In the current study, the sella nasion angle (N-S-BaH) is one standard deviation smaller for both sexes in the 11-14 age groups and for males in the 15-18 age group. The importance of this difference can be appreciated when comparing the Steiner and Downs analyses. A certain facial profile examined with the Steiner analysis may be described as prognathic where the Downs analysis describes the same profile as retrognathic. Examining the sella nasion angle (N-S-BaH) explains this phenomenon. An increase in the S-N angle will position nasion at a more posterior position as opposed to a decreased S-N angle, thus affecting the position of nasion in relation to “A” or “B” point. Sella is defined as the geometric center of the pituitary fossa in this study. We are recommending that 3.8° should be used for the S-N angle mean in males age 11-14 and 2.9° for females age 11-14 as opposed to the 7° suggested by the original study.

In the current study cranial base measurements other than the S-N angle are within one standard deviation of the original study except for in the male 15-18 year age group. This group was one standard deviation smaller than the original norms in the anterior cranial base (S-N a.l.), thickness of the frontal bone (F-N a.l.), effective depth of the anterior cranial base (S-N) and the increment and direction of the spheno-occipital synchondrosis or the Ba-S angle (S-Ba-BaH). As the male and female groups age, the male norms increase slightly more than the female, the current

study's male subjects from the 15-18 year age group show growth increase similar to that of the female group of the same age.

6.2.3 Contributions of Facial Depth to Facial Form

Total effective depth of the midface and lower face in the current study was within one standard deviation of the original study's norms when examining males and females between the ages of 7-14.

Examination of the males and females ages 15-18 reveal that the effective depth of the mandible (Ar-Po) is one standard deviation smaller for both groups. For the female age 15-18 group the total effective depth of the lower face (Ba-Po) is also one standard deviation smaller. The proportional measurements reveal that the males age 15-18, though one standard deviation smaller when examining the linear measurement of the effective depth of the mandible (Ar-Po), are within the proportional norm.

Upon further examination of the males age 15-18 group the effective depth of the mandible (Ar-Po) is one standard deviation smaller, yet the total effective depth of the face (Ba-Po) is within the norm. The position of the mandible relative to Basion (Ba-Ar) is slightly forward compensating for the smaller effective mandibular depth (Ar-Po). The same is not true of the females age 15-18. The effective mandibular depth (Ar-Po) is one standard deviation smaller, the total effective depth of the lower

face is also one standard deviation smaller (Ba-Po) due to the relative unchanged position of the mandible relative to basion (Ba-Ar).

Examination of the effective depth of the ramus (Ar-Go) in males age 7-10 reveals the current study has a one standard deviation larger measurement, with subsequent age group measurements being smaller and within one standard deviation of the norm, this measurement is noteworthy, though within the proportional norm.

Both the absolute (Go-Po' a.l.) and effective (Go-Po) depth of the mandibular body measurements are one standard deviation smaller in the current study compared to the original study in both sexes and age groups except the males age 11-14 group, which was within the original norm. The effective depth of the chin (B-Po) is one standard deviation smaller in the current study compared to the original study in both sexes and all age groups except the male 7-10 age group which was within the original study's norm. The anatomic (B'-Po' a.l.) depth of the chin was one standard deviation larger than the original norm for males.

Gonion, for purposes of this study is defined as the constructed point formed by the intersection of the posterior portion of the mandibular plane and the inferior portion of the ramal plane. Where the ramal plane is plotted when tracing a digital cephalometric radiograph influences the absolute (Go-Po' a.l.) and effective (Go-Po) depth of the mandibular body. The ramal plane will also influence the RI angle and the effective depth of the ramus (Ar-Go). In the current study the RI angle and effective depth of the ramus (Ar-Go) are within one standard deviation of the norm

with the exception of the male 7-10 age group, where the effective depth of the ramus (Ar-Go) is one standard deviation larger than the norm. The short absolute (Go-Po') and effective (Go-Po) depth of the mandibular body, therefore, is not a result of an incorrect positioning of Gonion. The larger RI and MPI angles may be a compensation for the smaller mandibular body measurements.

6.2.4 Contributions of Facial Height to Facial Form

In males ages 7-18 no trends different from the norm are appreciable until examination of the 15-18 year old group. The 15-18 year old males show a one standard deviation smaller effective height of the anterior cranial base (S-N), total effective height of the cranial base (Ba-N) and effective anterior mid-face height (N-Ans). Proportional measurements show one standard deviation smaller measurements for the effective height of the anterior cranial base (S-N), total effective height of the cranial base (Ba-N), total effective height of the lower face (Ba-M) and the vertical position of the posterior palate (Ba-Pns).

Sella, as defined in this analysis, is the point representing the visual geometric center of the pituitary fossa. The answer to the differences in the effective height of the anterior cranial base (S-N) between the current study and the original study may be a result of the relative smaller distances, $7.5 \pm 3.76\text{mm}$ for the original study and $3.1 \pm 5.17\text{mm}$ for the current study, measured compared to other measurements in the analysis. This would also affect the total effective height of the cranial base (Ba-

N) which is the summation of the effective height of the anterior cranial base (S-N) and the effective height of the posterior cranial (Ba-S). The proportional measurement differences may be a result of the same reasons.

The total effective height of the lower face (Ba-M) is within the linear norm of the original measurements, but is one standard deviation larger than the proportional norm. This is possible because the proportional measurement is measured as a percentage of the distance nasion to menton (N-M) compared to the linear measurement which is measured in millimeters. The same is true of the vertical position of the posterior palate (Ba-Pns).

Though the effective anterior mid-face height (N-Ans) is one standard deviation smaller in a comparison of the current study and the original study, the total anterior face height (N-M), which is the summation of the effective anterior mid-face height (N-Ans) and the effective anterior lower face height (Ans-M), is still within the original study norms.

6.3 Palatal Plane Inclination (Pal angle)

The palatal plane inclination (Pal angle) is defined as the angle formed between basion horizontal and a line extended through the points Ans to Pns. For use in the current study it will be in positive degrees ($^{\circ}$), in the original study it is in negative degrees ($^{\circ}$).

6.4 Assessment of the Standard Deviation

The wide range of standard deviations between the current study and original study are testaments to the variability present in a Class I occlusion, as all the subjects examined were of this Class. “No characteristic can be judged “normal” or “abnormal,” harmonious or unharmonious, without an appreciation of the role it plays in the total facial complex (Coben, 1955).” An infinite number of combinations exist to form a Class I occlusion or for that matter, a Class II or Class III occlusion.

6.5 The Distance between Basion and Articulare

Previous studies have noted the stability of the distance between Basion and Articulare (Coben, 1955; Ferrer, 1964; Jensen, 1964; Seward, 1981). The current study has also found that the distance between the two points is consistently within one standard deviation of the original study’s measurements for males and females. Therefore, this point is stable for research purposes.

6.6 The Differences

The general small differences between the current study and original study could be due to any number of factors. The current study and original study populations are from different regions of the United States. Diet, genetics, polymorphisms, physical activity or endocrine disrupting chemicals could all affect the sample populations (Juil, et al., 2006). Other growth studies have shown an

unexpected advance of pubertal onset in girls in the United States (Herman-Giddens et al., 1997; Sun et al., 2002; Wu et al., 2002; Foster et al., 1977; Lee, 1980). Similar pubertal growth studies in other countries have indicated similar trends to those above (Lindgren, 1996; Fredriks et al., 2000; Muinck et al., 2001; Parent et al., 2003; Castellino et al., 2005) whereas others have alluded that there is no evidence of early pubertal development (Engelhardt et al., 1995; De Simone et al., 2004; Juul et al., 2006). As opposed to girls, no studies have shown a trend in male pubertal timing.

It may suffice to say, “No characteristic, or combination of characteristics, yields an infallible formula to the growth potential of the individual face (Coben, 1955)”, applies not only to the human face.

CHAPTER 7

CONCLUSIONS

The conclusions of this study are as follows:

1. As evidenced by the larger standard deviations in the current study compared to the original study, even more individual variation exists among the facial skeletal components that form a Class I occlusion than previously thought.
2. We recommend 3.8° should be used for the S-N angle mean in males age 11-14 and 2.9° for females age 11-14 as opposed to the 7° suggested by the original study.
3. The hand tracing method previously employed uses graph paper with the coordinate system enlarged 8% to compensate for the 8% enlargement of the radiographic film. This is no longer necessary when tracing a digital cephalometric radiograph.
4. The distance from basion to articulare in this study is consistently within one standard deviation of the original study's measurements for males and females. This distance appears stable as previous studies have shown.
5. The Coben analysis linear and proportional measurements need not be adjusted due to the vast array of variables present in any

population which include, but are not limited to, variation in comparative sample populations, genetics, polymorphisms, or endocrine disrupting chemicals.

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APPENDIX A GLOSSARY OF TERMS

Points

“A” Point (Subspinale) – The deepest midline point on the maxilla between the anterior nasal spine and prosthion (Downs).

ANS (Anterior Nasal Spine) – The most anterior point of the anterior nasal spine.

Articulare (Ar) – The point of intersection of the images of the posterior border of the mandible and the inferior border of the basilar part of the occipital bone (as redefined by Bjork).

“B” Point (Supramentale) – The deepest midline point on the mandible between infradentale and pogonion (Downs).

Basion (Ba) – The point representing the apex of the image of the anterior margin of the foramen magnum, or as represented by the most superior point of the anterior margin of the base of the occipital condyle.

Frontale (F) – The landmark closely approximating the location of foramen caecum, representing the true terminus of the anterior cranial base, formed by the intersection of a perpendicular from the junction of the orbital roofs and the internal plate of the frontal bone to the Sella-Nasion plane.

Gonion (Go) – The constructed point formed by the intersection of the posterior portion of the mandibular plane and the inferior portion of the ramal plane.

Menton (M) – The most inferior midline point on the mandibular symphysis.

Nasion (N) – The most anterior point of the frontonasal suture.

Orbitale (O) – The lowest point on the anterior margin of the orbit.

Porion (P) – The highest point on the superior surface of the hard tissue of the external auditory meati as indicated by the radio-opaque rods of the cephalometer.

Pogonion (P) – The most anterior midline point of the mandibular symphysis.

Pogonion prime (Po') – The constructed point formed by the intersection of the mandibular plane and a perpendicular drawn from Pogonion to that plane.

Pterygomaxillary Fissure (Ptm) – The point of junction of the image of the anterior surface of the pterygoid process of the sphenoid bone and the posterior margin of the maxilla.

Sella (S) – The point representing the visual geometric center of the pituitary fossa.

Upper Central Incisor (U1) – The point on the incisal edge of the most prominent upper central incisor.

Lower Central Incisor (L1) – The point on the incisal edge of the most prominent lower central incisor.

Planes

Basion-Sella (Ba-S) – The line drawn from point Basion (Ba) to point Sella (S).

Frankfort Horizontal (FH) – The horizontal line passing through cephalometric point Porion (P) and point Orbitale (O).

Mandibular Plane (MPI) – The line drawn tangent to the inferior boarder of the mandibular symphysis and the posterior inferior border of the mandibular body.

Ramus Plane (RPI) – The line drawn from point Articulare (Ar) tangent to the posterior border of the mandibular ramus.

Sella-Nasion (S-N) – The line drawn from point Sella (S) to point Nasion (N).

Angles

Gonial Angle (Go) – The angle formed by the ramal plane and the mandibular plane, representative of the angle of the mandible.

Mandibular Plane Angle (MPI<) – The angle formed by the mandibular plane and a parallel of the Frankfort plane, representative on the inclination of the lower border of the mandible relative to Frankfort Horizontal.

Nasion-Sella-Frankfort Angle (N-S-FH<) – The angle formed at Sella by the intersection of Nasion-Sella plane and a parallel of the Frankfort Horizontal plane, representative of the angular inclination of the anterior cranial base in the pattern.

Angle of Ramus Inclination (RI<) – The deviation of the ramal plane from the ordinate, perpendicular to the Frankfort plane.

Sella Angle (S<) – The angle formed by the planes Basion-Sella and Sella-Nasion, representative of the angle of the cranial base.

Sella-Basion-Frankfort Angle (S-Ba_FH<) – The angle formed at Basion by the intersection of the Basion-Sella plane and a parallel of the Frankfort Horizontal plane, representative of the angular inclination of the posterior cranial base in the pattern.

Miscellaneous

Absolute Length (a.l.) – The absolute linear dimension between two cephalometric points expressed in millimeters

Coben Coordinate Analysis

Cranial Base Depth

Posterior Cranial Base Depth (Basion-Sella, Ba-S) - The horizontal effective depth of the posterior cranial base, the resultant of the absolute length of the posterior cranial base (Ba-S a.l.) and its inclination in the pattern as indicated by the Sella-Basion Frankfort Angle (S-Ba-FH <), expressed in millimeters (mm).

Basion-Sella (Ba-S (a.l.)) – The linear dimension between points Basion and Sella, representative of the absolute cephalometric length of the posterior cranial base, expressed in millimeters.

Sella-Basion-Frankfort Horizontal Angle (S-Ba-FH <) - The angle formed at Basion by the intersection of the Basion-Sella Plane and a parallel of Frankfort Horizontal Plane, representative of the angular inclination of the posterior cranial base in the pattern, expressed in degrees.

Anterior Cranial Base Depth (Sella-Nasion, S-N) -The horizontal effective depth of the anterior cranial base, the resultant of the absolute length of the anterior cranial base (S-N a.l.) and its inclination in the pattern as indicated by the Nasion-Sella-Frankfort Angle (N-S-FH <), expressed in millimeters (mm).

Sella-Nasion, (S-N (a.l.)) – The linear dimension of that segment of the cephalometric absolute anterior cranial base measured from Sella to a Point “F”, closely approximating the anatomic anterior cranial base, expressed in millimeters (mm).

Frontale-Nasion (F-N (a.l.)) – The linear dimension of that segment of the cephalometric absolute anterior cranial base measured from Point “F” to Nasion, representative of the thickness of the frontal bone, expressed in millimeters (mm).

Nasion-Sella-Frankfort Horizontal Angle (N-S-FH <) - The angle formed at Sella by the intersection of Nasion-Sella Plane and a parallel of the Frankfort Horizontal

Plane, representative of the angular inclination of the anterior cranial base, expressed in degrees (°).

Cranial Base Flexure Sella Angle (S<) - The angle formed at Sella by the intersection of the Basion-Sella-Plane and the Sella-Nasion Plane, representative of the flexure angle of the cranial base. The combined effect of the Sella Angle and the special positioning of the cranial base are measured by the S-Ba-FH < and N-S-FH < as indicated by the formula $S<-180^\circ + N-S-FH< - S-Ba-FH<$, expressed in degrees (°).

Total Cranial Base Depth (Basion-Nasion, Ba-N) – The horizontal length Basion-Nasion, representative of the effective depth of the cranial base, expressed in millimeters (mm).

Face Depth

Middle Face Depth

Middle Face Depth (Basion- “A” Point, Ba-A) – The horizontal length Basion-“A” point, representative of the total effective middle face depth and the summation $(Ba-S + S-Ptm + Ptm-A0)$, expressed in millimeters (mm).

Basion-Sella (Ba-S) – The horizontal length Basion-Sella, representative of the effective depth of the posterior cranial base, expressed in millimeters (mm).

Sella-Pterygomaxillary Fissure (S-Ptm) – The horizontal length Sella-Pterygomaxillary fissure, expressed in millimeters (mm).

Pterygomaxillary Fissure-“A” Point (Ptm-A) – The horizontal length Pterygomaxillary fissure-“A” point, representative of the length of the maxilla, expressed in millimeters (mm).

Lower Face Depth

Lower Face Depth(Basion-Pogonion, Ba-Po) – The horizontal length Basion-Pogonion, representative of the total effective lower face depth and the summation (Ba-Ar + Ar-Po), expressed in millimeters (mm).

Anteroposterior Position of the Mandible (Ba-Ar) – The horizontal length Basion-Articulare, representative of the anteroposterior position of the mandible in the cranial base as related to Basion, expressed in millimeters (mm).

Effective Depth of the Mandible (Ar-Po) – The horizontal length Articulare-Pogonion, representative of the mandibular contribution to lower face depth, expressed in millimeters (mm).

Articulare-Gonion (Ar-Go) - The horizontal length Articulare-Gonion, representative of the contribution of the mandibular ramus to lower face depth, and the resultant of the absolute length of the ramus (Ar-Go a.l.) and the ramus inclination in the pattern ($RI <$), expressed in millimeters (mm).

Articulare-Gonion (Ar-Go (a.l.)) – The absolute length Articulare-Gonion, representative of the height of the mandibular ramus, expressed in millimeters (mm).

Ramal Inclination Angle (R<) - The Angle of Ramus Inclination, representative of the deviation of the Ramus Plane from a vertical (90 degree) relation to the Frankfort Horizontal Plane, expressed in degrees (°).

Gonion-Pogonion (Go-Po) – The horizontal length Gonion-Pogonion, representative of the contribution of the mandibular body to the lower face depth, the resultant of the absolute length of the mandibular body (Go-Po a.l.) and the inclination of the mandibular plane in the pattern (MPI <), expressed in millimeters (mm).

Gonion-Pogonion (Go-Po (a.l.)) – The absolute length Gonion-Pogonion, representative of the length of the mandibular body, expressed in millimeters (mm).

Mandibular Plane Angle (MPI <) - The Mandibular Plane Angle, representative of the inclination of the Mandibular Plane (MPI) as related to the Frankfort Horizontal Plane, expressed in degrees (°).

Gonial Angle (Go<) - The angle formed by the intersection of the Ramus Plane and the Mandibular Plane, representative of the angle of the mandible. The combined effect of the Gonial Angle and the special positioning of the mandible are measured by the Ramus Inclination Angle (RI <) and the Mandibular Plane Angle (MPI <) as indicated by the formula $Go< = 90^{\circ} + RI< + MPI<$, expressed in degrees (°).

Basion-Pogonion (B-Po) – The anteroposterior positioning of the alveolar process on the body of the mandible, represented by B point related to Pogonion, expressed in millimeters (mm).

Face Height

Posterior Face Height

Anterior Cranial Base Height (Nasion-Sella, N-S) – The vertical length Nasion-Sella, representative of the height of the anterior cranial base, expressed in millimeters (mm).

Posterior Face Height (Sella-Gonion, S-Go) – The vertical length Sella-Gonion, representative of the total effective posterior face height and the summation (S-Ar + Ar-Go), expressed in millimeters (mm).

Sella-Articulare(S-Ar) – The vertical length Sella-Articulare, representative of the vertical positioning of the mandible related to Sella, expressed in millimeters (mm).

Articulare-Gonion(Ar-Go) – The vertical length Articulare- Gonion, representative of the contribution of the mandibular ramus to posterior face height, the resultant of the absolute length of the ramus (Ar-Go a.l.) and the ramus inclination in the pattern (RI <), expressed in millimeters (mm).

Articulare-Gonion (Ar-Go (a.l.)) – The absolute length Articulare-Gonion, representative of the height of the mandibular ramus, expressed in millimeters (mm).

Ramal Inclination(RI <) - The angle of Ramus Inclination, representative of the deviation of the Ramus Plane from a vertical (90°) relation to the Frankfort Horizontal Plane, expressed in degrees (°).

Anterior Face Height

Anterior Face Height (Nasion-Menton, N-M) – The vertical length Nasion-Menton, representative of the total anterior face height and the summation (N-Ans + ANS-M), expressed in millimeters (mm).

Upper Face Height (Nasion-Anterior Nasal Spine, N-Ans) – The vertical length Nasion – Anterior Nasal Spine, representative of upper face height, expressed in millimeters (mm).

Lower Face Height (Anterior Nasal Spine – Menton, Ans-M) – The vertical length Anterior Nasal Spine-Menton, representative of lower face height and the summation (Ans-U1 + M-L1 + U1-L1), expressed in millimeters (mm).

Anterior Nasal Spine – Upper Central Incisor (Ans-U1) – The vertical length Anterior Nasal Spine – Upper Central Incisor, representative of upper dental height, expressed in millimeters (mm).

Menton – Lower Central Incisor (M-L1) – The vertical length Menton-Lower Central Incisor, representative of lower dental height, expressed in millimeters (mm).

Upper Central Incisor – Lower Central Incisor (U1-L1) – The vertical length Upper Central Incisor – Lower Central Incisor, representative of the denture overbite, expressed in millimeters (mm).