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The Integration of Denture and Skeletal Facial Profile Changes During Growth

Donald Charles Hilgers
Loyola University Chicago

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THE INTEGRATION OF DENTURE AND SKELETAL FACIAL PROFILE
CHANGES DURING GROWTH

by

Donald Charles Hilgers

A Thesis Submitted to the Faculty of the Graduate School of Loyola University in Partial Fulfillment of the Requirements for the Degree of
Master of Science

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1961
The author was born in Plainville, Kansas, on November 22, 1932. He received his primary school education at Sacred Heart Grammar School in Plainville, Kansas, and at St. Patricks in Tacoma, Washington. He attended Regis High School in Denver, Colorado, and graduated from Boulder Preparatory High School in Boulder, Colorado.

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During the last two years at Loyola University he has had a teaching fellowship in orthodontics.

The author is married and has three children.
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CHAPTER I

INTRODUCTION

Introductory remarks and statement of the problem

This study is a drama involving forty-one characters, and the theme of this drama is "growth." One of the forty-one characters in this drama is the author, and it is his privilege to observe, to record, and to marvel at the other forty individuals as they grow and grow up.

Such old adages as "chip off the old block" and "the very spit and image of," are not completely true because no matter how much a child resembles someone else, he is really himself. The uniqueness of an individual is very apparent. The dynamics of biology show infinite variation in size, form, and growth of all structures. The growth impulses that characterize all normal individuals ensures progress towards maturity. It is obvious that growth does not take place in all dimensions at the same time. Certain areas have rapid growth changes at specific times so that the needs of the developing organism can be and are anticipated.

Growth, development, and function, whether abnormal or normal, are factors in orthodontic therapy. Is a specific dental
malocclusion associated with a specific facial imbalance and, if so, is the malocclusion a symptom or a defect? These questions and others have confronted the orthodontist, and as a result he has become clinically and scientifically interested in growth. Extraction of teeth to obtain better arch form and for the improvement of the facial profile, is now an accepted procedure. Uprighting the mandibular incisors during orthodontic treatment has not only improved the stability of the denture, but it has also improved the esthetics, because it has reduced the dento-alveolar prognathism. The orthodontist is no longer a mechanical "wire bender." He must have an esthetic perception ability, he must be capable of critical judgment, he must be intellectually inquisitive, and he must accept the intellectual challenge to enhance his academic and intellectual background.

Advances in the knowledge of growth have been the reward of many biological dreamers. Knowledge often breeds curiosity and curiosity leads to further exploration. Thus the end product of any knowledge gained from research is not the end of the investigation, but often the real beginning.

The divergency of opinion and the biological crimes printed in the literature are recognized. Many concepts mingle with speculation derived from statistical mean values or statistical significant tests, and the fundamental questions concerning growth are unanswered. This investigation studies mean values,
individual trends, and the integration of linear and angular dimensions of specific individuals. It is hoped that key growth traits for an individual may be observed by correlating odonto-logical and osteological traits of an individual.

Review of the Literature

Knowledge is added to by two major means. First, by new methods or tools by which the investigator is able to attack the many problems left unsolved. Second, by keen observations that enable an investigator to formulate a new idea or hypothesis that answers many questions which were up to this time un-deciphered.

Prior to 1931, cephalofacial growth studies had been limited by a lack of more suitable methodology. Thus, before 1931 most growth studies were on dry human skull material and animals. The study of the human head was then the problem of the craniologist and the anthropologist who from measurements on the skull attempted to systematize and characterize the different races of mankind, so that he could establish man's ancestry. This has enlightened man concerning the phylogeny of the head. After the turn of the century, scientific investigators turned to the ontogenetic development of the skull. Information derived from the dry human skulls was restrictive because of the uncertainty of the age of the skull.
Basically, there are three approaches to studying growth and development of the human head. Vital staining is the first method. This tells us where and how growth is taking place. The second method is craniometrics, by which human heads, living and dead, may be compared to animal skulls. The third and most recent method is that of cephalometric roentgenology, which may be employed in a cross-sectional or a longitudinal investigation of the individual. Cephalometric roentgenological studies can be further divided into quantitative and qualitative studies.

Vital staining by madder feeding and alizarine red "S" intraperitoneal injections has revealed sites of bone growth. If caution is used the rates of bone growth may be studied. From the studies of Brash (1924), Massler and Schour (1944), Moore (1949), and other investigators conclusions have shown that the human skull increases in size by natural growth, appositional growth, and modeling resorption on the bone surfaces, and by cartilage centers located in the cranial base and the condyles of the mandible.

**Studies Based on Skull Material**

Most of the early work with skull material was done by the physical anthropologists. With the use of linear measurements and the establishment of planes and angles, the anthropologists studied racial characteristics and the ancestry of man.
Holl, in 1899, studied 180 skulls which ranged in age from infancy to senility. He attributed the changes in the facial skeleton to the differential rate of growth of different facial bones or to a differential rate of growth of a bone in relation to its surrounding bones. Holl recognized the increased vertical height of the face during the eruption of the deciduous and the permanent dentition, and he felt that this was the greatest factor in altering the facial skeleton of a child to that of an adult.

Keith and Campion (1922) used immature and mature skull material to study human facial growth. They compared skulls of different ages for the amount of growth and the sites of growth. Although they worked with limited skeletal material, they suggested that hormones affected bone growth and bone arrest. They observed that a transformation took place between the child's face and that of an adult. In a study of a series of skulls they stated that cranial base growth occurred at the sphenoooccipital, sphenooethmoidal, and the fronto-nasal sutures.

Rollman (1927) studied a collection of seventy-eight Indian skulls of unknown sex determination. He divided the skull material into seven groups according to their dental age and facial dimensions. He concluded that the development of the face was brought about by an increase in size, form, variation in position, or a change in proportion to the individual bone.
Hollman interpreted his data to indicate that the variability in rate and the time of growth of different structures gave rise to a variability in parts which make up each structure. Measurements on the skulls were in depth, height, and width. Hollman asserted that the mandible grows more rapidly than the upper face, in both depth and height.

Gregory's work (1929) was outstanding in that he investigated the phylogenetic development of the face from the invertebrate to man.

In 1930 Krogman compared the basic growth patterns of man and anthropoids. He noted that growth was composed of two elements—proportional growth and readjustment. He stated that variations were different only in degree and not in kind. This he concluded when he compared man to the anthropoids.

Todd (1932) reported on a study of Negro skull material. Because the face is attached to the cranial base it is carried forward by growth of the cranial base, and it is this mode of growth which develops space for the permanent molars in an anterior-posterior dimension. He stated that in order to appreciate facial growth one must study cranial growth.

Todd remarked on the periodicity of growth between six and eight years, followed by a slump until fourteen years, when he saw another growth spurt. This spurt tapered off after age fifteen. He stated that the direction of facial growth is in a
forward, vertical, and transverse direction. Todd feels that there is no true prognathism in man as compared to animals. He noted that the face and cranial growth of the Negro was at the same pace, but in Caucasians the facial growth tends to lag behind the cranial growth pace.

Bjork (1950) studied the phylogenetic differences in prognathism using cephalometric radiograms. He included samples from the lower aper, man-like aper, fossil aper man, and homo sapiens. He reported that simultaneously with a diminishing in the length of the jaw there was a shortening and deflection of the cranial base. He states that the shortening and deflection of the cranial base was not the reason for the reduced prognathism in man. The shortened jaws of homo sapiens were more affected in the alveolar parts than the basal parts of the jaws.

Anthropometric Studies of Living Individuals

The limitations of cross-sectional data from dry skulls was very apparent. Therefore a large number of investigators turned to longitudinal data and to living humans to study growth of the face.

Bell (1829) was the first to emphasize the necessity for a longitudinal study of growth and development of teeth.

Hellman (1932, 1935) studied 705 males and 986 females ranging from three to twenty-two years of age. He used calipers to measure 54,711 external dimensions of the face. He observed
that as the face increases in size it changes proportions. He states that the average face grows longer with age, and that the posterior vertical length of the face (ramus height) grows more than the anterior vertical length (total facial height) of the face. The depth of the face increases more below than above, according to Hollman. He states that the ratio of facial length to bizygomatic width is greater in the female than in the male. Hollman concluded that male faces are broader than female faces, but female faces are more protrusive in the denture and alveolar region. During the changes from the child's face to the adult face, Hollman says, the face moves forward in relation to the cranium. This forward drift of the face was recognizable as three trends—a forward face, a backward divergent face, and the average or orthognathic face.

Fleming (1933) investigated 4,000 males and females with an age-span of three to eighteen years. He noted that the means of all measurement of the males exceed those of the females. This observation was explained by the fact that the prepubertal spurt of the male exceeded that of the female and that the male continues to grow several years after cessation of growth in the female.

Goldstein (1936) reported a detailed serial study of the growth and development of the face. His observations were made on fifty Jewish males ranging in age from two and one-half
years to twenty-one years. To study the changes of the face in
puberty, he studied fifty men with an average age of seventy-
four. He took his measurements every other year and observed
that the face increased in height most, in depth less, and in
width least. Although the lower part of the face grew more than
the upper face, he observed that the relative proportions of the
face did not increase. From the dimensions reported, it is easy
to see that an early growth spurt took place between three and
five years. This was followed by a slump, which again was
effected by an acceleration of growth at thirteen to fifteen
years. The variability was relatively highest in the vertical
dimension, less in width, and least in depth. Although this was
a monumental piece of work, it did not explain individual growth
behavior.

Davenport (1940) investigated postnatal development of
the face and cranium, utilizing longitudinal material of several
hundred children. The ages of these children ranged from birth
to twenty years. He separated sexes and races. He measured the
proportions and the sizes of the face. Strikingly variable were
the individual curves for different head dimensions. These di-
mensions increased to puberty; then they showed an adolescent
acceleration. The height of the chin varied in different indi-
viduals, and Davenport associated this with special glandular
activities.
In 1931 Broadbent introduced a technique by which standardized serial roentgenograms of a growing individual could be obtained. Thus an accurate technique was now available which allowed an investigator to study internal structures and external structures which were covered by soft tissue mass. Now morphological studies on the growth of living individuals could be started.

Broadbent (1937) diagrammatically reported on the normal development of the face, utilizing a serial cephalometric technique. The findings of Broadbent were presented qualitatively in the form of superimposed tracings of the same person from one month to adulthood. This investigation illustrated that growth was an orderly pattern with none of the complexities that it seemed to be, if one only used superimposed tracings of cranio-static drawings from skulls.

A quantitative study was published by Brodie (1941), showing growth from the third month to eight years of age. Brodie employed angular relations and angles to study twenty-one males by the use of serial cephalometric roentgenograms. The methodology was similar to that used by Keith and Campion. The facial skeleton was divided into four functional areas: brain case, nasal area, upper alveolar area with the teeth, and the
mandible. Utilizing the mean pattern of the sample, Brodie showed that the direction of growth of almost all points followed a straight line. The facial growth path conformed to the direction of the sells gnathion plane. The maxillary first molars always lie on this sells gnathion plane regardless of age. The mandibular molars maintained a constant relation to the mandible during growth. The distance from the mandibular first molar to the posterior border of the mandible and to the lower border of the mandible always maintained a 3:2 ratio regardless of age. The gonial angle was constant throughout growth. The nose was always a certain per cent of the total facial height, regardless of age. After an early age the nasal floor, occlusal plane, and the lower border of the mandible were shown to retain stable angular relations during growth. During the age span studied, no growth spurt was observed and there was little change in the mean pattern.

Bjork (1947) roentgenographically studied facial prognathism of 322 twelve-year-old Swedish boys and compared them to 281 Army conscripts ranging in age from twenty to twenty-two years. Bjork utilized both angular and linear measurements to show that the total vertical height of the face increases with an age increase, and that there is also an increase in prognathism with growth. Since he could not detect changes in the shape of the cranial base, he attributed the prognathism to
altering of the relation between cranial base and the jaw length. He noticed a greater increase in mandibular prognathism than maxillary prognathism and attributed this to the whole mandible being displaced forward in relation to the upper jaw. The profile becomes straighter and the teeth more upright because of the slight forward increase in the relative position of the mandible to the maxilla. The doubled rate of increase in ramus height in comparison to the mandibular body length was the reason for the forward movement of the body of the mandible, according to Bjork. He noted differences in the gonial angle, cranial base morphology and the ramus inclination when he compared the boys and the conscripts. Another factor which Bjork attributed to the straightening of the profile during growth was the slower rate of increase in the alveolar bone as compared to the basal part of the jaw.

In 1947 Wylie reported on his investigation involving abnormal growth. He states that dysplastic craniofacial relations may be in an anterior-posterior direction, vertical direction, or due to condyle displacement.

Shaeffer (1948) reported on the behavior of the axes of the human incisor teeth during growth. He used serial cephalometric roentgenographic records of forty-seven individuals. Eighteen of these series were females and all forty-seven individuals had a class I occlusion with the exception of six. He
reported on the following three angles: lower incisor to gonion-
mathion plane, upper incisor to Frankfort horizontal plane, and
the angle formed by the long axis of the lower incisor to the
long axis of the upper incisor.

Scheffer states that these three angles appear to have
a constant mean but a wide range. Each of these angles may in-
crease, decrease, or remain the same during growth of the indi-
vidual. He could find no correlation between the three angles,
and of the thirteen possible combinations only four were not
observed in his sample. He found no correlation of the palatal
plane to the mandibular plane and of the angle formed by the
intersection of the long axis of the teeth. Scheffer did observe
that regardless of the angular changes in the long axis of the
two incisors the incisors did occupy a more posterior relation
on the supporting bone. With this observation he hypothesized
that possibly this explained the improvement in esthetics of
those individuals having a dental prognathism in their early
years.

Reidel (1948), using cephalometric roentgenographs,
studied the relation of the maxilla to the cranial base in indi-
viduals with normal occlusion and cases of malocclusion. He re-
ported that the two groups (with malocclusions and without mal-
occlusions) had the same maxilla to cranial base relation. He
reported that growth of the maxilla causes the upper face to become more prognathic. He showed growth did not change the angle formed by sella-nasion to infraspinale and the angle formed by sella-nasion to supramentonale.

In 1949 Brodie and Ortiz reported on the growth of the normal child from birth to three months. At this age level, Brodie observed a stable growth pattern for the individual.

In 1951 Bjork published some serial observations in which he states that in the individual, maxillary and mandibular prognathism may increase, decrease, or remain unchanged. Bjork also noted that the average overjet decreases during growth. He associated growth changes occurring in the incisal inclination with changes of the profile.

In 1951 Lande quantitatively studied thirty-four males, using serial cephalometric roentgenograms. He concluded that during growth from the age of seven to seventeen the angle of facial convexity decreased. He attributed this to the fact that the mandible becomes more prognathic to the cranial base than does the maxilla, and that in a horizontal direction alveolar bone does not keep pace with the growth of the skeletal base.

Lande also observed a decrease in the inclination of the lower border of the mandible associated with an increase in mandibular prognathism. Lande showed that there was no correlation between the original facial type at seven years of age and
the growth changes at gnathion later in life. He states that the majority of the cases studied showed this same general tendency in their growth patterns.

Baum (1951) studied sixty-two children covering the age span of eleven, twelve, and thirteen years. An equal number of both sexes was included. The investigation revealed that the youngest group had a more convex face, more procumbent incisors, and a more protrusive denture when measured to the infraspinal pogonion plane. He summarized his reports with the conclusion that it is important to compare a child to a normal range for his own age group.

Brodie (1953) reported on late changes in the human face. This study was based on a quantitative evaluation of nineteen male individuals, using serial cephalometric radiographs. Brodie stated that there is a tendency for the nasal floor to remain stable. In an anterior posterior direction the pterygo-maxillary fissure was the most stable point in the face. He states that one-half of the occlusal planes remained stable and the other half dropped posteriorly. The mandibular plane also remained stable in one-half of the group and followed the occlusal plane in the other half. The nasion-sella to gnathion angle (Y axis) remained stable in eleven of the nineteen cases and in the other eight one decreased and seven increased in this angle.
The angle formed by the sella-nasion plane to the mandibular plane showed an increase in fifteen of the nineteen cases, and the other four showed no changes. Late stages of growth showed that the anterior nasal spine and pogonion continued downward and forward. Porion showed the greatest amount of variation as some moved straight backward and some straight forward. Brodie stated that "the findings would be disturbing but for the fact of consistency and stability of the individual pattern."

Allan Brodie, Jr. (1953), reported on the behavior of the cranial base during growth, using serial cephalometric roentgenograms. Brodie, Jr., observed that growth curves of the whole cranial base resembled the neural type of growth and once established the growth pattern did not change significantly.

Rose (1953) reported that the menarcheal status seems to have a marked effect on the size of the total maxillary and mandibular areas.

O'Nyer (1954) studied the changes of the alveolar process with age and integrated these changes to the total facial profile. He found a greater increase alveolar height in males than in females. In the mandible he observed a greater increase in the height of the alveolar bone in the incisal area than in the molar area. The maxilla showed just the opposite of the mandible and because of this the occlusal plane drops posteriorly with growth.
Muzj, Maj, Processi, Lucchese, Luzj, and Miotlia (1955) studied 116 males and 114 females whom they classified as normal. The age range was from twenty to thirty years old. Basically, their work was based on the idea that there is no single normal individual or type, but two extreme types, both of which are normal. From their work they concluded that specific somatic types could be correlated to specific arch form and profiles. Specifically, they stated that a brevilinear somatic type could, in the majority of the cases, be associated with a rectilinear profile and an arch with a large "U"-shaped radius. The longilinear somatic type could usually be associated with an angular profile, long narrow face, and a "V"-shaped arch.

Ricketts (1955) investigated the relative changes of the face and the part that growth at the tempromandibular joint played in these facial changes. He reported that not only the amount of condylar growth, but also the direction of condylar growth, plays an important part in facial profile changes. Facial growth is important in orthodontic treatment in that it affects overbite, anchorage, positioning of the lower incisor, and retention. Ricketts specifically states that not all growth is necessarily advantageous to the orthodontist. He reported (1961) that in ninety-nine out of one hundred malocclusions, the attitude "watch and wait" for growth allowed the malocclusion to get worse. Ricketts feels that specific treatment techniques
have a direct effect on the growth behavior of the maxilla.

Coben (1955) studied forty-seven individuals using serial cephalometrics. The age span for the investigation covered from eight to one year to sixteen to one year. Coben states that the females and males showed no significant differences at the prepubertal stage. He states that the average tendencies of the growth behavior at any specific age level would not allow the clinician to predict the ultimate potential for any given individual's total facial complex. Coben observed that many faces show extreme variations, but it was an integration of these variations to the total facial morphology which determines harmony or disharmony of the face.

Nanda (1955) did a cephalometric study of the human face using serial cephalometric roentgenograms. The material studied included ten boys and five girls. Nanda noted that the growth of all the facial dimensions studied followed a general skeletal growth pattern, except sella-nasion plane which was a combination neural-skeletal pattern of growth. He observed that the circumpuberal maximum for facial growth tended to occur at a later age than the circumpuberal maximum for general body height. The females showed less facial growth than the males during adolescence. Nanda's investigation showed that the seven dimensions studied had a varying rate of growth which produced changes in the facial form because of this differential growth.
Pelton and Elsasser (1955) did a total facial soft tissue profile study on 2,676 males and 3,153 females, with ages varying from five to twenty-four years of age. Using cephalometrics, they showed an increase in soft tissue prognathism with age. They noted a differential growth between maxilla and mandible, which produced a greater increase in maxillary prognathism in females than in males. It must be remembered that this was an analysis of the total soft tissue profile. Because of this lack of greater prognathism in the mandible according to their material, Pelton and Elsasser did not observe a reduction in facial convexity in the male as seen by Bjork (1947) and Lande (1952). They state that the average profile of either sex will not improve with age unless there is orthodontic intervention. They did observe that the teeth failed to keep pace with the forward movement of the profile. Pelton and Elsasser conclude their paper by expressing the idea that the facial prognathism increases with maturation and if straightening of the profile constitutes an increase in esthetics then the facial soft tissue profile does not improve.

Moss and Greenberg (1955) studied 151 individuals from the ages of one year to two years and eleven months using cephalometric roentgenograms. They also studied forty-nine adolescents with Class II, Division I and Class III occlusions. Moss and Greenberg state that midline structures of the cranial base (for
example, the cribiform angle) are more stable than lateral structures. They supplement the observations of Brodie that the individual's angular measurements of skull base, nasal floor, occlusal plane, and the inferior border of the mandible are stable from one year to eighteen years.

Marshall (1950) observed on cephalometric roentgenograms that the anterior posterior growth of the face takes place in three spurts. The first spurt is at six months and is related to the deciduous dentition formation and eruption. The second spurt is at the age of four to seven years and he associates this with the second molars' formation. The third spurt is at fifteen to nineteen years.

Pruzanovsky (1958) described a technique for taking cephalometric roentgenograms of infants under sedation. He reported on several cases where he used serial cephalometric roentgenograms to study abnormal growth of the neural cranium and the facial structures.

Kraus, Wise, and Frei (1959) reported a serial cephalometric study on six sets of same sex triplets. They stated that in their attempt to study heredity and facial growth they observed that the craniofacial complex is an intermingling of many interactions of discrete forces, so that the role of heredity cannot even be estimated.
Subtelny (1959) used thirty individuals—one-half of these individuals were males and one-half were females—to compare the changes in the skeletal and dental profile to that of the soft tissue profile. All profiles were classified as normal and were studied from three months to eighteen years, using serial cephalometric roentgenograms. Subtelny showed that the increased mandibular prognathism and disproportional growth rate of the nose seemed to counterbalance facial changes. The total facial soft tissue profile increases but is not so observable because of the integrated increased mandibular prognathism. He relates that the lower incisor tends to upright and recede in the mandible; thus the denture is not truly stable in its skeletal base. Both the skeletal and the integumental chin move forward to cranial base during growth. The skeletal profile tended to decrease in facial convexity, but the total soft tissue profile (includes the external nose) was found to increase in convexity with growth.

Subtelny states that "if we exclude the nose from the soft tissue profile, then the degree of convexity tends to remain stable." Lip posture is closely related too and shows the same changes as the alveolar process and teeth.

Meredith (1960) states that the size of a four- to five-year-old child tells us nothing which is clinically significant about the subsequent growth. The rate and the amount of growth for the child is variable.
Cephalometric Roentgenology and Orthodontic Diagnosis and Prognosis

The years 1907 and 1936 stand out as changing points in orthodontic history. In 1907 Edward H. Angle first proposed a classification of dental malocclusions into three distinct classes. In 1936 Charles Tweed first published his philosophy of treating malocclusions based on the axial inclination of the lower incisors. Interest was aroused and a great deal of research and controversy has evolved from these two different ideas. Tweed (1936) felt that for greater esthetics and stability of the denture the lower incisor must be uprighted over the mandibular base, even if it entailed extraction. Angle's treatment did not allow for extraction if his normal occlusion was to be the end result.

The attempt to apply cephalometric roentgenographs to orthodontics is now described in a chronological order. Adams (1939) showed in a cross-sectional cephalometric study that no differences in angular and absolute values could be detected in the mandibles of patients with Class I and Class II occlusions. Baldridge (1940) reported that the molar is in the same relation to the maxilla in Class I and Class II occlusions. With this conclusion Baldridge verified the validity of Angle's classification for Class I and Class II occlusions.

Tweed (1944) declared that the relation of the lower
incisor should be at 90 ± 5° to the lower border of the mandible. Margolis (1943) suggested using composite x-ray photographs to study the lower incisor. He observed that orthodontic treatment reduced the incisor mandibular plane angle. Margolis and Speidel (1943) and Stoner (1943) reported similar means for the incisor mandibular plane angle, but they showed a large range for this angle.

Brodie (1944), in a cross-sectional study, showed that the incisor mandibular plane angle for different malocclusions have different means and very different ranges. Brodie states that extraction is based on the greatest variable "human judgment." Esthetics is an individual interpretation, and Brodie stated that the large range he observed in the incisor mandibular plane angle in his cross-sectional study shows the fallacy of employing a mean criterion for the individual.

Wylie (1946), with cross-sectional cephalograms, showed that the relation of overbite to the lower facial height is significant. He also reported a significance between the overbite and the molar height.

In 1946 Brodie, in discussing facial patterns, asked for an abandonment of the "norm concept" in orthodontic treatment.

Corlett (1947), using cephalometric roentgenograms made a cross-sectional study of 452 patients from the age of four to
twenty-five years. Corlett reported from his investigations that class I and Class II occlusions have the same relation of the lower incisor to the mandibular base. He states that those who feel that the lower incisor is forward in Class II occlusions are only considering the axial inclination.

In Corlett's appraisal the anterior posterior measurement of the lower incisors' position is dependent on pogonion and the lower border of the mandible. Corlett stated that the distance from the most anterior point on the curvature of the crown of the most prominent lower incisor to a line which is perpendicular to the mandibular plane and passes through pogonion has a median measurement of 7.4 millimeters.

Higley (1947) reported that the apices of the teeth may be in a normal position and yet the long axis of the tooth may be procumbent. He states that the normal position for the apex of the central incisor is lingual to the center of the mandibular base (buccolingual).

Margolis (1947) noted that the smaller the cranio-mandibular angle (N-So plane to mandibular plane) the more the chin recedes. Margolis established means and ranges for the three angles in his maxilla-facial triangle.

Downs, in 1948, studied the denture, facial skeleton, and the relation of these structures to the cranial base. His material consisted of twenty individuals from the ages of twelve
to seventeen years. He studied the angle of facial convexity and found a mean of 160° with a range of +10 to -3.5°. Mayne (1946) and Bushra (1950) reported similar means as Downs', but with a much larger range. Downs studied the relation of the dental procumbency by measuring the long axis of the lower incisor to the upper incisor. The mean was 134.4° with a range of 130 to 150.5°. Downs reported the mean of the incisor mandibular plane angle as 91.4° with a range of +7 to -6.5°. Downs states that the combined readings of the denture and skeletal measurements to cranial base are of value in an analysis of the face, but not just a single reading.

Elman (1948), utilizing cross-sectional cephalometric roentgenograms of seventy-two individuals, showed that there was no difference in the relation of the lower first molar to the mandible in Class I and Class II malocclusions. Schoenwetter (1948) studied the relation of the first permanent molars to the face in Class III malocclusions. Stepf (1948) studied the facial pattern of Class III malocclusions, using cephalograms.

In 1951 three investigators, Takano, Cotton, and Wong, applied the Downs' analysis to three different ethnic groups. Each studied twenty individuals. The ethnic groups covered were the Negroes, the American-born Japanese, and the Chinese. The Japanese group appraisal showed that the growth of the cranial base in this ethnic group is short in an anterior posterior
direction. The face showed growth predominantly downward in the Japanese sample. Significantly, the Japanese appeared more protrusive than Downs' Caucasian group. Wong, who studied the twenty Chinese individuals, stated that what are normal measurements for Downs' Caucasian sample would be a Class II denture in the Chinese facial skeleton.

Cotton's Negro sample all appeared to be more protrusive in both the denture and the facial skeleton. Takano concluded that it was fallacious to apply morphological standards from one ethnic group to another ethnic group. Wylie, who evaluated the four ethnic groups, noted that the Downs' analysis is a good way to distinguish the Chinese and the Japanese races on a skeletal facial and denture basis.

Silverstein (1953) studied changes produced during orthodontic treatment in Class II, Division I occlusions. He concluded that orthodontic treatment does not alter skeletal growth but it does change the facial profile, especially in the females. The angle formed by sella-nasion to infraspinale decreased in males, but did not decrease in females. He states that although males and females differ in growth trends this was not significant in his sample. He explains this last statement by stating that, because of the wide ranges, there was an overlapping, and this overlapping masks any significant difference present.
In 1953 Steiner reported the use of angular and linear measurements to record the positioning of the denture in relation to the facial skeleton. Steiner uses the angle formed by the gonion-mpathion plane to the sella-nasion plane instead of the Frankfort mandibular angle. He states that the average mean for this angle is 32°. Steiner studied the linear relation of the upper first molar and central incisor to the nasion subspinale plane. He also uses the linear measurement from the lower first molar and the lower central incisor to the nasion supramentale plane. With these linear measurements he compares and attempts to correlate them to angular measurements of the incisor teeth and thus arrive at a treatment plan. Steiner does not include the incisor mandibular plane angle in his analysis because there is no definite straight line on the inferior border of the mandible. Steiner states that in some cases ideal results cannot be expected from orthodontic treatment because the basic skeletal framework may not be present.

Holdaway (1956) states that in treatment a good facial profile can be obtained if the apical base of the mandible and the maxilla do not exceed too great an anterior posterior relation to each other. This range can be compensated for by inclination of the incisors.

Holdaway has for one of his treatment objectives the reduction of the A.N.B. difference to 2° or less. He states
that the greatest change is seen in the S.N.A. angle and that growth with Class II elastic force aids in stimulating a favorable change of the maxillary and mandibular bases.

Braun and Schmidt (1956), using cross-sectional cephalometric roentgenograms of a well-defined sample studied the curvature of Spee in Class I and Class II, Division I occlusions. They showed that there is no significant difference between the curvature of Spee of these two types of occlusions. They felt that the difference is either in the maxilla, the position of maxilla and mandible to cranial base, the relative difference of maxilla to the curvature of Spee, or a difference in the relative position of the maxilla to the mandible.

Elsasser (1957) studied 203 of Tweed's ideal facial profiles with what Tweed termed excellent occlusions. Elsasser made a cephalometric linear analysis of their profiles and concluded that Tweed can pick individuals who fulfilled Tweed's requirements of an ideal facial profile. Elsasser also felt that the orthodontist would be more able to quantitatively classify his patients to a treatment plan if he took advantage of the coordinate linear methods.

McGovern (1957) made a comparison of Class II, Division I and Class III occlusions, using cephalometric roentgenograms. He found that there was no correlation between the angle nasion-sella to the maxillary first molar and a linear measurement which
was perpendicular to and from the sella-nasion plane to the maxillary first molar.

Reidel (1957) utilized candidates chosen to represent the Seattle Seafair Maidens. Reidel concluded from this cephalometric study that the tissue profile is related to the denture and skeletal facial structures that comprise the bony profile. He also states that the orthodontists' and the public's concept of facial esthetics is in good agreement.

Sassouni (1957) took a sample of 102 children to study the position of the mandibular first molar in the cephalofacial complex. He utilized posterior and lateral cephalometric roentgenograms. He concluded from his investigations that the classification of malocclusions based on the molar relation is a very crude gross clinical demarcation.

In 1958 Burstone studied the integumental facial profile, using forty children in a cephalometric roentgenogram investigation. He states that optimum facial harmony is as important as occlusal excellence in orthodontic treatment. He states that if subspinale moves posteriorly in treatment the total facial profile improves at the expense of creating a more prominent nose.

Lunáquist (1958) studied the influence of the positioning of the lower incisor on stability and esthetics. He
concluded that the Tweed analysis places teeth more lingually and more upright than does the Downs' analysis. He concluded that formulas using only angular measurements are a fallacy based on the assumption that the apices of the teeth will not move.

Lindquist stated that the lower incisor had an indirect relation to aesthetics and its use in any formula is no more than a guide.

Steiner (1959) describes the way cephalometrics may be used to write an "orthodontic prescription" for treating malocclusions. Steiner restates Holdaway's view that the relation of pogonion to the nasion-supramentale plane should be correlated linearly to the lower incisor.

Segor (1954) stresses that we should use a soft tissue analysis if we prefer a scientific approach to our treatment plan because the soft tissue profile changes do not necessarily change with the dentoskeletal improvements. He feels profile photographs could be used in connection with cephalometric headplates.

**Purpose**

The purpose of this investigation is to study the resultant effects of growth on various planes involving both the denture, the skeleton, and how this behavior affects the facial profile. The author is not interested in where the growth sites were, but attention has been directed toward general trends and to the range of variability. Attention was also directed at
correlating individual growth behavior to the original dentofacial profile. In the review of the literature it was observed that many conclusions were distorted and changed, and it is the hope that we may untwist certain facts and add a few new concepts to clear the confusion. Orthodontic treatment has produced many changes to the dentition and skeletal profile. This stimulates a question: How much of these changes were produced by orthodontic treatment and how much by growth? This can best be studied by a longitudinal cephalometric roentgenographic approach, and this is one of the reasons for this investigation.

The purpose of this investigation is also to study growth changes of the denture and skeletal facial profile and to demonstrate any common trends underlying the changes. Specifically, the following linear and angular measurements will be studied:

1. Linear measurements:
   a. The maxillary central incisor extended to the sella-nasion plane. Measurements are from nasion and sella to this intersection.
   b. Changes in sella-nasion plane during growth.
   c. Measurement of vertical line from "Ja" point to the mandibular central incisor.
   d. Measurement from sella and nasion to the intersection of a perpendicular line from the S-N plane extended to the maxillary first molar.
2. Angular Measurements:

a. Angle of facial convexity.

b. Angle of the maxillary central incisor extended to the S-N plane.

c. Angle formed by the intersection of a line drawn through the mandibular central incisor to the gonion-gnathion plane.

d. Angle formed by the intersection of lines drawn through the long axis of the mandibular and maxillary central incisor.
CHAPTER II

MATERIALS AND METHODOLOGY

Material

The present investigation is based upon serial lateral cephalometric roentgenograms. These records were obtained from the files of the Child Research Council, University of Colorado School of Medicine, Denver, Colorado. A group of forty individuals, twenty males and twenty females, was selected on the basis of the quality of the roentgenograms and the completeness of each individual series. The ages investigated were from five years to eighteen years in every case. The individuals studied consisted of two types of occlusion: Angles Class I occlusion and those within the range of having a "normal" occlusion. Patients having Angle's Class II and Class III occlusions were not included in this study. The dentition was considered to be in normal occlusion when it conformed to the standard set by Angle, with the exception of minor rotations of individual teeth or slight crowding of the mandibular incisors.

The program and nature of the records being maintained by the Child Research Council have been fully discussed by Waldo (1936), McDowell (1941), and Washburn (1954). All subjects in
this investigation were white healthy individuals, born and reared in Denver. They are ethnologically predominantly of Northern European extraction and belong to a middle- or upper-middle socio-economic group. The Child Research Council films are exposed 3/20th of a second employing 100-125 miliampere at a 100-kilowatt peak. All films are given standard development.

Methodology

Each roentgenogram was traced on matte acetate paper with a sharp 4-H lead pencil, using the usual translumination. The luminous area of the viewbox was restricted to the small working space so that there was no unnecessary glare affecting the eyes. The room lighting was kept to a low level or eliminated in order to pick up the detailed outline from darker radiographs. The x-rays for each individual were traced in a random sequence to remove any bias in anticipating growth changes. Utmost care was exercised to exclude the fatigue factor and to obtain as accurate tracing as possible. The required cephalometric landmarks were located and drawn with a 4-H pencil on a second sheet of matte tracing paper over an illuminated viewbox. The linear measurements were taken with a straight ruler having graduations every one-half millimeter. The angles were measured with a protractor having a radius of three inches and one-half degree graduations. Each measurement was taken to the nearest
half graduation. The occlusion of each individual was appraised at the terminal age from plaster casts of the individual. Angle's classification of malocclusion was used. The age for circum-puberal maximum in body height was obtained through the courtesy of Dr. Edith Boyd. Dr. Boyd is Professor Emeritus at the Child Research Council, University of Colorado School of Medicine, Denver, Colorado.

Testing the Error in the Tracings of Cephalometric Radiographs and Taking the Measurements

An estimate of the error involved in taking the cephalometric roentgenograms and the difference in the size of the head to its image have been considered in the past. (Broadbent, 1937; Adams, 1940; and Hamernik, 1957.) The utility of this method has been adequately demonstrated.

Gron (1960) stated that the errors introduced into linear and angular measurements on lateral cephalometric roentgenograms by variation in relation of the mid-saggital plane to the central ray are negligible if these variations are five angular degrees or less. He concluded that cephalometric roentgenography was a reliable tool for the study of both linear and angular changes as they occur during growth.

To sensitize the records of each series of readings taken from the cephalometric roentgenograms of each individual,
five well-experienced second-year students in graduate orthodontics at Loyola University School of Dentistry retook the readings on each of these individuals, and where more than one-half a degree or one-half a millimeter of a graduation existed between the author's measurements and the second-year students' measurements, the author reread the angle or linear measurement and made appropriate corrections if they were necessary.

To determine the precision of the operations performed in taking the landmarks from the radiographs, tracing the radiographs, and taking the measurements, as was done in this investigation, ten cephalometric roentgenograms, equally divided between one boy and one girl and taken at similar age periods, were traced seventeen days after the originals were traced. Both the readings pertaining to the five angular measurements and the six linear measurements were obtained in a manner previously described. The two sets of data (originals and duplicates) were then tested by the analysis of variance. For analysis, the data for a number of similar dimensions were pooled and a single estimate of error was made from them. It was found that angular measurements had a greater error than linear measurements. The second set of tracings in which the author traced his landmarks from the original tracings were tested for the error involved in transferring these landmarks and making the measurements. This
procedure was done by duplicating ten tracings twenty days after
the first tracings were made. The standard deviation for the
angle of facial convexity and the interincisal angle was .25.
This would indicate that the error involved in tracing and making
these two measurements was .5 degrees. The angles 1 to 8 and 1
to 80N has a standard deviation of .28, which would indicate that
the error involved in tracing and measuring these two angles is
.55 degrees. The standard deviation for the remaining six linear
and angular dimension was .2. This would indicate that the error
involved in taking these landmarks used in this investigation was
.4 degrees or millimeters.

Most of the x-rays had been taken on the ninth monthly
birthday visit of the individual at the Child Research Council.
In those cases where the radiographs had not been obtained at
this exact age, the increment between two consecutive measure-
ments were interpolated to calculate the value for the interim
age, so that the measurements were thus adjusted to uniform
yearly intervals. The figures were rounded off to one decimal
place. Measurements of the angle of facial convexity (nasion to
infraorbitale to pogonion) was sometimes negative; thus, fifteen
was added to every recorded angle so that all numbers studied
were positive and thus usable by the International Business
Machine Computers.
The analysis of data was handled by a sequence of "transverse sections." According to this plan, each characteristic was analyzed at a given age independent of all other ages. There were ten characteristics including the angular and the linear dimensions. Each transverse section represented an age at which measurements were considered to have been made. Sources of variation recognized in each one of the tables were sex, occlusion, interaction, and within subgroup variation which serves as the measure of experimental error. The calculations to obtain the various sums of the square were done by the International Business Machine computers. When the figures 5-9, 6-9, 7-9, 8-9, 9-9, 10-9, 11-9, 12-9, 13-9, 14-9, 15-9, 16-9, and 17-9 were used, the first number represented years and the second number represented months. Thus the 5-9 figure would indicate the age level five years, 9 months of age.

The Child Research Council in Denver has referred to each individual as a numerical series. Thus when the term "Series 92" is referred to, this is the total twelve-year tracings of one individual labeled as Series 92 by the Research Council.

GLOSSARY

The points and planes defined represent mid-sagittal landmarks, or bilateral images treated as mid-sagittal landmarks.
### Points

*(See Figure OA)*

<table>
<thead>
<tr>
<th>Point</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Subspinale</td>
</tr>
<tr>
<td></td>
<td>The deepest midline point on the maxilla between the anterior nasal spine and prosthion (Downs' Point A).</td>
</tr>
<tr>
<td>B</td>
<td>Incision Inferior Apex</td>
</tr>
<tr>
<td></td>
<td>The center of the apex of the most prominent mandibular incisor (B point after Shaeffer, 1948).</td>
</tr>
<tr>
<td>C</td>
<td>Incision Superior Apex</td>
</tr>
<tr>
<td></td>
<td>The center of the apex of the most prominent maxillary incisor (point C after Shaeffer, 1948).</td>
</tr>
<tr>
<td>D</td>
<td>Incision Inferior</td>
</tr>
<tr>
<td></td>
<td>The incisal point of the most prominent mandibular incisor.</td>
</tr>
<tr>
<td>E</td>
<td>Incision Superior</td>
</tr>
<tr>
<td></td>
<td>The incisal point of the most prominent maxillary incisor.</td>
</tr>
<tr>
<td>F</td>
<td>&quot;Je&quot; &quot;Ja&quot; Point</td>
</tr>
<tr>
<td></td>
<td>The intersection point on the mandibular plane and at a right angle to the mandibular plane of a line drawn through the incisal edge of the most prominent mandibular incisor (I.I.).</td>
</tr>
<tr>
<td>G</td>
<td>Manton</td>
</tr>
<tr>
<td></td>
<td>The most inferior midline point on the mandibular symphysis.</td>
</tr>
<tr>
<td>H</td>
<td>Maxillary Molar Contact</td>
</tr>
<tr>
<td></td>
<td>As used in this investigation, this is the most mesial point of the maxillary first molar.</td>
</tr>
<tr>
<td>I</td>
<td>Nasion</td>
</tr>
<tr>
<td></td>
<td>The most anterior point of the fronto-nasal suture.</td>
</tr>
<tr>
<td>J</td>
<td>Pogonion</td>
</tr>
<tr>
<td></td>
<td>The most anterior midline point of the mandibular symphysis.</td>
</tr>
<tr>
<td>K</td>
<td>Maxillary Molar Point</td>
</tr>
<tr>
<td></td>
<td>A point formed by the intersection of a line drawn from the nasal contact point of the maxillary first molar (H) to the sella-nasion plane and perpendicular to this plane.</td>
</tr>
</tbody>
</table>
CEPHALOMETRIC LANDMARKS

FIGURE OA
1. Incision Sperius Point

A point formed by the intersection of the nasion-sella plane by a line drawn through the long axis of the most procumbent maxillary central incisor (i.e. to E).

3. Sella

The point representing the geometric center of the pituitary fossae.

Planes

<table>
<thead>
<tr>
<th>Plane Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>E-I3</td>
<td>Maxillary Incisor Axis</td>
</tr>
<tr>
<td></td>
<td>A line drawn from the apex of the root (E) to the incisal edge (IS) of the most anterior maxillary incisor representing the long axis profile of the incisor.</td>
</tr>
<tr>
<td>N-II</td>
<td>Mandibular Incisor Axis</td>
</tr>
<tr>
<td></td>
<td>A line drawn from the apex of the root (N) to the tip (II) of the most anterior lower incisor representing the long axis profile of the incisor.</td>
</tr>
<tr>
<td>&quot;Ja&quot;-II</td>
<td>&quot;Ja&quot; Plane</td>
</tr>
<tr>
<td></td>
<td>A line drawn perpendicular to the mandibular plane (&quot;Ja&quot;) which extends to the tip of the most prominent mandibular incisor (II).</td>
</tr>
<tr>
<td>MPL</td>
<td>Mandibular Plane</td>
</tr>
<tr>
<td></td>
<td>The line drawn tangent to the inferior border of the mandibular symphysis (Menton) and the posterior inferior border of the mandibular body.</td>
</tr>
<tr>
<td>N-1</td>
<td>Nasion-Maxillary Incisor</td>
</tr>
<tr>
<td></td>
<td>The line from nasion (N) to the intersection of the long axis of the maxillary incisor (I/) on the sella-nasion plane (SN).</td>
</tr>
<tr>
<td>N-S</td>
<td>Nasion-Maxillary Molar</td>
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<tr>
<td>-----</td>
<td>------------------------</td>
</tr>
<tr>
<td>N-A</td>
<td>Nasion-Subspinale</td>
</tr>
<tr>
<td>Po-A</td>
<td>Pogonion-Subspinale</td>
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<tr>
<td>S-I</td>
<td>Sella-Maxillary Incisor</td>
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<td>S-5</td>
<td>Sella-Maxillary Molar</td>
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<tr>
<td>S-N</td>
<td>Sella-Nasion</td>
</tr>
</tbody>
</table>

Angles
(See Figure 0B)

| N-A-Po | Angle of Convexity | The angle formed by the intersection of the planes nasion-subspinale (N-A) and pogonion-subspinale (Po-A) which is representative of the convexity of the profile. The angle is read as a plus or minus deviation from 180°, plus when subspinale ("A") is anterior to the facial plane (nasion-pogonion), and minus when posterior to the facial plane. (Downs) |
1. Angle SN - Go Gn
2. Angle 1 - to SN
3. Angle of Facial Convexity
4. Interincisal Angle
5. Angle T to Go Gn

FIGURE OB
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>I'/PA</td>
<td>Incisor Mandibular Plane Angle</td>
<td>The angle formed by the intersection of the long axis of the most procumbent mandibular incisor (II-II) with the mandibular plane.</td>
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<td>1</td>
<td>Axial Inclination of Mandibular and Maxillary Incisor</td>
<td>The angle formed by the intersection of the long axis of the mandibular (II-II) with the maxillary incisor (IS-E). (Measures the degree of procumbency of the incisor teeth.)</td>
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<td>1 to SN</td>
<td>Angle of the Maxillary Incisor with Sella-Nasion</td>
<td>The angle formed by the intersection of the long axis of the most procumbent maxillary incisor (IS-E) to the sella-nasion (SN) plane.</td>
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<td>SN-MPL</td>
<td>Sella Nasion-Mandibular Plane Angle</td>
<td>The angle formed by the intersection of the sella-nasion (SN) plane with the mandibular plane.</td>
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All of these points were marked by inspection according to Salzmann (1957). In case of lack of superposition of the right and left skeletal outlines, the average between the two was drawn by inspection and the cephalometric points were located in reference to this arbitrary line.

The following specific measurements were taken for the purpose of this investigation:

**Linear Dimensions**

1. The length of the sella-nasion plane (N.S.)
2. The length of the sella-maxillary molar plane (S-M)
3. The length of the nasion-maxillary molar plane (N-M)
4. The length of the sella-maxillary incisor plane (S-I)
5. The length of the nasion-maxillary incisor plane (N-\perp)
6. The length of the "Ja" plane ("Ja"-II)

Angular Measurements
1. The sella-nasion-mandibular plane angle (SN-MPL/\perp)
2. The sella-nasion-maxillary incisor angle (SN to \perp)
3. The mandibular plane to mandibular incisor angle (MPL to \perp)
4. The angles formed by the intersection of the axes of the mandibular and maxillary incisor teeth. (H'I to H to E) or (\perp)
5. The angle of facial convexity (nasion subspinale plane and pogonion subspinale plane intersection angle) (N="A"-Po \perp)

Method of Analysis

1. Discussion of statistical means
   a. Male and female means
   b. The total group means
   c. Class I occlusion means and normal occlusions means
   d. Subgroup means for sex and occlusion
      (1) male normal occlusion means
      (2) male class I occlusion means
      (3) female normal occlusion means
      (4) female class I occlusion means
   e. Four individuals are selected at random, one from each subgroup, to represent the subgroups and to be compared to the means and to each other
   f. The 99 per cent confidence limit is discussed
2. Discussion of the general trends of the individual which were not revealed by the statistical means

3. The appraisal of (8) individual patterns by the integration of all the linear and angular measurements for the individual

a. Two photographs showing four different age-level tracings superimposed on sella along sella-nasion plane

b. Composite twelve-year tracing of the angle of facial convexity

c. A graph showing a composite of all linear and angular dimensions studied for an individual with the vertical line on the graph indicating the circumpuberal maximum height age level for the individual

d. Summary of changes seen for an individual for twelve years' studied.
CHAPTER III

EXPERIMENTAL RESULTS

The findings for each dimension investigated have been divided and discussed in three divisions. The first division was limited to the discussion of means which will be used to reveal the behavior of the group and subgroups. Because the stability of mean values may be caused by a balancing effect from equal but opposite trends in different individuals, the second division will be directed toward discussing general trends of individuals, which was not revealed by the statistical method used. The third part will be directed towards the appraising of individual patterns of eight individuals.

I. Means and 99 Per Cent Confidence Limits

A. Linear Dimensions

1. Sella to Nasion

a. Total Group Means (see Table 1)

The total group mean at the 5-9 age-level represented an absolute length of 62.6 millimeters. At the 17-9 age-level the absolute length was 71.2 millimeters. This indicated that for the total group mean the increment for the 12 years was 8.5
millimeters. The growth acceleration was greatest between the 12-9 to 13-9 age-level, when the one-year increment was 1.1 millimeters. A small growth acceleration was observed between the 5-9 and the 6-9 age-level. These accelerations for the sella to nasion dimension were not typical of skeletal growth accelerations.

h. Male and Female Means (see Table 1)

In appraising the group mean for the 20 males we see that the males at the 5-9 age-level have an absolute length of 64.3 millimeters and at the 17-9 age-level an absolute length of 73.8 millimeters. This would indicate that the male group means have a 12-year increment of 9.5 millimeters.

The female group mean at the 5-9 age-level had an absolute length of 60.9 millimeters and at the 17-9 age-level an absolute length of 68.6 millimeters. This is an increment of 7.8 millimeters for the 12 years investigated. The growth acceleration for the male means between the 12-9 and the 13-9 age-level is the most prominent for the 12 years studied. The female group means show no prominent 1-year acceleration rate, but from the 9-9 to the 13-9 age-level we see an increase in growth acceleration which remains constant for this 4-year interval. After the 13-9 age-level the growth for females along the sella-nasion plane seems to decelerate, because an increment of only .42
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millimeters is observed from the 14-9 to the 17-9 age-level.

The male means at the 5-9 age-level have approximately 3.5 millimeters more length on the sella-nasion plane than the female group mean. At the 14-9 age-level this difference in absolute length between female and male group means is still approximately 3.5 millimeters. From the 14-9 to the 17-9 age-level the male group means have an anterior cranial base (sella-nasion) which is approximately 5.1 millimeters more than the female group mean length. This indicates that the female group mean shows less growth in the sella-nasion plane than the male group mean after the age 14-9. It also indicates that the yearly increment for male and female group means is approximately the same from the 5-9 to the 14-9 age-level. The female has an acceleration rate which is earlier than that of the male, less in intensity, and which extends over a greater number of months. Growth before the 5-9 and after the 14-9 age-level is what makes the male group means, absolute length of sella to nasion, greater than the female means.

c. Class I and Normal Oclusion Group
 Means (see Table 1)

By observation of the normal occlusion group mean, it is seen that at the 5-9 age-level the absolute length of sella to nasion is 62.5 millimeters and at the 17-9 age-level it is 71.5
millimeters. This is a 12-year increment of 9 millimeters. The growth acceleration for both the normal occlusion group mean and the Class I group mean was between 12-9 and the 13-9 age-level.

The Class I occlusion group mean at the 5-9 age-level has an absolute length of 62.7 millimeters and at the 17-9 age-level an absolute length of 71.0 millimeters. This is a total 12-year increment of 8.3 millimeters. The growth acceleration for the Class I occlusion mean is composed of two smaller accelerations between the 9-9 to 10-9 and the 12-9 to 13-9 age-levels. The normal occlusion group mean shows a greater increment of absolute length for the 12 years investigated than the Class I occlusion means do. From the 14-9 to the 17-9 age-level the yearly increment is greater for the normal occlusion means than it is for the Class I means.

d. Subgroup Means for Sex and Occlusion (see Figure 1)

(1.) Male Normal Occlusion Means.---The male normal subgroup means at the 5-9 and through the 17-9 age-level are always slightly greater than the total group means. This subgroup mean shows a growth acceleration from the 12-9 to the 13-9 age-level. The subgroup continues to show a yearly increment of 1 millimeter or more from the 13-9 to the 16-9 age-level. The total increment for this subgroup mean from 5-9 to 12-9 age-level was 9.5 millimeters.
FIGURE 1

SSELLA --- NASION

99% Confidence Limit
Female Normal Mean
Female Class I Mean
Total Group Mean
Male Normal Mean
Male Class I Mean
(2) Male Class I Occlusion Means.---The male Class I subgroup mean at the 5-9 age-level is 65.4 millimeters. The absolute length of sella to nasion at the 17-9 age-level is 74.9 millimeters. This shows a total 12-year increment of 9.5 millimeters. The growth acceleration for this subgroup is most prominent between the 13-9 and 14-9 age-levels. A less prominent growth spurt is seen between the 9-9 and 10-9 age-levels. This subgroup mean has an absolute length of the sella nasion plane at the 5-9 age-level which is 3 millimeters more than the total group mean. At the 17-9 age-level, it is approximately 3.5 millimeters longer than the total group mean.

(3) Female Normal Occlusion Means.---The subgroup female normal means at the 5-9 age-level have an absolute length of 60.9 millimeters and at the 17-9 age-level an absolute length of 69.1 millimeters. The total twelve-year increment is 6.2 millimeters. The most prominent growth acceleration is seen between the 12-9 and the 13-9 age-level.

(4) Female Class I Occlusion Means.---The female Class I occlusion means at the 5-9 age-level have an absolute length of 60.9 millimeters and at the 17-9 age-level a length of 68.4 millimeters. This is an increase of 7.47 millimeters for the total 12 years investigated. This subgroup has very small growth accelerations with the most observable one between the 11-9 and
the 12-9 age-level. After the 13-9 age-level the yearly increment is .22 millimeters.

When we compare the means of these 4 subgroups we see that the male Class I means have an absolute length of the sella-nasion plane for the 12 years investigated, which is .5 millimeters greater than the female Class I mean and the female normal occlusion means. The Class I male means absolute length of sella-nasion plane is also 2 millimeters, or more than the male normal means for the 12 years studied. The female Class I means show the least yearly increment after the 13-9 age-level of any of the subgroups investigated. The female Class I means also show the least total 12-year increment of the sella-nasion plane.

e. Individuals within Subgroups (See Figure 2)

(1) Series 32 Male Normal Occlusion. --The individual representing the male normal occlusion subgroup means was randomly selected as series 32. This individual did not represent his subgroup mean trend. He appeared to have small dimensions for his entire facial skeletal system. His circumpuberal maximum height was at the 14-9 age-level, and his maximum growth acceleration was between the 15-9 and the 16-9 age-level. From the 16-9 age-level to the end of the data investigated, this individual shows very few significant changes along the sella-nasion
FIGURE 2

99% Confidence Limit
Female Normal No. 40
Female Class I No. 86
Total Group Mean
Male Normal No. 32
Male Class I No. 51
plane. This individual (series 32) was below his subgroup mean and the total group mean throughout the 12 years investigated, with the exception of the 5-9 age-level. The case represents a variation within a subgroup. The individual did follow a basic pattern for himself as he started with a small sella to nasion measurement and remained small in this single dimension. From the 9-9 to the 13-9 age-level the growth appears to have decelerated, as no measurable significant change was recorded during this period. The total 12-year increment for this plane was 7.7 millimeters. This was less than the subgroup means for both the males and the females for the 12-years investigated.

(2) Series 51 Male Class I Occlusion. -- The individual selected for this dimension is represented in Figure 2. He follows the mean of his subgroup rather well. His greatest growth acceleration is between the 12-9 and the 13-9 age-level. This individual had an increment of absolute length of 9.0 millimeters for the total 12 years studied. At the 5-9 age-level this individual's sella-nasion plane dimension was 4 millimeters longer than the total group mean for this age-level, and at the 17-9 age-level he was still 4.0 millimeters greater than the total group mean.

(3) Series 40 Female Normal Occlusion. -- The female with normal occlusion, randomly selected for this dimension, was number 40. This individual follows her subgroup mean trend. Her cir-
crucauberal maximum height is at the 12.5 age-level and her max-
imum growth acceleration along the sella-nasion plane is at the
11-9 age-level. This is closely correlated to the circumpuberal
maximum height. The last 5 years investigated revealed a yearly
increment of 0.2 millimeters for this dimension. She is below
the total group mean for sella-nasion throughout the 12 years
investigated.

(h) Series 86 Female Class I Occlusion.--The female
number 86 is represented in Figure 2. This individual showed a
maximum growth acceleration between the 8-9 and the 9-9 age-
levels. Her circumpuberal maximum height was at 10.65 years. A
growth acceleration was also observed between the 11-9 and 12-9
age-level. A special feature of this case was that she had the
least total increment for the 12 years investigated of all the
individuals within the study. The total increment was 6.9 milli-
ometers. The last 5 years this individual showed a yearly increm-
ent of 0.2 millimeters. The absolute length of the sella-nasion
plane at the 5-9 age-level was 59.2 millimeters and at the 17-9
age-level it was 65.5 millimeters. This individual showed an
extreme for her subgroup for this dimension, but she followed a
definite pattern as an individual.

f. The 99 Per Cent Confidence Limit

The 99 per cent confidence limit for these 12 age-levels
shows that there is a slight increase from 5-9 to 13-9 age-level.
From the 13-9 to the 17-9 age-level the confidence limit became progressively smaller. The maximum confidence limit was ± 10.9 at the 13-9 age-level, which is the same age-level at which the total group growth acceleration is seen. The confidence limit is never smaller than ± 7.8 at the 5-9 age-level. At the 17-9 age-level the confidence limit is ± 9.23 millimeters.

2. Sella to the Maxillary First Molar Measured on the Sella-Nasion Plane (5 to 6)

a. The Total Group Means (see Table 2)

The total group means represent an absolute length of the sella to B dimension at the 5-9 age-level of 24.7 millimeters. At the 17-9 age-level the absolute length of sella to B is 35.2 millimeters. From the previous two linear observations we can state that the increment of absolute length for the 12 years investigated is 10.5 millimeters. One of the most prominent growth accelerations is seen between the 12-9 and the 13-9 age-levels. It is an interesting observation that, between the 5-9 and the 6-9 age-level in all groups and subgroups, with the eruption of the first maxillary molars the yearly increment from sella to B is 1.5 millimeters. The 1-year increment at this age-level is the most prominent for the 12 years investigated.

b. Male and Female Group Means

The male group mean at the 5-9 age-level has an abso-
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**TABLE 2**
lute length from sella to 6 of 35.5 millimeters, and at the 17-9 age-level an absolute length of 37 millimeters. The total 12-year increment of absolute length is 11.5 millimeters for the male group mean. The maximum growth acceleration was present between the 12-9 and the 13-9 age-level, in which year the increment was 1.51 millimeters. The female group mean has an absolute length from sella to 6 at the 5-9 age-level of 23.9 millimeters and at the 17-9 age-level of 33.4 millimeters. The total increment for the female group mean for the 12 years studied was 10.5 millimeters. This is 1.0 millimeter less than the male group mean for the 12 years studied. The female group mean at the 5-9 age-level is 1.6 millimeters longer than the male mean at this age level. The male group mean at the 17-9 age-level is 37 millimeters and the female mean is 33.4 millimeters. Thus the difference between male and female means at this age level is 3.68 millimeters.

The male group mean shows an increase of approximately 3.5 millimeters from the 6-9 to the 10-9 age-level, whereas the female mean has only a 2.5 millimeter increase. The female group mean has a forward movement of the maxillary molar or growth of the maxilla that is greatest between the 10-9 and the 11-9 age-level. This 1-year increment is 2.0 millimeters. From the 12-9 to the 17-9 age-level the female mean has a total increment of only 2.5 millimeters and the male mean has a 5.0 millimeter increase for the same age-span.
c. Class I and Normal Occlusion Means

The normal occlusion group mean at the 5-9 age-level is the same as the Class I occlusion mean. These two group means tend to maintain this trend. From the 5-9 to the 10-9 age-level the normal occlusion mean shows an absolute length increment of 5.2 millimeters, while the Class I occlusion mean shows a 3.9 millimeter increase in this dimension. The total increment of absolute length for the 12 years studied was 11.7 millimeters for the normal occlusion means and 9.7 millimeters for the Class I means. The normal occlusion means are greater for this dimension by 2.1 millimeters than the Class I occlusion means.

d. Subgroup Means for Sex and Occlusion (see Figure 3)

(1) Male Normal Occlusion Means.—The male normal occlusion mean at the 5-9 age-level has a sella to 6 absolute length of 24.5 millimeters. At the 6-9 age-level this absolute length is 26.2 millimeters. This is a 1-year increment of 1.75 millimeters. From the 6-9 to the 12-9 age-level we see a constant increase in the absolute length of sella to 6. Between the 12-9 and the 13-9 age-levels we see another growth acceleration with a 1-year increment of 1.5 millimeters. From the 13-9 to the 17-9 age-level the total increase in this dimension is 2.0 millimeters. The absolute length at the 17-9 age-level is 36.6 millimeters. The total increment for the 12 years studied is 12.2 millimeters.
FIGURE 3

AGE

Total Group Mean

Male Normal Mean

Male Class I Mean
(2) Male Class I Means.--Male Class I means start at a greater absolute length of Sella to 6 than do the male normal group means. The male Class I means had their greatest anterior movement of the first maxillary molar from the 12-9 to the 13-9 age-level. At the 13-9 age-level the male Class I mean is 2.0 millimeters larger than the male normal mean. However, at the 16-9 age-level the male normal mean is only 1.0 millimeter different from the male Class I mean. At the 17-9 age-level the male Class I mean has a 37.6 millimeter absolute length. The total increment for the 12 years investigated is 10.9 millimeters. From this observation we can say that Class I means and normal occlusion means for males reveal that the normal occlusion group mean represent 1.3 millimeters greater increment of absolute length for the 12 years studied.

(3) Female Normal Occlusion Means.--The female normal mean reveals that the distance from sella to 6 is 24.7 millimeters at the 5-9 age-level. A 1-year increment of absolute length of 1.8 millimeters is observed between the 5-9 to 6-9 age-level. The female normal mean shows an acceleration in the anterior positioning of 6 between the age-levels 9-9 and 11-9 and then a more prominent acceleration between age-levels 12-9 and 13-9. From 13-9 to 17-9 there is a total increment of 1.0 millimeter. The absolute length of sella to 6 at the 17-9 age-level is 35.7. The total absolute increment for the 12 years studied is 11.0 millimeters.
(4) Female Class I Mean.--The female Class I means at the 5-9 age-level has the shortest absolute length from sella to 6 of any subgroup studied, namely 23.6 millimeters. The molar moved forward between the 5-9 and the 6-9 age-level less than in any other subgroup studied. The 1-year increment for this subgroup mean between 5-9 and 6-9 was 1.24 millimeters. Between the 11-9 and the 12-9 age-level a 2.1 millimeter increment was observed. The age-level 17-9 showed a 32.4 millimeter length for the sella to 6 dimension. The total 12-year increment was 8.9 millimeters. This increase for the 12 years was the least increment observed in any of the subgroups. The absolute length at the 17-9 age-level was 3.2 millimeters less than the female normal occlusion mean at the same age-level, 5.2 millimeters less than the male Class I mean, and 4.2 millimeters less than the male normal occlusion mean. These figures indicate that the Class I occlusion for both males and females showed a smaller increment from sella to 6 for the 12 years studied than the male and female normal occlusion means.

e. Individuals within Subgroups (see Figure 4)

(1) Male Normal Occlusion Series 109.--The male series 109 at the 5-9 age-level had an absolute length of 23.8 millimeters for the sella to 6 dimension. At the 8-9 age-level we see a large increase in the length of sella to 6. Over a 1-year period an increment of 3.5 millimeters in absolute length was
observed. At the 14-9 age-level another anterior displacement was observed, namely a 3.2 millimeters increment for one year. At this age-level the absolute length was 42 millimeters. This length is great and not characteristic of the subgroup mean. The absolute length is 7 millimeters greater than the male normal occlusion mean at the 17-9 age-level. At the 5-9 age-level the individual had a relatively small linear measurement, but the anterior displacement of $\delta$ was rapid and of long duration. This individual did not follow his own primary basic pattern. He was an extreme variation within his own facial skeletal pattern. This series 109 male had a late circumpuberal maximum height and thus could be correlated to the late growth acceleration and the longer duration of his facial growth.

(2) Male Class I Series 14.—This individual, selected at random, started with a relatively posteriorly positioned maxillary first molar in relation to sella. He had an absolute length of 23 millimeters at the 5-9 age-level. This is 3.7 millimeters less than his subgroup mean at this age-level. His readings are less than the total group mean, except at the age-levels of 16-9 and 17-9. The maximum anterior movement of the molar was at the 14-9 age-level. The circumpuberal maximum for this individual was at 15 years of age. The total increment for the 12 years studied was 10.8 millimeters. He is atypical of his subgroup. He followed a trend similar to the female normal mean.
This again shows that the wide ranges within subgroups tend to negate any significant differences between subgroups.

(3) Female Normal Occlusion Series 14.—The female normal individual selected at random was series 114. At the 5-9 age-level the absolute length of sella to 6 was 19.5 millimeters. This was the smallest reading recorded for this dimension in the total group of 40 individuals. An anterior displacement of the maxillary molar was prominent between the 9-9 and 11-9 age-levels. Another growth acceleration was observed at the 13-9 age-level, but this was of shorter duration and less intense than the first one recorded. It was observed that the individual's trend began with a short length of sella to 6 and that at the terminal age of the study the individual was still rather small in this single dimension.

(4) Female Class I Occlusion Series 79.—The female Class I individual series 79 was randomly selected to represent her subgroup mean. She also started with a rather small absolute length from sella to 6. At the 5-9 age-level the length was 21.5 millimeters. A small anterior displacement of the maxillary molar was observed between the 7-9 and the 8-9 age-levels. The total 12-year increment was 7.7 millimeters. This is the smallest increment for this dimension of any of the 40 individuals studied. Only a 0.2 millimeter increment was observed from the 13-9 to the 17-9 age-levels. The circumpuberal maximum
height for this individual was recorded at 12.4 years, and growth appears to have decelerated at approximately the 13-9 age-level. The absolute length for this dimension at the 17-9 age-level was 29.2 millimeters. This was also the smallest terminal-age-length that any of the 40 individuals had for this dimension. This individual appeared to follow a basic pattern for herself as an individual throughout the 12 years she was studied.

1. The 99 Per Cent Confidence Limit

The 99 per cent confidence limit at the 5-9 age-level is ± 9.62 and this decreases until the age 10-9, when it is at its lowest value of ± 8.81. From the 10-9 age-level to the 16-9 age-level the confidence limit increases to the ± 12.14 millimeters. At the 17-9 age-level the confidence limit becomes smaller and its numerical value is ± 11.83 millimeters.

2. Maxillary First Molar to Nasion Measured on the Sella-Nasion Plane (C to N)

a. The Total Group Mean (see Table 3)

The absolute length of nasion to the maxillary first molar at the 5-9 age-level is 37.9 millimeters. The total group mean at the 17-9 age-level is 35.9 millimeters. The total decrease for the 12 years is 1.93 millimeters. As the molar is moving forward with the maxilla, nasion is growing forward by apposition, and thus away from the molar. For this reason there is a slight increase in the nasion to 6 dimension between the
7-9 and the 8-9 age-level. From the 9-9 age-level to the 17-9 age-level, the maxillary molar is moving anteriorly, and thus relatively closer to nasion.

b. Male and Female Means

The male mean at the 5-9 age-level has an absolute length of 38.7 millimeters and at the 17-9 age-level has decreased to 36.7 millimeters, which is a total decrease for the 12 years of 2 millimeters. The male mean shows the greatest decrease between the 10-9 and 11-9 age-level.

The female mean at the 5-9 age-level has an absolute length of 37 millimeters. This is 1.7 millimeters less than the male mean at this age-level. The female mean shows the greatest decrease between the 8-9 and the 9-9 age-level. The mean for females at the 17-9 age-level is 35.2 millimeters. The total absolute length showed a decrease from the 5-9 to the 17-9 age-level of 1.8 millimeters.

c. Class I and Normal Occlusion Means

The normal occlusion mean at the 5-9 age-level shows an absolute length of 37.8 millimeters and at the 17-9 age-level of 35.2 millimeters. The total decrease for the 12 years investigated was 2.64 millimeters. The normal group mean shows a growth change between the 7-9 and the 8-9 age-level, when the dimension
nasion to 6 increases rather than decreases. Thus growth over-
compensates for mesial movement of the molar, and this dimension
shows a temporary increase.

The Class I occlusion mean at the 5-9 age-level repres-
sents an absolute length of 37.9 millimeters. At the 17-9 age-
level the mean for this group is 36.5 millimeters. The total
decrease for the 12 years investigated was 1.4 millimeters.
When this total decrease was compared to the normal occlusion
mean total decrease for the 12 years it indicated that in Class
I occlusion means the molar does not move as far forward as it
does in normal occlusion means.

d. Subgroup Means (see Figure 5)

(1) Male Normal Occlusion Means.—The male normal
occlusion mean seems to be very similar to the total group mean.
This subgroup mean at the 5-9 age-level is approximately 1.0 mil-
limeter greater than the total group mean at the same age-level.
Throughout the 12 years studied this subgroup mean was approx-
imately 1.0 millimeter greater than the total group mean at each
age-level. An increase in the nasion to 6 distance is seen
between the 7-9 and the 8-9 age-level. The absolute length of
this dimension (N to 6) at the 5-9 age-level was 38.7 millimeters.
At the 17-9 age-level it was 36.1 millimeter. Therefore the
total decrease in length for the 12 years studied was 2.6 milli-
meters.
(2) Male Class I Means.--The male Class I mean at the 5-9 age-level was 38.7 millimeters and at the 17-9 age-level it was 37.3 millimeters. There was a total decrease for the 12 years studied of 1.43 millimeters. From the 7-9 to the 10-9 age-level the distance between nasion to 6 became greater due to growth being greater than the anterior movement of the molar. From the 10-9 to the 17-9 age-level the distance between nasion to 6 decreased slowly with the greatest decrease occurring between the 11-9 and the 12-9 age-level. The male Class I molars did not move anteriorly as much as the male normal mean.

(3) Female Normal Occlusion Means.--The female normal occlusion mean showed the smallest mean of the four subgroups. The absolute length of the nasion to 6 dimension at the 5-9 age-level was 36.1 millimeters and at the 17-9 age-level it was 33.4 millimeters. The total decrease for the 12 years was 2.73 millimeters. Throughout the age-levels investigated the female normal means were 1.5 millimeters less than the total group means. From the 7-9 to the 9-9 age-level, growth between 6 and nasion was greater than the anterior movement of the maxillary first molar. The molar moved forward the greatest amount between the 9-9 to 11-9 age-levels. This is the age when the deciduous tooth in the buccal segment are being replaced by the succedaneous tooth.
(h) Female Class I Means.—The female Class I mean had an absolute length at the 5-9 age-level of 37.4 millimeters and at the 17-9 age-level of 36 millimeters. The total decrease in this dimension from 5-9 to 17-9 was 1.41 millimeters. From the 7-9 to the 8-9 age-level there was a 1-year increment of 1.2 millimeters. This would indicate that growth took place between nasion and the maxillary first molar which was 1.2 millimeters greater than the anterior movement of the maxillary first molar. From the 10-9 to the 11-9 age-level the molar appears to have moved anteriorly more than at any other 1-year span studied. The female Class I means for this dimension were always greater than the female normal occlusion means.

6. Individuals within Subgroups (see Figure 6)

(1) Male Normal Occlusion Series 109.—Series 109 was used as the individual to represent the males with normal occlusions. This individual started and remained below the total group and his own subgroup mean. From the 5-9 age-level to the 7-9 age-level the distance from nasion to 6 decreased rather slowly, and then between the 7-9 and 8-9 age-level the distance increased. Between the 8-9 and the 9-9 age-levels the distance decreased rapidly, showing an absolute decrease of 3.5 millimeters. From the 9-9 to the 11-9 age-level the distance again increased, due to growth. The decrease was gradual from the 12-9
to the 17-9 age-level. This individual started below the total group mean and subgroup mean and continued to remain below the mean throughout the 12 years investigated. The individual represented a variation from his own subgroup, but did follow a basic trend for his own individual pattern.

(2) Male Class I Series 21.—This individual was consistently much higher than the subgroup mean. At the 5-9 age-level his absolute length from nasion to 6 was 44.6 millimeters, and, except for a slight increase in length at the 6-9 age-level, the distance was slowly reduced to 42.5 millimeters at the 10-9 age-level. At the 11-9 age-level the absolute length of nasion to 6 was 44.0 millimeters, an increase of 1.5 millimeters. The length was slowly reduced after the 11-9 age-level until at the 15-9 age-level, when an increase of 1.0 millimeter was observed. From the 15-9 to the 17-9 age-level, the length slowly decreased. This individual remained above the total group mean approximately the same amount for all 12 age-levels. The individual had a relatively stable pattern, with two small forward movements at two different age-levels. The circumpuberal maximum height of this individual was at 14.4 years. The growth pattern showed the most prominent change at 14-9. This would indicate a facial growth acceleration which is later than the circumpuberal maximum height.
(3) Individual Female Normal Occlusion Series 40.—The female normal occlusion individual randomly selected was series 40. The maximum circumpuberal height was at 12.05 years. From the 6-9 to the 8-0 age-level the absolute length of nasion to 6 decreased. Between the 8-9 and the 9-9 age-levels the distance from nasion to 6 showed an increase due to a growth acceleration. From the 10-9 to the 11-9 age-level the dimension decreased in absolute length. The absolute length decreased a total of 0.3 millimeters from the 5-9 to the 17-9 age-level. The individual remained below her subgroup mean throughout the 12 age-levels, but she did follow a stable pattern for herself.

(4) Female Class I Occlusion Series 86.—The individual randomly selected, series 86, had a circumpuberal maximum height at the 10.65 age. The individual at the 5-9 age-level had an absolute length of 39 millimeters. This is a very large dimension for this subgroup at this age-level. The distance nasion to 6 rapidly decreased from the 5-9 to the 7-9 age-level. Between 7-9 and 8-9 there was a growth acceleration. From the 8-9 to the 12-9 age-level the distance from nasion to 6 was reduced rapidly. At the 17-9 age-level the absolute length of nasion to the maxillary first molar was 35.3 millimeters, which was below the total group mean value. The absolute decrease for the 12 years studied was 4 millimeters.
# "JA" PLANE

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millimeters. At the 13-9 age-level the male had a 1.75 millimeter greater absolute length of the "Ja" plane than the female. Between the 13-9 and 14-9 age-level the male mean showed another small acceleration rate which was not present in the female mean. From the 13-9 age-level to the 17-9 age-level the male showed an increment of 3.07 millimeters while the female mean during the same age-span showed an increment of only 1.33 millimeters.

From this knowledge we can say that not only does the mandible of the male grow at a greater incremental rate, but it also grows for a longer time in both a vertical and a horizontal direction. The total increment rate for the 12 years studied for the males was 10.14 millimeters and for the females only 7.5 millimeters.

c. Normal and Class I Occlusion Means

When we compare the Class I and normal occlusion means we observe that from the 5-9 age-level to the 17-9 age-level the trend was for the Class I occlusion means to represent approximately 0.9 millimeters more absolute length on the "Ja" plane than the normal occlusion means. Both the Class I and normal occlusion means between the 6-9 and 7-9 age-level had an acceleration rate of 1.6 millimeters.
d. Subgroup Means (see Figure 7)

(1) Male Normal Means.—The male normal mean absolute length of the "Ja" to ii dimension at the 5-9 age-level was 32.7 millimeters and at the 17-9 age-level it was 42.3 millimeters. The total increment for the 12 years was 9.6 millimeters. The incremental rate for 1 year from 6-9 to 7-9 was 1.4 millimeters. The growth along the "Ja" plane between the 16-9 and 17-9 age-level was 0.3 millimeter.

(2) Male Class I Means.—The male Class I mean began with a 1.6 millimeter greater absolute length than the male occlusion mean. At the 17-9 age-level the male Class I mean was 1.64 millimeters longer on the "Ja" plane than was the male normal occlusion group. The male Class I group had an acceleration rate of 1.5 millimeters between the 5-9 and 6-9 age-level. Between the 6-9 and the 7-9 age-level the 1-year increment in absolute length was 2.4 millimeters. At the 7-9 age-level the Class I group had an absolute length of 38.2 millimeters, while the male normal mean was only 35 millimeters at the same age. The difference between these two male occlusion means at the 7-9 age-level was 3.2 millimeters. From the 7-9 age-level to the 17-9 age-level the male normal occlusion means showed a greater yearly increment. This reduced the difference between the "Ja" plane of those two male occlusion means.
(3) Female Class I Means.—The female Class I mean for the absolute length of the "Ja" plane at the 5-9 age-level was 32.7 millimeters and at the 17-9 age-level 40.4 millimeters. The incremental length for the 12 years studied was 7.65 millimeters. The increment of growth from 9-9 to the 17-9 age-level for the female Class I mean was 4.4 millimeters. This was a yearly increment of 0.57 millimeters. It is interesting to note that the male and female normal occlusion means had less absolute length on the "Ja" plane when compared to the male Class I mean and the female Class I mean, respectively. This observation was a common trend for all of the age-levels investigated.

o. Individuals within Subgroups (see Figure 8)

(1) Male Normal Occlusion Individual Series 57.—The male normal individual number 57 was randomly selected to represent his subgroup means. This individual at the 5-9 age-level was below the total group mean and below his subgroup mean. Throughout the entire 12 years this individual was below the total group and subgroup means. A growth acceleration for this individual was between the 5-9 and the 6-9 age-level. The total growth increment was 8.8 millimeters. This was below the mean for this subgroup.

(2) Male Class I Individual Series 116.—The male Class I individual number 116 was randomly selected and showed a typical
"Ja" POINT TO II

AGE

Total Group Mean

Female Normal No. 40
Female Class I No. 106

Male Normal No. 57
Male Class I No. 116

99% Confidence Limit

Figure 8
growth pattern for the Class I occlusion subgroup. This individual had two growth accelerations. The first was between the 6-9 and the 7-9 age-level; the second was between the 11-9 and the 13-9 age-level. The circumpuberal maximum height was recorded at the 13-year age-level. The total increment of growth for the 12 years studied was 11.0 millimeters. The male individual number 116 was above his subgroup mean throughout the 12 years studied and at the 7-9 age-level this individual approached the 99 per cent confidence limit. At the 5-9 to 6-9 age-level this individual showed a growth increment of approximately 4.0 millimeters. The individual had a tendency to follow his own definite pattern, which in his case was large for his subgroup and for this dimension.

(3) Female Normal Occlusion Individual Series 40.--The individual number 40 was randomly selected to represent this subgroup. She was below the total group mean throughout the 12 years investigated. The total increment for the 12 years was 9.0 millimeters. This total 12-year increment was greater than the total 12-year increment for her subgroup. She followed her own basic pattern throughout the years that this investigation covered.

(4) Female Class I Individual Series 106.--This female Class I was randomly selected to represent her subgroup. This
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**TABLE 5**
cumbency was reduced to approximately 91.7 degrees and remained relatively stable at this angle from the 13-9 to the 17-9 age-level. At the 17-9 age-level the total group mean was at a 91.9 degree angle.

b. The Male and Female Means

When the male means and the female means were compared, it was observed that the female was more procumbent, by a 2.5 to 4.0 degrees, than the male incisor mean angle. The female mean incisor angle at the 5-9 age-level was 86.34 degrees and the male mean for this angle at the same age-level was 85.0 degrees. At the 11-9 age-level the female mean lower incisor angle was 94.6, while the male mean angle was more upright at 91.2 degrees. The female for the 12 years investigated had an absolute angular increment of 7.5 degrees, while the male angular mean increment was 4.93 degrees. It was also very noticeable that the means for both female and male represented a greater axial inclination of the lower incisor at the 10-9, 11-9, and 12-9 age-levels than at any other time during the 12 years investigated. Both male and female had a vertical eruption of the lower incisor, then an increased inclination which reached a maximum procumbency at the 10-9 age-level. From the 10-9 to the 17-9 age-level the tooth became more upright. The maximum procumbency for the male means was 91.54 degrees at the 10-9 age-level and 94.8 degrees for the females at the same age-level.
c. Normal Occlusion Means and Class I Means

The lower incisor to gonion-gnathion angle for the normal occlusion means showed a trend for being more upright than the Class I means. The normal occlusion mean was at 84.7 degrees at the 5-9 age-level, while the Class I mean angle at this age-level was 86.4 degrees. The normal occlusion mean angle never exceeded 91.8 degrees, while the Class I mean reached a maximum procumbency of 94.3 degrees. At the 13-9 age-level the Class I mean angle is more upright at 92.9 degrees, but from this age-level to 17-9 the incisor tends to become more prognathic. At the 17-9 age-level the normal occlusion mean had a lower incisor to gonion-gnathion angle of 89.6 degrees and a Class I mean of 93.6 degrees.

d. Subgroup Means (see Figure 9)

(1) Male Normal Occlusion Individual.—The male normal mean for the lower incisor to gonion-gnathion angle were always 1.35 degrees less than the male Class I mean. At the 5-9 age-level the male normal mean was 84.4 degrees, which was more upright than the other subgroup means. The maximum procumbency for the male normal occlusion mean was at the 10-9 age-level and the angle was 90.3 degrees. From the 10-9 to the 17-9 age-level the lower incisor tends to become more upright until at the 17-9 age-level the incisor was at 87.5 degrees.
(2) Male Class I Means.--The male Class I subgroup at
the 5-9 age-level had a mean angle of 85.3 degrees. This sub-
group was at a maximum procumbency at the 10-9 age-level, when
the protrusion was 93 degrees. As a subgroup mean the angle
decreased until 13-9, when it tended to show an increase in axial
inclination. At the 17-9 age-level the mandibular incisor was
axially inclined to an angle of 92.9 degrees.

(3) Female Normal Occlusion Means.--The female normal
occlusion subgroup had a lower incisor to gonion-gnathion mean
angle of 85.3 at the 5-9 age-level. This subgroup had a greater
maximum procumbency for the lower incisor than any of the other
three subgroups. This maximum procumbency was at the 9-9 age-
level when it was 96.5 degrees. From the 9-9 age-level to the
13-9 age-level the lower incisor became less inclined and more
upright. The male normal means showed a greater procumbency and
a maximum procumbency at an earlier age than the other three sub-
group means. The terminal angular reading at the 17-9 age-level
for the female normal occlusion subgroup mean was 93.5 degrees.

(4) Female Class I Occlusion Means.--The female Class I
mean at the 5-9 age-level was a 86.8 degree angle. The maximum
incisor procumbency for this subgroup was at the 10-9 age-level
and was 95 degrees. At the 13-9 age-level the mean female Class
I procumbency was 93.5 degrees and tended to remain stable at
this inclination. At the 17-9 age-level the mean mandibular incisor angle was 94 degrees.

1. Individuals within Subgroups (see Figure 10)

(1) Male Normal Occlusion Individual Series 65.—The male normal individual number 65 represented his subgroup mean. At the 5-9 age-level the lower incisor to the gonion-gnathion plane angle was 87 degrees. At the 10-9 age-level the incisor was at its maximum inclination of 91 degrees. From the 11-9 to the 17-9 age-level the lower incisor became less procumbent. At the 17-9 age-level the incisor to the gonion-gnathion plane was at an angle of 85.6 degrees.

(2) Male Class I Individual Series 51.—Individual number 51 was randomly selected to represent his subgroup. This individual varied significantly from his mean. At the 5-9 age-level the incisor was in an upright position, but it became progressively more procumbent with age. Between the 11-9 and the 15-9 age-level the incisor inclined from 93 degrees to a more procumbent 97 degrees. The incisor inclination did not decrease from this age-level. Thus this individual represents an example of an incisor which did not decrease in procumbency with age.

(3) Female Normal Occlusion Individual Series 114.—The individual selected from this subgroup was number 114. The angle formed by the lower incisor to gonion-gnathion plane at the
Figure 10

Angle

1 to Gonion-Gnathion Plane

99% Confidence Limit

Female Normal No. 114

Female Class I No. 105

Male Normal No. 65

Male Class I No. 51

AGE

5-9
6-9
7-9
8-9
9-9
10-9
11-9
12-9
13-9
14-9
15-9
16-9
17-9

Total Group Mean

No. 114

No. 105

No. 65

No. 51

99% Confidence Limit

Degrees
4-9 age-level was 97 degrees. The angle increased very rapidly so that at the 9-9 age-level the axial inclination of the lower incisor was 102 degrees. From this age-level the lower incisor became more upright until the 15-9 age-level, when the incisor was at 90 degrees and remained stable in this position through the 17-9 age-level.

5. Female Class I Individual Series 105.—Female individual number 105 at the 5-9 age-level showed a rather severely retruded incisor at an angle of 78 degrees. The angle increased rapidly and at the 13-9 age-level the lower incisor was at an angle of 96 degrees. The incisor became less procumbent at the 14-9 age-level (94.5 degrees) and then the axial inclination increased at a slow but steady rate to the 17-9 age-level. This individual had a lower incisor which became more axially inclined with age.

f. The 99 Per Cent Confidence Limit

The 99 per cent confidence limit trend became progressively larger with age. The confidence limit at the 5-9 age-level was ± 18.8 degrees and at the 17-9 age-level it had increased to ± 21.2 degrees.
2. Angle of the Maxillary Incisor
to the Collaasion Plane (see Table 6)

a. Total Group Mean

At the 5-9 age-level the total group mean was 92.6 degrees, which would indicate that the vertical eruption of the upper incisor was comparable to the same eruption pattern of the lower incisor. At the 6-9 age-level the mean for the total group showed that the incisor was rapidly becoming more procumbent. The absolute angular increment from 5-9 to the 6-9 age-level was plus 4.1 degrees. From the 6-9 to the 7-9 age-level it had an increment of 3.0 degrees. For the 7-9 to the 8-9 age-level the increment was 1.5 degrees. From the 9-9 to the 15-9 age-level the upper incisor's axial inclination mean for the total group was relatively stable. The 16-9 and 17-9 age-level showed a small increase in the axial inclination of the upper incisor. The 17-9 age-level had a total group mean axially-inclined incisor of 103.2 degrees.

b. Males and Females Mean

At the 5-9 age-level the male maxillary incisor was 2.5 degrees more procumbent than the female maxillary incisor mean. Starting at 6-9 the female incisor mean was 3.0 degrees more procumbent than the male mean. At the 7-9 age-level the female mean was 4.0 degrees greater than the male mean. At the 8-9
## ANGLE 1 - TO SN

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**Table 6**
age-level the female mean was 5.0 degrees greater than the male mean. The female mean was 6.0 degrees greater than the male mean at the 11-9 to 13-9 age-level. From the 14-9 to the 17-9 age-level the female mean angle for the maxillary incisor was 4.0 to 5.0 degrees more procumbent than the male mean.

c. Normal and Class I Means:

At the 5-9 age-level the normal occlusion means were more procumbent than the Class I means (95.4 to 90.6 degrees). The Class I mean became 5.0 degrees more procumbent at the 6-9 age-level. The Class I occlusion mean became greater than the normal occlusion mean at the 6-9 age-level and remained greater through the 17-9 age-level. From the 10-9 age-level the Class I means had a maxillary incisor angulation of 103.3 degrees and maintained this angulation or a slightly greater angulation for rest of the years investigated. From the 10-9 to the 17-9 age-level the normal occlusion group mean maxillary incisor increases its axial inclination from 100.9 degrees to 102.6 degrees. Thus at the 17-9 age-level the Class I mean was 1.0 degree more than the maxillary incisor angle for the normal occlusion mean.

d. Subgroup Means

(1) Male Normal Means (see Figure 11).—The male normal mean at the 5-9 age-level had a maxillary incisor inclination of 95.6 degrees. This angle increased to 99.3 degrees at the 9-9
Angle
1 to Sella-Nasion
age-level. From the 9-9 to the 12-9 age-level the angular inclination of the maxillary incisor decreased. From the 12-9 to the 17-9 age-level the maxillary incisor increased, and at the 17-9 age-level the incisor had an angular inclination of 101 degrees.

(2) Male Class I Means.—The male Class I mean at the 5-9 age-level represented a vertically erupted maxillary incisor. At the 9-9 age-level the maxillary incisor had an angular inclination of 100.4 degrees. The angular inclination of the incisor increased to 101.5 degrees at the 10-9 age-level; then it had a constant decrease in the angle, so that at the 13-9 age-level the incisor was at an angle of 99.4 degrees. Throughout the 14-9 and 15-9 age-levels the angulation of the incisor remained relatively stable at 101.4 degrees, and then decreased to 100.7 degrees at the 16-9 and 17-9 age-levels.

(3) Female Normal Occlusion Means.—The female normal occlusion mean at the 6-9 age-level represented an incisor whose axial angulation was more procumbent than any of the other 3 subgroup means at this age-level. At the 5-9 age-level the female mean was 95 degrees; at the 7-9, 8-9, and 9-9 age-levels the angulation was approximately 106.4 degrees. The incisor became more upright at the 10-9 age-level (105 degrees). At the 11-9 age-level the incisor increased in its axial inclination to 106.2 degrees. From the 12-9 to the 17-9 age-level the axial inclination of the maxillary incisor averaged 105.5 degrees.
Figure 12

Angle 1 to Sella-Nasion

99% Confidence Limit
Female Normal No. 72
Female Class I No. 111
Total Group Mean
Male Normal No. 109
Male Class I No. 92

Age
decreased rapidly to 104.5 degrees, but it was back to 109 degrees at the 12-9 age-level. From the 12-9 to the 17-9 age-level the maxillary incisor angle decreased slightly, but then reached its maximum of 110.7 at the last year of the investigation.

(2) Male Class I Individual Series 92.—The male Class I individual, series 92, was randomly selected to represent his subgroup mean. He followed his subgroup mean quite well. From the 5-9 to the 6-9 age-level this series, 92, showed a sharp rise in the angle of axial inclination for the maxillary incisor. Between the 7-9 and 8-9 age-level the angle decreased to approximately 99.7 degrees. The maxillary incisor's axial inclination remained rather constant, with the exception of a small decrease at the 12-9 age-level. At the 17-9 age-level the inclination of the maxillary incisor to the sella-nasion plane was 101.5 degrees.

(2) Female Normal Occlusion Individual Series 72.—The female with normal occlusion, number 72, represented this subgroup mean. The individual did not follow a basic pattern that was present at the 5-9 age-level. At this age-level the individual had a very procumbent maxillary incisor which had an absolute angular inclination of 102.0 degrees. At the 9-9 age-level the maxillary incisor for this series was at its maximum procumbency of 107.0 degrees. From the 9-9 to the 10-9 age-level the maxillary incisor became more upright until at the 10-9 age-
level it was 100.6 degrees. The incisor remained relatively stable throughout the remaining years investigated. It was at an axial angular inclination of 101.0 degrees at the 17-9 age-level.

 Female Class I Individual Series III. Series number 111 was randomly selected and showed a continuous increased axial inclination for the maxillary incisor, with the exception of a decrease at the 12-9 age-level. The incisor angulation showed an increment for the 12 years studied of 20.0 degrees. At the 17-9 age-level the angulation of 1 to SN was 110.0 degrees.

f. The 99 Per Cent Confidence Limit

The 99 per cent confidence limit at the 5-9 age-level was ± 14.8 degrees. At the 17-9 age-level the confidence limit was ± 17.2 degrees. The confidence limits showed minor fluctuations from year to year.

3. Interincisal Angle (1 to I) (see Table 7)

This angle is altered by changes in sella-nasion plane, mandibular plane, changes of the mandibular incisor angularly or bodily, and changes in the maxillary incisor angularly or bodily.

a. The Total Group Mean

The interincisal angle mean at the 5-9 age-level was approximately 147.0 degrees. The maxillary and mandibular incisors became more procumbent to the sella-nasion and gonion-
### INTERINCISAL ANGLE

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</table>

**TABLE 7**
mation plane, and thus the interincisal angle decreased at the angular rate of 6.0 degrees per year. At the 6-9 age-level the interincisal mean angle was 132.0 degrees. The interincisal angle did vary somewhat from the 6-9 age-level, but it never changed more than ± 1.0 degrees from this angular mean. At the 17-9 age-level it was 132.3 degrees. This does not mean that the angular means were stable, but it does suggest that the changes of one plane or incisor was compensated by changes of the incisor of the opposing jaw, or the plane of the opposing jaw.

b. Male and Female Means

These means both follow the same pattern as described for the total group means. It must be pointed out, however, that the female mean for the interincisal angle was always less than the male mean.

c. Normal and Class I Means

The normal occlusion and the Class I means at the 5-9 age-level had an interincisal angulation of 146.1 and 147.4 degrees, respectively. The normal occlusion mean for the interincisal angle was reduced 5.0 degrees at the 6-9 age-level, whereas the Class I mean decreased 7.5 degrees. At the 10-9 age-level the Class I mean had the smallest angle for the 12 years studied, an angle of 127.2 degrees. The normal occlusion mean was minimal at the 9-9 age-level, an angle of 131.3 degrees.
At the 17-9 age-level the normal occlusion mean was 135.6 degrees, while the Class I mean for the same age-level was 129.8 degrees. From the general observable trend for the 12 years investigated it is plausible to state that the Class I means are representative of a greater dental procumbency than the normal occlusion means.

d. Subgroup Means (see Figure 13)

(1) Male Normal Means.—The male normal mean was 145 degrees at the 5-9 age-level. The angle was reduced at the rate of 2.0 degrees per year until it reached 137.6 degrees at the 8-9 age-level. From the 8-9 to the 11-9 age-level the interincisal angle decreased 1.0 degree per year. At the 17-9 age-level the interincisal angle mean was 139.3 degrees.

(2) Male Class I Means.—The male Class I means followed a similar pattern to the male normal means, but at the 6-9 to 7-9 age-level the interincisal angle mean was reduced 5.0 degrees more than the male normal mean angle was. The angle of inclination at the 7-9 age-level had a mean of 135.7 degrees. The angle continued to decrease at the same rate as the male normal mean did, and reached its minimum value at the 10-9 age-level, when it was 130.3 degrees. It increased at a mild rate and reached 133.6 degrees at the 13-9 age-level. Between the 13-9 and 14-9 age-levels, the interincisal mean angle decreased and then remained relatively constant to the 17-9 age-level. The interincisal angle mean at the 17-9 age-level was 132.6 degrees.
INTERINCISAL ANGLE
1 to 1

FIGURE 13

99% Confidence Limit
Female Normal Mean
Female Class I Mean
Male Normal Mean
Male Class I Mean

AGE
5-9 6-9 7-9 8-9 9-9 10-9 11-9 12-9 13-9 14-9 15-9 16-9 17-9

Degrees
(3) Female Normal Means.--The female normal occlusion mean at the 5-9 age-level was relatively high, with a reading of 146.3 degrees. Between the 5-9 and the 6-9 age-level the mean angle decreased 20.0 degrees. The minimum mean angle for this subgroup was 122.5 degrees, at the 9-9 age-level. At the 13-9 age-level the angle increased to 130.3 degrees. The mean inter-incisal angle decreased to 128.7 degrees at the 17-9 age-level.

(4) Female Class I Means.--The female Class I subgroup mean at the 5-9 age-level was 148.4 degrees and decreased a total of 16.0 degrees to the 7-9 age-level. The angle continued to decrease and at the 10-9 age-level it was 125.2 degrees. At the 13-9 age-level it had increased to 128.2 degrees, and at the 17-9 age-level the mean interincisal angle was 128.0 degrees.

e. Individuals within Subgroups (see Figure 14)

(1) Male Normal Occlusion Individual Series 32.--Individual number 32 followed his subgroup mean for this dimension. At the 5-9 age-level he had an interincisal angle of 135.7 degrees. This angle increased to 147.7 at the 6-9 age-level, decreased to 138.3 at the 8-9 age-level, and remained relatively stable until the 12-9 age-level. Between the 12-9 and 14-9 age-levels the interincisal angle increased to 142.9 degrees, and then decreased to 138.5 degrees at the 17-9 age-level.

(2) Male Class I Occlusion Individual Series 51.--The male with Class I occlusion randomly selected was individual
INTERINCISAL ANGLE

Figure 14

99% Confidence Limit
Female Normal No. 40
Female Class I No. 86
Male Normal No. 32
Male Class I No. 51
number 51. At the 5-9 age-level the interincisal angle was 135.0 degrees. He showed a rapid increase at the 6-9 age-level. From the 6-9 age-level to the 9-9 age-level the interincisal angle decreased approximately 20.5 degrees. From the 10-9 to the 13-9 age-level the interincisal angle increased, then at the 14-9 age-level it had decreased to 122.3 degrees. At the 17-9 age-level the interincisal angle was 126.8 degrees.

(3) Female Normal Occlusion Individual Series 40.—The female series 40 was randomly selected to represent her subgroup mean. She had an extreme interincisal angle at the 5-9 age-level, namely 165.0 degrees. At the 7-9 age-level the angle had decreased to 135.0 degrees, which was 30.0 degrees in 2 years. At the 9-9 age-level the interincisal angle was at its lowest value, 130.0 degrees. From the 9-9 to the 13-9 age-level the angle increased to 147.0 degrees. The interincisal angle had decreased to 143.4 degrees at the 17-9 age-level. This individual showed the wide variation that an individual may have from the total group, but at the same time maintained a constant pattern for herself as an individual.

(4) Female Class I Individual Series 66.—The female Class I individual randomly selected was number 66. She started with a relatively small interincisal angle of 136.5 degrees. The angle decreased to 123.0 degrees at the 9-9 age-level; then
showed a mild increase of almost 1.5 degrees from the 5-9 to the 11-9 age-level. From the 12-9 to the 17-9 age-level the angle was relatively stable and was 126.5 degrees at the 17-9 age-level. This individual also followed a basic pattern for herself, as she started with a relatively small interincisal angle at the 5-9 age-level, and it was still small at the 17-9 age-level.

1. The 99 Per Cent Confidence Limit

The 99 per cent confidence limit for this angle was very large. At the 5-9 age-level the reading was ± 31.5 degrees. From the 6-9 through the 17-9 age-level the value was 25.5 ± 1.5 degrees.

1. The Angle of Facial Convexity (NAP) (see Table 8)
a. The Total Group Mean

The total group mean for the angle of facial convexity at the 5-9 age-level was +8.7 degrees. At the 7-9 age-level the angle showed a decrease of 1.5 degrees, which indicates that the profile was becoming straighter. From the 8-9 to the 13-9 age level the total group mean was approximately +5.5 degrees. From the 14-9 to the 17-9 age-level the profile became straighter, as revealed by the decrease in the angle of facial convexity. At the 17-9 age-level the angle of facial convexity was +2.1 degrees.
## Angle of Facial Convexity

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<th>WMN AVG</th>
<th>GRP AVG</th>
<th>NRM AVG</th>
<th>CL Avg</th>
<th>MN Avg</th>
<th>MI Avg</th>
<th>FN Avg</th>
<th>FI Avg</th>
</tr>
</thead>
</table>

**Table 8**
b. Male and Female Means

The male means revealed that the males were less procumbent than the females for the 12 years studied. At the 5-9 age-level the angle of facial convexity for the males was +7.4 degrees and for the females +10.0 degrees. At the 17-9 age-level the male mean had an angle of facial convexity of +.9 degrees, while the female mean was +3.3 degrees. The male mean at the 7-9 age-level was +5.6 degrees and then the male mean showed that the angle of facial convexity was reduced (less convex). From the 8-9 to the 13-9 age-level the males remained relatively stable at a +4.0 degrees for the angle of facial convexity. From the 14-9 to the 17-9 age-level the angle decreased approximately 1.0 degree per year, thus at the 17-9 age-level the angle was +0.9 degrees.

The female mean at the 5-9 age-level had an angle of facial convexity which was more convex than the male mean. At the 6-9 age-level the female profile began to become less convex, and between the 8-9 and the 13-9 age-level the angle was stable at approximately +5.7 degrees to +5.0 degrees. Between the 13-9 and the 14-9 age-level the female mean angle of facial convexity became 1.3 degrees less convex. From the 14-9 to the 17-9 age-level the female mean decreased 1.19 degrees and the male mean angle decreased 2.34 degrees. Both the male and female
means reveal that the angle of facial convexity decreased with age; however, the female mean started with a more procumbent profile of 2.7 degrees and tended to remain more procumbent than the male through the 12 years investigated.

4. Normal and Class I Means

The normal occlusion mean at the 5-9 age-level had an angle of facial convexity which was +7.7 degrees. It was less convex than the Class I occlusion mean at the same age-level. At the 7-9 age-level both the Class I mean and the normal occlusion mean showed approximately a 2.0 degree reduction in this angle. The normal occlusion mean decreased more than the Class I mean between the 7-9 to 9-9 age-level. From the 8-9 to the 13-9 age-level the normal occlusion group had a mean of approximately +4.0 degrees. The group had a mean which decreased 1.0 degree per year from the 13-9 to the 17-9 age-level. At the 17-9 age-level the normal occlusion group had a mean which was -0.63 degrees, while the Class I occlusion group had a convex face which was +4.22 degrees. Thus there appears to be a significant difference between Class I occlusion and normal occlusion means for the angle of facial convexity. This significant difference was present for all of the 12 years investigated.
d. Subgroup Means (see Figure 15)

(1) Male Normal Occlusion Means.—The male normal occlusion group at the 5-9 age-level had a mean of +7.2 degrees for the angle of facial convexity. From the 8-9 to the 13-9 age-level the angle remained rather constant at approximately +3.2 degrees. From the 13-9 to the 14-9 age-level the angle of facial convexity decreased approximately 2.0 degrees. Between the 15-9 and the 16-9 age-level a 1.4 degree decrease in the angle of facial convexity was observed. At the 17-9 age-level the angle of facial convexity was 2.8 degrees, which would represent a concave face. This was the only subgroup studied which had a concave profile. The actual angular decrease observed for the 12 years studied was 9.0 degrees.

(2) Male Class I Mean.—The male Class I occlusion mean had an angle of facial convexity at the 5-9 age-level of +7.58 degrees. The angle became more convex at the 6-9 age-level, then decreased to +6.17 degrees at the 7-9 age-level. From the 8-9 age-level to the 15-9 age-level the angle of facial convexity remained relatively stable and varied only slightly from a +5.5 degrees. At the 17-9 age-level the angle of facial convexity was still slightly convex with an absolute angular measurement of +4.15 degrees. The decrease in the angle of facial convexity for the 12 years studied was only 3.43 degrees.
This total decreased when compared to the 9.0 degrees decrease for the normal occlusion mean is very significant. This observation would indicate that the male Class I subgroup tended to have a stable angle of facial convexity or one that decreased very little with growth in comparison to the male normal occlusion subgroup mean.

(3) Female Normal Occlusion Means.--The female normal occlusion subgroup mean at the 5-9 age-level was more convex than either of the two male subgroup means. The angle of facial convexity at the 5-9 age-level was +0.67 degrees for the female normal occlusion mean. This angle was relatively stable until the 8-9 age-level. At the 8-9 age-level the angle of facial convexity was +4.85 degrees. From the 9-9 to the 13-9 age-level the facial profile was relatively stable. At the 14-9 age-level the angle of facial convexity was +2.3 degrees, and it decreased more, until at the 17-9 age-level the angle was +1.15 degrees.

It is interesting to compare the male and female normal occlusion means, as we see that for the 12 years investigated the females were 2.0 to 3.0 degrees more convex in the angle of facial convexity. The total angular decrease for the 12 years studied was 7.5 degrees.

(4) Female Class I Means.--The female Class I mean had an angle of facial convexity that represented a more convex angle for the 12 years investigated than did any of the other subgroup
means. At the 5-9 age-level this convexity for the female Class I mean was +10.58 degrees. The angle of facial convexity became less from the 5-9 to the 8-9 age-level. At the 8-9 age-level the angle of facial convexity tended to remain at the +7.9 degrees position until the 12-9 age-level, after which there was a constant decrease in this angle. At the 17-9 age-level the angle was +4.26 degrees. This terminal reading at 17-9 for the female class I mean was almost identical to the male Class I mean at the 17-9 age-level. The total absolute angular decrease for the female Class I mean was 6.3 degrees.

b. Individuals within Subgroups (see Figure 16)

(1) Male Normal Occlusion Individual Series 108.--The male individual number 108 was typical of his subgroup mean. The angle of facial convexity for this individual was +10.5 at the 5-9 age-level. In comparison to the other individuals from each of the subgroups this individual started with the smallest angle of facial convexity at the 5-9 age-level and still had a small angle at the 17-9 age-level. At the 17-9 age-level his angle of facial convexity was 0.0 degrees. The total angular decrease for the 12 years studied was 10.5 degrees. The angle of facial convexity was very irregular from year to year.

(2) Male Class I Individual Series 10.--The male Class I individual selected at random was number 10. This individual
ANGLE of FACIAL CONVEXITY (NAP)

FIGURE 16

99% Confidence Limit
Female Normal No. 72
Female Class I No. 86

Total Group Mean
Male Normal No. 108
Male Class I No. 10
followed a pattern similar to the normal occlusion male mean. The angular changes were not as irregular from year to year as they were in individual number 108 of the male normal occlusion subgroup studied. This individual started with a facial angle of convexity of +11.5 degrees at the 5-9 age-level; it decreased to +5.0 degrees at the 9-9 age-level, and remained relatively stable at this angle until the 12-9 age-level. The angle of facial convexity decreased to 0.0 degrees at the 15-9 age-level and remained at this angle through the 17-9 age-level.

(3) Female Normal Occlusion Individual Series 72.--The individual selected at random from this subgroup was number 72. This individual at the 5-9 age-level had an extreme +15 degree angle of facial convexity. The angle decreased rapidly after the 6-9 age-level. At the 9-9 age-level the angle of facial convexity was +8.0 degrees. From the 9-9 to the 13-9 age-level the face became more convex (+10.5 degrees). At the 15-9 age-level the angle of facial convexity decreased to +5.0 degrees. The angle increased to +6.0 degrees at the 17-9 age level. This individual showed an irregular NAP angle for the 12 years investigated. Her pattern for this angle varied from her subgroup mean.

(4) Female Class I Individual Series 86.--The female Class I individual randomly selected was number 86. The angle of facial convexity at the 5-9 age-level was +10.5 degrees; at
the 6-9 age-level it was +6.5 degrees, and at the 12-9 age-level it became more convex, with an angle of 13.0 degrees. From the 12-9 to the 17-9 age-level the angle varied from +9.5 to +10.0 degrees. This individual never was more than 2.5 degrees more convex than she was at the 5-9 age-level. The angle of facial convexity at the 17-9 age-level was +9.5 degrees, which was 1.0 degree less than her angle of facial convexity at the 5-9 age-level.

6. The 99 Per Cent Confidence Limits

The 99 per cent confidence limit showed wide differences for the 12 years studied. It was +11.3 degrees at the 5-9 age-level and +13.3 degrees at the 17-9 age-level.

II. General Trends for Individuals

For the proper evaluation of an individual within a group or subgroup, we must have knowledge of the behavior of the group as represented by means of the total group, means of the subgroup, and the 99 per cent confidence limit. In the previous section, the findings reported show group behavior trends as represented and reported with the statistical method. The means of the total group and of the subgroup, standard deviations, and the 99 per cent confidence limit cannot be used as a normal standard to interpret and classify individuals having a normal or abnormal growth pattern. The statistical findings previously stated are
used only as a method to index the characteristics of a single
dimension for the majority of the population investigated. It
was observed that the four angular dimensions investigated ap-
peared to follow three definite trends which were of clinical
value to the orthodontist and yet not revealed by the statistical
method.

A. Angular Relation of the Mandibular Incisor
to the Gonion-Gnathion Plane

The angle formed by the long axis of the mandibular
incisor intersecting the gonion-gnathion plane was studied for
each individual, and it appeared that the individuals followed
one of three basic trends. Contrary to popular opinion the lower
incisors' axial inclination did not always decrease with age. It
was observed that the axial inclination of the mandibular incisor
during the growth and development processes of the individual
could become more procumbent, remain relatively stable, or could
become upright and in lingual axial inclination. Thus the lower
incisor angle could increase, remain stable, or decrease. Table
9 and Table 10 represent the angles for males and females, re-
spectively. It was observed from Table 9 that the male mandibular
incisor angle decreased in 10 of the 20 male individuals studied.
Only 2 of the males had a mandibular incisor angle which in-
creased with age. The remaining 7 male individuals had a stable
incisor-mandibular plane angle.
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<th>Interincisal Angle</th>
<th>1 to SN Angle</th>
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Dental Angles for Females

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</table>

TABLE 10
Table 10 represents the individual females' angle of the lower incisor to the gonion-gnathion plane. It is observed that the majority of the females had a stable incisor mandibular plane angle. Only 1 of the 20 females had a lower incisor angle that was decreasing, and this is in direct contrast to the male individuals. Six female individuals had the angle formed by the lower incisor with the gonion-gnathion plane increasing. This observation was opposite of the male individual observations.

It is also observed that both males and females are found as representatives of each of the three trends. Figure 17 graphically shows these three possible trends. These tracings were made by taking each age-level and drawing the lower incisor, the symphysis, the gonion-gnathion plane, and a line through the long axis of the incisor. The gonion-gnathion plane of the first age-level recorded was kept parallel to the lower border of a second sheet of paper, and the incisor, symphysis, gonion-gnathion plane, and the line drawn through the long axis of the tooth were drawn on the second sheet of paper. The acetate tracing for the next age-level was placed so that the first and the second tracings gonion-gnathion planes were parallel, and the long axis of the incisor of the first age intersected the long axis of the incisor of the next age tracing on the gonion-gnathion plane of the second age-level. This was done for each age-level for the complete series. Each new age level's gonion-gnathion plane was
THREE TRENDS SEEN DURING GROWTH OF ANGLE TO GONION-GNATHION

INCREASE SERIES 79
STABLE SERIES 85
DECREASE SERIES 92
kept parallel to the preceding age traced and the long axis of the
teeth made to intersect each new gonion-gnathion plane.

B. Angular Relation of the Maxillary Incisor
to the Sella-Nasion Plane

The angle of the maxillary incisor to the sella-nasion
plane also shows the three possible trends: increasing, remaining
stable, or decreasing. These trends are diagrammatically seen in
Tables 9 and 10.

The male individuals were rather well distributed be-
tween those three trends. The male individuals had five individu-
als whose maxillary incisor to sella-nasion plane angle was
stable. Eight males showed a decrease in this angle and 7 males
showed an increase in this angle.

The female group had 9 individuals who were stable, 4
individuals who decreased, and 7 individuals who increased in
this angle (1 to SN). The males and females appeared to have
approximately the same distribution of individuals within the
three trends. Figure 18 pictorially shows these three trends
for this angle. The figures were drawn as described for the lower
incisor to gonion-gnathion plane, but for the gonion-gnathion
plane we have used the sella-nasion plane. The pictorial
representation of these three trends includes the angle for each
age-level of each entire series.
THREE TRENDS,
SEEN DURING GROWTH OF THE ANGLE 1 TO SELLA - NASION
C. Interincisal Angle (I to I Angle)

The interincisal angle also appears to follow three trends. These trends are diagrammatically represented in Table 9 and Table 10.

The male individuals in Table 9 represent 3 individuals whose interincisal angle is stable, 12 individuals who show an increase, and 5 who have an interincisal angle which decreases.

The females are distributed as individuals in Table 10. The females have 9 individuals who have a stable trend for the interincisal angle, 3 who show an increase, and 8 individuals who show a decrease for this angle. The male and female individuals seem to show a difference in that 12 of the males show an increase in this angle, and only 3 females have a trend which appears to increase. Figure 19 pictorially represents the three trends for this interincisal angle. The graphic representation of this angle differed from the previous two angles in that a different method was used to chart each trend for each series. The mandibular incisor's long axis was always kept perpendicular to the lower border of the paper. All of the mandibular incisors long axis were kept parallel to each other. The maxillary incisors long axis was made to intersect with the long axis of the maxillary incisor that was traced one year later or at the next age-level in the series. This graphic representation is not a true picture of the tooth on the headplate, but the angles are,
THREE TRENDS SEEN DURING GROWTH FOR THE INTERINCISAL ANGLE

INCREASE SERIES 14
STABLE SERIES 114
DECREASE SERIES 62

FIGURE 19
and the representation clearly defines those series which show an increase and those series which are stable or have a decreasing interincisal angle. When the interincisal angle remained stable a straight line was produced by the graphic representation described. If the angle decreased a curve was concave on its left side, and if the angle increased the curve had its concavity on the right side. From this description, if we looked at the teeth from the labial the curve would tend to show the teeth moving out if the angle increased, and would show the teeth moving in if the angle was decreasing, or producing a concave curve from the labial view of the teeth.

D. Integration and Correlation of the Three "Dental Angles" Investigated

1. I to gonion-gnathion
2. I to sella-nasion
3. Interincisal angle

If we attempt to correlate the three angles to each other we find that there is very little correlation. There are 13 possible ways that these angles might affect and be affected by each other. All 13 possibilities were present in this sample of 40 individuals (Tables 9 and 10). This would indicate that if the mandibular incisor becomes more procumbent, the maxillary incisor could become more procumbent, less procumbent, or stable.
Furthermore, in relation to the preceding statement, the interincisal angle might decrease, increase, or remain stable, while those other dental angles are changing. Any combination of angular changes was seen.

E. Individual Trends of the Angle of Facial Convexity

The angle of facial convexity follows three trends through the 12 years investigated. This angle may remain stable, decrease, or increase. Only 1 male Class I individual out of a group of 40 individuals showed a trend of having an angle of facial convexity which was increasing (Table II).

The female group contained 9 individuals whose trend for this angle was to remain relatively stable. The remaining 11 individuals had an angle which decreased with age. Seven of the 9 females who had a stable angle of facial convexity had a Class I occlusion.

The male individuals (Table II) had only 4 individuals who had a stable angle of facial convexity, and these 4 individuals were divided equally between normal occlusion and Class I occlusion. Fifteen of the male individuals had an angle of facial convexity which decreased with age. Only 1 individual from the group of 40 had an angle of facial convexity which increased with growth. This individual had a Class I occlusion.
# Angle of Facial Convexity

<table>
<thead>
<tr>
<th>Sex and Occlusion</th>
<th>Stable</th>
<th>Increases</th>
<th>Decreases</th>
</tr>
</thead>
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<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Female Class 1</td>
<td>7</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>Male Normals</td>
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<td>0</td>
<td>9</td>
</tr>
<tr>
<td>Male Class 1</td>
<td>2</td>
<td>1</td>
<td>6</td>
</tr>
</tbody>
</table>

**TABLE 11**
Growth Changes of the "JA" PLANE

Series 89 (Male Normal Occlusion)

Series 85 (Male Class 1 Occlusion)

Series 87 (Female Class 1 Occlusion)

Series 40 (Female Normal Occlusion)

Figure 20
Growth Changes of

1. SELLA NASION PLANE
2. SELLA TO G PLANE
3. G TO NASION PLANE

Series 87 (Female with Class 1 Occlusion)

Series 92 (Male with Class 1 Occlusion)

Figure 21
III. Appraisal of Individual Patterns by Integrating All of the Dimensions and Angles for that Individual

In the previous material a framework for characterizing individuals by the use of trends, means, and 99 per cent confidence limits has been described. Previous studies have shown that means and trends often obscure, rather than reveal, facts about an individual's pattern. To comprehend the individual's pattern we must not limit ourselves to single variations alone, because the significance of a single dimension or angle lies in the integration of the measurement to the total dental and facial skeletal profile. No single dimension can be called normal or abnormal without an integration of this dimension to the individual's total dimensions. What is abnormal for one individual may be ideal for the next individual. Absolute increments of growth, direction of growth, and differential rates of growth of different areas must be considered to understand the individual pattern.

Eight individuals have been selected to represent the total group and the dimensions for each individual are integrated on graphs to see if this integration discloses any reason for the facial profile to be what it is for this individual. Two of the 6 individuals were selected from each subgroup (2 male normal occlusion, 2 male Class I occlusion, 2 female normal occlusion, and 2 female Class I occlusion). These 2 individuals from each
subgroup were further divided into one having a stable angle of facial convexity and one having an angle of facial convexity which decreased during growth. Individual number 85 was a male Class I individual and was the only individual who had an angle of facial convexity which increased with age. For this reason he was studied as an individual.

In growth and development of the dental organ and facial skeleton, changes in any one part of this structure causes adjustments in contiguous structures, and therefore the contribution of any one part causes changes and affects other parts of this complex. Stability of mean values can be caused by equal but opposite trends of different individuals. This leaves us with the thought that only the individual can tell us his own growth pattern.

In the discussion of the individual by integrating all of the angular and linear dimensions, it was decided that, for the reader's visual understanding of each individual, four tracings at different age-levels would be included in the thesis, so that the entire dental, skeletal, and soft tissue profile of the face could be studied. These tracings were placed on two separate photographs. The first photograph shows the 5-9 age-level, which represents the profile at the beginning of the investigation. Superimposed on the point sella and along the sella-nasion plane is the 17-9 age-level tracing. This first photograph will allow
the readers to observe dental and skeletal changes for the 12 years investigated. The second photograph will have two superimposed tracings which cover the rapidly increasing growth ages. This will usually be the 9-9 and the 12-9 age-levels. This second photograph will show the changes taking place between the two age-levels on the photograph in addition to being available to compare to the initial (5-9) and the terminal (17-9) tracings. The third photograph for each individual will show the changes of the angle of facial convexity during growth. It is hoped that the composite tracings of the angle of facial convexity can be used to show the differential growth rates between the anterior cranial base (SN), the maxilla (subspinale), and the mandible (pogonion). The fourth photograph for each individual is a graph of the composite dimensions for this individual. This will include both angular and linear dimensions. With these four photographs of each individual we shall see and will read about the dental and skeletal facial changes of the individual. These four figures allow us to describe the individual in four parts:

1. Tracings
2. Angular Dimensions
3. Linear Dimensions
4. Summary of the Individual Total Pattern
### Circumpuberal Maximum Height

#### Angular Dimensions
- Angle of Convexity (NAP)
- NS to Go.Gn. Angle
- i to Go.Gn. Angle
- I to SN Angle
- Interincisal Angle

#### Linear Dimensions
- S to 6 plane
- i i to "Ja" point
- N to 6 plane
- Sella Nasian plane
A. Male Normal Occlusion--Individual Number 89

1. Tracings (see Figures 22 and 23)

The observations of the tracings (Figures 22 and 23) reveal that the lower border of the mandible is at a steep inclination for all of the tracings. In the early years of the investigation the maxilla and forehead (nasion) are as prominent as the mandible (pogonion). With an increase in age the maxilla (subspinale) and nasion appear to become less prominent while the mandible is becoming more prominent. Although the mandible is moving forward bodily, it is observed that pogonion has become very prominent and that this is caused by apposition of bone on this area as well as the forward movement of the mandible by condylar growth. The nose appears to have become more prominent and enlarged after the 14-9 age-level. Figure 24 reveals that nasion, the maxilla (subspinale), and the mandible (pogonion) do not move forward simultaneously, but that one may grow at a more rapid rate while the other growth center areas are relatively inactive.

2. Angular Dimensions

a. The Angle of Facial Convexity (NAP) (see Figures 24 and 25)

The angle of facial convexity for series 89 was +8.4 degrees at the 5-9 age-level and -6 degrees at the 17-9 age-level. From the 5-9 to the 17-9 age-level the angle decreased 14.0
FIGURE 22

MALE NORMAL OCCLUSION
SERIES 89
MALE NORMAL OCCLUSION
SERIES 89

Figure 23
Male Normal Occlusion
Series 89

(NAP)
ANGLE of FACIAL CONVEXITY

FIGURE 24
MALE NORMAL OCCLUSION
SERIES 89

AGE 5-9 6-9 7-9 8-9 9-9 10-9 11-9 12-9 13-9 14-9 15-9 16-9 17-9

FIGURE 25
degrees. The angle of facial convexity for this individual follows an irregular pattern. From the 5-9 to the 8-9 age-level the angle has decreased to +1.0 degree, which indicates that the face is becoming straighter. From the 8-9 to the 10-9 age-level the angle increases to +3.0 degrees, then decreases to +1.0 degree at the 13-9 age-level. Between the 13-9 and 14-9 age-levels the angle decreases 3.5 degrees to a -2.5 degrees. At the 17-9 age-level the angle is -6.0 degrees, and this is indicative of a concave facial profile. A concave facial profile is one in which, in the vertical plane, supramentale (point B) is anterior to subspinale (point A) and nasion. This individual does not represent his subgroup mean for this angle, as he is much too concave.

b. The Angle Formed by Nasion Sella Intersecting the Gonion-Gnathion Plane (see Figure 25)

The angle (NS to GoGn) at the 5-9 age-level is 47.0 degrees, which is extremely high for this angle. The angle decreases a total of 5.4 degrees so that at the 17-9 age-level the angle is 41.6 degrees. The angle showed a constant slow trend as it decreased. The individual's (89) reading for this angle was above the subgroup mean. As this angle was decreasing the angle for the mandibular incisor (I to GoGn) was decreasing, stable, or increasing. There appeared to be no correlation between the two angles.
c. The Maxillary Incisor Angle (\( I \) to \( SN \))

This angle at the 5-9 age-level was 94.1 degrees and at the 17-9 age-level the angle was 97.0 degrees. The maxillary incisor angle (\( I \) to \( SN \)) for this individual was below his subgroup mean. The angle showed a changing irregular trend. From the 6-9 to the 12-9 age-level the angle decreased from 99 to 92.5 degrees. From the 12-9 to the 17-9 age-level the angle increased from 92.5 to 97.1 degrees. It is observed that the axial inclination of the maxillary incisor is constantly changing its relation to the sella-nasion plane. Comparing the trends of the mandibular and maxillary incisor angle (\( I \) to \( GgGn \) and \( I \) to \( SN \) it is observed that while one angle is increasing the other angle is decreasing and vice versa. Thus, these two angles have opposite trends.

d. The Mandibular Incisor Angle
(\( I \) to \( GgGn \)) (see Figure 25)

The mandibular incisor angle (\( I \) to \( GgGn \)) is 13.0 to 17.0 degrees less than the subgroup mean for the 12 years investigated. At the 5-9 age-level the angle is 71.2 degrees and at the 17-9 age-level the angle is 70.6 degrees. The mandibular incisor angle is constantly fluctuating in its inclination. From the 5-9 to the 9-9 age-level the incisor becomes more upright (78.0 degrees). From the 12-9 age-level to the 17-9 age-level the angle decreases from 77.0 degrees to 70.6 degrees. The
curve for this angle (Figure 25) follows a general trend which is similar to the curve for the angle of facial convexity and the curve for the linear measurement nasion to the maxillary first molar (N to 6). The irregular curve is indicative of the instability of the axial inclination of these teeth.

e. Interincisal Angle (I to 1)

The interincisal angle at the 5-9 and the 17-9 age-levels is 150.0 degrees. This is higher than the subgroup mean for these age-levels. At the 9-9 age-level the interincisal angle has decreased to 140.5 degrees. From the 9-9 to the 17-9 age-levels the angle increases, with a few minor fluctuations.

2. Linear Measurements

a. Sella-Nasion Plane

This linear dimension for individual number 89 follows the subgroup mean very closely. At the 5-9 age-level the sella-nasion plane has a total absolute length of 62.9 millimeters and at the 17-9 age-level the length is 72.7 millimeters. From the 8-9 to the 9-9 age-level and the 12-9 to the 13-9 age-level, the yearly increment was 2.7 and 2.0 millimeters, respectively. From the 14-9 to the 17-9 age-level the sella-nasion plane increases only 0.7 millimeters. This would indicate a deceleration growth rate at the 14-9 age-level for this linear dimension.
b. Sella to the Maxillary First Molar (S to 6)

At the 5-9 age-level the linear length of (S to 6) is 25.2 millimeters and at the 17-9 age-level the length is 37.2 millimeters. The total increment for the 12 years studied was 12.0 millimeters. From the 12-9 to the 14-9 age-level the length of this plane increases rapidly and is very closely correlated to the growth of the Sella-Nasion plane and maxilla. Studying Figure 25 it is observed that the sella-nasion plane, S to 6 plane, and the "Ja" plane curves have a similar trend.

c. Nasion to the Maxillary First Molar (N to 6)

At the 5-9 age-level this dimension (N to 6) is 37.8 millimeters and at the 17-9 age-level the length is 35.6 millimeters. The anterior movement of the molar, which was not compensated for by growth between N and 6, was 2.2 millimeters. From the 6-9 to the 7-9 age-level the length decreased rapidly. The dimension (N to 6) decreases slowly except where growth is greater than the anterior movement of the molar.

d. "Ja" to 11 Dimension ("Ja" plane) (see Figure 25)

This dimension ("Ja" to 11) measures the height of the anterior part of the lower one-third of the face. The "Ja" plane at the 5-9 age-level is 33.4 millimeters and at the 17-9 age-level the length is 43.5 millimeters. This is similar to the subgroup mean. The total increment for the 12 years studied was
10 millimeters. The only growth acceleration observed was between the 12-9 and the 15-9 age-levels when a total of 5.0 millimeters was measured. The reason for this increased vertical height was probably because of a rapid downward growth of the mandible during this age-level, which was compensated for by increased vertical height of the alveolar process. The subgroup means have a growth acceleration trend at the 5-9 to the 6-9 age-level. This was not observed in this individual and was probably due to the linguo-version of the axial inclination of the permanent incisors at this age-level.

4. Summary for Individual 89

(1) The angle of facial convexity decreases with age, is below the subgroup mean, and follows an irregular pattern for the 12 years studied.

(2) The NS-GoGN angle is relatively high for this individual and is considerably higher than the subgroup mean for this dimension.

(3) The angle of the maxillary incisor (I to SN) is below the subgroup mean, decreased with age, and showed a fluctuating irregular pattern. This angle showed an opposite curve trend when compared to the lower incisor angle (I to GoGN).

(4) The interincisal angle decreases with age, has an irregular pattern, and is above the subgroup mean.
(5) The lower incisor angle (Ⅰ to GoGn) decreased with age, had an irregular fluctuating trend, and was 13.0 to 17.0 degrees below the subgroup mean.

(6) The sella-nasion plane was similar to the subgroup mean, but the length increased at an earlier age and decelerated at an early age.

(7) The sella to the maxillary first molar (3 to 6) dimension was similar to the subgroup mean. An increased acceleration rate was seen between the 12-9 and the 14-9 age-level.

(8) The linear dimension (N to 6) was similar to the subgroup mean.

(9) The "Ja" plane length for this individual is similar to the subgroup mean, with the exception that an acceleration rate of 5.0 millimeters is observed between the 12-9 and the 15-9 age-level.

B. Male Class I Occlusion—Individual Number 92

1. Tracings (see Figures 26 and 27)

The tracings reveal what the author considers an excellent profile for an individual. The face is straight and the chin becomes prominent with growth. The soft tissue beneath the lower lip has a concurvature which could be reduced for esthetic purposes.
MALE CLASS I OCCLUSION
SERIES 92

FIGURE 26
MALE CLASS I OCCLUSION
SERIES 92

FIGURE 27
2. Angular Dimensions (see Figures 28 and 29)

a. The Angle of Facial Convexity

The angle of facial convexity at the 5-9 and the 17-9 age-levels is +9.5 and +1.5 degrees, respectively. The angle was above the subgroup mean at the 5-9 age-level and below the subgroup mean at the 17-9 age-level. From the 5-9 to the 8-9 age-level the angle decreased to +3.6 degrees. From the 9-9 to the 11-9 age-level the angle varied from +5.9 to +6.5 degrees.

Starting at the 12-9 age-level the angle shows a constant decrease from +4.6 degrees to +1.5 degrees. After the circumsuboral maximum height the angle shows a constant slow decrease.

b. The Angle Formed by the Intersection of the Nasion-Sella Plane with the Gonion-Gnathion Plane

This angle (NS to GoGn) follows a curve which is similar to the angle of facial convexity. The interesting fact about this angle is that the angle does not decrease with age. The angle does vary from year to year, but the angle is 36.3 degrees at both the 5-9 and the 17-9 age-levels. Although most individuals had a decreasing angle, this individual's remained stable with only a few minor fluctuations.
Male Class I Occlusion
Series 92

(NAP)
ANGLE of FACIAL CONVEXITY
FIGURE 28
1. The Maxillary Incisor Angle (I to SN)

At the 5-9 and 17-9 age-levels the angle (I to SN) was 94.0 and 101.6 degrees, respectively. At the 7-9 age-level the angle had increased to 102.6 degrees. From the 8-9 to the 13-9 age-level the incisor showed a slight variation around 99.5 degrees and then continued to show a steady increase through the 17-9 age-level. There is a constant gradual increase after the circumpuberal maximum height age-level.

d. The Mandibular Incisor Angle (I to GoOn)

At the 5-9 age-level the angle was 87.5 degrees and at the 17-9 age-level the angle was 90.2 degrees. From the 5-9 to the 10-9 age-level the angle increased from 87.5 to 91.8 degrees. After the 10-9 age-level the angle showed a constant slow decrease to 88.2 degrees. This individual was one of the few individuals studied who did not have a lower incisor whose axial inclination was constantly changing. The angle decreased with age and was below the subgroup mean for the 17-9 age-level.

c. The Interincisal Angle

At the 5-9 and 17-9 age-levels the interincisal angle was 141.7 and 133.0 degrees, respectively. At the 6-9 age-level the angle decreased to 128.6 degrees. The angle increased to 132.3 degrees at the 9-9 age-level, decreased to 130.6 degrees at the 10-9 age-level, and then increased to 133.1 degrees at the
12-9 age-level. From the 12-9 to the 17-9 age-level the angle did not vary from 133.0 degrees. It is noticeable that after the 6-9 age-level the angle was relatively stable and that after the circumpuboreal maximum height age-level the angle was extremely stable.

3. Linear Measurements (see Figure 29)

a. Sella-Nasion Plane

Relative to other individuals this individual's dimension (S-N) had many dynamic changes. At the 5-9 and 17-9 age-levels the absolute length of this dimension was 66.6 and 77.3 millimeters, respectively. The length of this plane (S-N) is greater than the subgroup mean for all 12 age-levels. Growth acceleration rates are observed between the 9-9 and the 10-9 age-levels and the 12-9 and the 13-9 age-levels. These prominent "spurts" are not usually observed for the sella-nasion dimension.

b. Point Sella to the Maxillary First Molar (3 to 6)

This linear dimension at the 5-9 and the 17-9 age-level was 26.0 and 34.6 millimeters, respectively. The individual total 12-year increment for this dimension was 8.7 millimeters and the subgroup mean total increment was 10.9 millimeters. Therefore the molar has not moved forward for this individual as much as it has in the subgroup mean figures.
The 1-year increment at the 6-9 and at the 11-9 age-level was 2.8 and 1.5 millimeters, respectively. From the 14-9 to the 17-9 age-level the molar had not changed its position on the sella-nasion plane.

c. Nasion to the Maxillary First Molar (N-6)

The dimension (N-6) at the 5-9 and the 17-9 age-levels is 40.6 and 43.5 millimeters, respectively. The total 12-year increase was 3.1 millimeters. The total increase is much higher than the subgroup mean. Usually this dimension decreases with age, but for this individual the length increased. This probably means that the increased growth of sella-nasion during these age-levels more than compensated for the total forward movement of the molar and the growth of the maxilla. From the 6-9 to the 8-9 age-level the length of this plane increased 3.0 millimeters. From the 10-9 to the 17-9 age-level this distance increased rather than decreased, and this was the only individual in the total group of 40 individuals who had this trend.

d. "Ja" to 11 ("Ja" Plane)

Starting at the 5-9 age-level the dimension ("Ja" to 11 was 34.0 millimeters in length. At the 17-9 age-level the dimension was 41.3 millimeters. Thus the total increase in this dimension for the 12 years studied was 7.3 millimeters. This is below the subgroup mean. Growth accelerations are seen at the
5-9 to 6-9 age-levels, 6-9 to 7-9 age-levels, and the 7-9 to 8-9 age-levels. From the 12-9 to the 17-9 age-level the increase in the length of the "Ja" plane is only 0.5 millimeters. This individual is below his subgroup mean for this dimension.

3. **Summary**

1. The tracings reveal a growth pattern which is steady and parallel. The border of the mandible, occlusal plane, and teeth appear to be changing position, but to remain parallel to each other.

2. The angle of facial convexity decreased with age, especially after the circumpuberal maximum height, and is below the subgroup mean at the 17-9 age-level.

3. The angle formed by the sella-nasion plane intersecting the gonion-gnathion plane remained relatively stable during growth and did not follow the subgroup mean.

4. The angle of the maxillary incisor (1 to SN) was above the subgroup mean and increased with growth. The angle did not show extreme variations from year to year such as was seen with many other individuals.

5. The mandibular incisor angle decreased with age, was below the subgroup mean, and did not show extreme variations from one year to the next year.

6. The interincisal angle was stable for the 12 years studied and showed no change of significance after the 12-9 age-level.
(7) Sella-nasion was above the subgroup mean and showed spurts for this dimension, which was not characteristic of the dimension.

(8) The dimension (3 to 6) was below the subgroup mean and remained very stable after the 15-9 age-level.

(9) The dimension (6 to 8) was above the mean. This individual was the only one who had an increased length for this dimension at the 17-9 age-level.

(10) "Ja" plane was very stable after the 8-9 age-level and was below the subgroup mean for this dimension.

(11) This individual showed a greater amount of stability than any of the other cases studied. After the 10-9 age-level the curves on Figure 29 were very smooth and non-fluctuating.

C. Male Class I Occlusion—Individual Number 51

1. Tracings (see Figures 30 and 31)

The tracings reveal that the face was slightly procumbent due to a receded point nasion. The mandible and the maxilla appeared to be growing at an equal rate, but nasion was posterior of these two bones. The overjet (horizontal overbite) and the overbite (vertical overbite) both appeared to be approximately 2.0 millimeters. The nasal bone and the chin (pogonion) appeared to have grown very large between the 12-9 and the 17-9 tracings.
MALE CLASS I OCCLUSION
SERIES 51

FIGURE 30
MALE CLASS I OCCLUSION
SERIES 51

9-3
12-3

FIGURE 31
2. Angular Dimensions

a. Angle of facial Convexity (see Figures 32 and 33)

The angle of facial convexity at the 5-9 and 17-9 age-levels was +0.6 and +4.8 degrees, respectively. The total decrease in this angle was 1.8 degrees, and it remained stable from the 12-9 to the 17-9 age-level. Thus it has been classified as a stable angle.

From the 5-9 age-level to the 11-9 age-level the angle decreased to +3.5 degrees. This individual has an angle of facial convexity which is similar to his subgroup mean.

b. The Angle Formed by the Intersection of the Nasion-Sella Plane and the Gonion-Grnathion Plane (see Figure 33)

This angle at the 5-9 age-level was 38.6 degrees and at the 17-9 age-level had decreased to 33.4 degrees. The angle (NS-GnGn) was stable from 11-9 to 17-9, as it decreased only 0.2 degrees. From the 11-9 to the 17-9 age-level this angle was stable, while the mandibular incisor angle was increasing from 91.0 to 97.0 degrees. There would appear to be no correlation during growth between these two angles.

c. Maxillary Incisor Angle (1 to SN) (see Figure 33)

At the 5-9 age-level the angle (1 to SN) was 95.7 degrees. The angle showed a gradual increase from the 5-9 to the 8-9 age-level and then a 5.8 degree increase from the 8-9 to
Male Class I Occlusion
Series 51

(NAP)
ANGLE of FACIAL CONVEXITY
FIGURE 32
the 9-9 age-level. At the 14-9 age-level the angle was 109.0 degrees. From this age-level to the 17-9 age-level the angle (1 to SN) decreased. At the 17-9 age-level the angle is 100.0 degrees. It is interesting to note that the angle decreased 6.0 degrees after the circumpuberal maximum height age (14.55 years).

d. Mandibular Incisor Angle (I to GoGn)

This angle at the 5-9 age-level was 85.2 degrees and at the 17-9 age-level the angle was 97.0 degrees. The angle from the 7-9 to the 9-9 age-level increased from 87.0 to 94.0 degrees. From the 9-9 to the 12-9 age-level the mandibular incisor angle decreased to 90.6 degrees. From the 12-9 to the 17-9 age-level the incisor (I to GoGn) becomes more procumbent until at the 17-9 age-level, the angle is 97.0 degrees. The angle increased with age and was above the subgroup mean at the 17-9 age-level. The angle (I to GoGn) increased 4.0 degrees immediately after the circumpuberal maximum height (14.55 years).

e. Interincisal Angle

At the 5-9 and the 17-9 age-levels the interincisal angle was 135.3 and 126.8 degrees, respectively. The angle increased to 141.8 degrees at the 7-9 age-level, and then became 121.0 degrees at the 9-9 age-level. It is interesting to note that from the 8-9 to the 17-9 age-level the interincisal angle
fluctuates only 4.0 degrees. This was caused by the opposite trends of the maxillary incisal angle and the mandibular incisal angle. While one of these angles was increasing, the other angle was decreasing, and vice versa.

3. Linear Dimensions (see Figure 33)

a. Sella-Nasion Plane

The sella-nasion plane at the 5-9 and 17-9 age-level was 66.5 and 75.5, respectively. A 1.8 millimeter growth acceleration was observed between the 5-9 and 6-9 age-level. An acceleration rate of 1.7 millimeters was observed between the 12-9 and the 13-9 age-levels. This individual was similar to the subgroup mean, but differed from the mean in that only a 0.5 millimeter increase was seen from the 13-9 to the 17-9 age-level. For this dimension no growth acceleration was observed after the circumpuberal maximum height age-level.

b. Sella to the Maxillary First Molar (S to M)

At the 5-9 and the 17-9 age-level the dimension (S to M) was 25 and 35.4 millimeters, respectively. The total 12-year increase for this plane was 10.4 millimeters. This individual's (S to M) dimension was slightly less than the subgroup means for all 12 years investigated. From the 10-9 to the 12-9 age-level a large increment was observed, and this was correlated to the movement of the molar forward during exchange of the deciduous
teeth for the permanent teeth and the growth of the maxilla.

c. Nasion to the Maxillary First Molar

The total absolute length for this dimension at the 5-9 and 17-9 age-levels was 41.4 and 40.1 millimeters, respectively. The dimension (N to 6) decreased 1.3 millimeters for the 12 years studied. There were age-levels when growth between nasion and 6 exceeded the movement of the maxillary molar. Therefore, this dimension increased, and the increase was greater than its subgroup means, but the total decrease in the length was similar to the subgroup means.

d. "Ja" to 11 ("Ja" plane)

The "Ja" plane at the 5-9 and 17-9 age-levels was 36.5 and 47.7 millimeters, respectively. A growth acceleration of 1.6 millimeters was seen between the 5-9 and the 6-9 age-level. A growth acceleration was seen after the circumpuberal maximum height from the 14-9 to the 15-9 age-level. This increase between the two age-levels was 2.5 millimeters. After the 15-9 age-level, the "Ja" plane showed a constant yearly increment of 1.2 millimeters or greater.

4. Summary

(1) Close examination of the tracings reveals a procumbent profile at the 17-9 age-level because of the posterior position of nasion in relation to pogonion and subspinale. The
tracings of the 8-9 and 12-9 age-level reveal that vertical height changes in the lower face are at a minimum.

(2) The angle of facial convexity is relatively stable after the 8-9 age-level. The individual has a +4-degree convex face from the 8-9 to the 17-9 age-level.

(3) The angle formed by the intersection of the sella-nasion plane and the gonion-gnathion plane showed a constant decrease from the 5-9 to the 11-9 age-level, and then remained stable after the 11-9 age-level.

(4) The maxillary incisor angle (I to SN) was similar to its subgroup mean, decreased with growth, and fluctuated considerably. The angle decreased 6.0 degrees after the individual circumpuberal maximum height age-level.

(5) The mandibular incisor angle (I to GoGn) decreased with age, fluctuated from any specific angle, and was above the subgroup mean.

(6) The interincisal angle fluctuated only 4.0 degrees from the 8-9 to the 17-9 age-level because of the equal but opposite trends of the maxillary and mandibular incisal angles. The angle was below the mean and decreased with age.

(7) The sella-nasion plane was similar to the subgroup mean, but the growth was from the 5-9 to the 11-9 age-level and decelerated after the 13-9 age-level. Only 0.5 millimeters growth was recorded from the 13-9 to the 17-9 age-level.
(8) The linear dimension of to $b$ was less than the subgroup mean in its absolute length, yet the total 12-year increment was similar to the subgroup mean.

(9) The linear dimension $(N-6)$ was greater than the subgroup mean, but the total 12-year increment was the same.

(10) The length of the "Ja" plane was above the subgroup mean, and in addition it showed most of the significant changes in length after the circumpuberal maximum height (14.55 years).

D. Male Class I Occlusion—Individual Number 85

1. Tracings (see Figures 34 and 35)

Observing the tracings, it appears that nasion advanced forward relatively little, while the maxilla and the mandible both grow rapidly forward. This individual had a very convex face at the 17-9 age-level, which is atypical for a male.

2. Angular Dimensions (see Figures 36 and 37)

a. Angle of Facial Convexity

This is the only individual of the total group of 40 individuals who had an angle of facial convexity which increased with growth. Why? The angle at the 5-9 age-level was $+11.5$ degrees and at the 17-9 age-level almost $+13.0$ degrees. The angle increased from $+11.0$ degrees at the 12-9 age-level to $+13.0$ degrees at the 17-9 age-level. The angle was above the subgroup
MALE CLASS I OCCLUSION
SERIES 85

FIGURE 34
MALE CLASS I OCCLUSION
SERIES 85

FIGURE 35
Male Class I Occlusion
Series 85

(NAP)
ANGLE of FACIAL CONVEXITY
FIGURE 36
mean, increased with age, but showed no rapid changes.

b. The Angle Formed by the Intersection of the Nasion-Sella Plane with the Gonion-Gnathion Plane

The angle (NS-GoGn) at the 5-9 and the 17-9 age-level was 33.0 and 29.0 degrees, respectively. The angle showed a constant decrease, with no significant fluctuation from the 6-9 to the 17-9 age-level.

c. The Maxillary Incisor Angle (1 to SN)

The angle (1 to SN) at the 5-9 and the 17-9 age-level was 96.0 and 102.9 degrees, respectively. This angle was above the subgroup mean. At the 6-9 age-level the angle decreased to 93.0 degrees and then increased to 109.0 degrees the following year. The permanent tooth replaced the deciduous incisor and was the reason for this change. From the 7-9 to the 12-9 age-level the angle was 109.0 ± 1.0 degree. The reading of 106.5 degrees at the 13-9 age-level probably is an error due to incorrect tracing of the apex of the maxillary incisor. The angle decreased from the 12-9 to the 17-9 age-level.

d. The Mandibular Incisor Angle (I to GoGn)

At the 5-9 and the 17-9 age-levels the mandibular incisor angle (I to GoGn) was 88.0 and 102.0 degrees, respectively. The angle increased 14.0 degrees from the 5-9 to the 17-9 age-level. This was above the subgroup mean for this angular
dimension. Although the angle showed an overall increase, the angle was very stable for the last 4 years studied. From the 8-9 to the 14-9 age-level the angle (to GoGn) was stable at 103.0 ± 1.0 degree. At the 11-9 and the 12-9 age-levels the angle became 99.5 degrees. This might be caused by error, or it might be a true value. The angle decreased after the circumprolabral maximum height and then was relatively stable. It is interesting to note that while the maxillary incisor angle was decreasing, the mandibular incisor angle was stable.

e. The Interincisal Angle

At the 5-9 and the 17-9 age-level the interincisal angle was 139.0 and 121.7 degrees, respectively. The angle decrease was rather pronounced between the 6-9 and the 7-9 age-levels. At the 7-9 age-level the angle was 114.0 degrees and then it increased to 121.0 degrees at the 11-9 age-level. At the 13-9 age-level the angle had decreased to 116.5 degrees. From this age-level to the 17-9 age-level the angle showed a constant increase. The angle was very small for the last 9 age-levels studied and was indicative of procumbent incisors.

3. Linear Dimensions

a. Sella-Nasion Plane

The linear dimension (SN) at the 5-9 and the 17-9 age-levels was 6.5 and 71.9 millimeters, respectively.
This was below the subgroup mean. Very little change was seen from the 15-9 to the 17-9 age-level. Small acceleration growth-rates were observed between the 9-9 and the 11-9 age-levels. The 17-9 age-level dimension is 3.0 millimeters less than the subgroup mean.

b. Sella to the Maxillary First Molar (5 to 6)

From the 5-9 to the 17-9 age-level this dimension's absolute length increased 15.5 millimeters. This is 5.0 millimeters more than the subgroup mean 12-year increment. At the 5-9 age-level the length was 27 millimeters and at the 17-9 age-level the length was 42.5 millimeters. If we recall that the sella-nasion plane was below the subgroup mean, then it is remarkable that the molar had moved forward this amount. Between the 11-9 and the 13-9 age-levels the length of this dimension had increased 4.3 millimeters.

c. Nasion to the Maxillary First Molar

At the 5-9 and the 17-9 age-levels the dimension was 36.5 and 29.3 millimeters, respectively. The total 12-year decrease in length for this dimension was 7.2 millimeters. This large decrease in this dimension must be explained as due to the movement of the entire maxilla with the molar, while the anterior cranial base (SN) was relatively stable. This differential growth rate of the maxilla in a forward direction might be the reason for the increased angle of facial convexity.
d. "Ja" Plane ("Ja" to 11)

At the 5-9 and the 17-9 age-level the "Ja" plane's absolute length was 36.0 and 49.6 millimeters, respectively. The total 12-year increase in length of this plane was 13.6 millimeters. These values are considerably higher than the subgroup mean for this dimension. This individual had a relatively long vertical lower face. Increased acceleration rates were seen at the 5-9 to 6-9 age-level and between the 12-9 and 13-9 age-level. The circumnuberal maximum height for this individual was recorded at the 14-year level and a growth spurt of 2.2 millimeters was seen between the 14-9 and 15-9 age-level. This individual dimension is well above the subgroup mean.

4. Summary

(1) In the tracing nasion appears to be less prominent than the maxilla and the mandible. The maxilla was as prominent as the mandible.

(2) The angle of facial convexity was increasing with age, above the mean, and was indicative of a procumbent convex profile.

(3) The angle (SN-GoGn) decreased with age and was below the subgroup mean.

(4) The maxillary incisor angle (1 to SN) was above the mean and decreased with age.
(5) The mandibular incisor angle (I to GoSn) was pro-
cumbent, above the subgroup mean, and stable.
(6) The interincisal angle was below the mean and in-
creased with age.
(7) The sella-nasion plane was below the subgroup mean
and showed very small growth accelerations.
(8) The linear dimension (S to 5) was greater than the
mean and increased very rapidly in "spurts."
(9) The linear dimension (N to 6) was less in absolute
length than the subgroup mean. The length decreased 7.3 milli-
meters, which is a very extreme amount.
(10) The "Ja" plane ("Ja" to 1) was above the mean and
had numerous gross growth accelerations.

E. Female Normal Occlusion--Individual Number 40

1. Tracings (see Figures 38 and 39)

A prominent nose is observed. A straight facial pro-
file at the 17-9 age-level and the shape of the mandible give the
face a square appearance.

2. Angular Measurements (see Figures 40 and 41)

a. The Angle of Facial Convexity

At the 5-9 and 17-9 age-level the angle of facial con-
vexity was +9.0 and +0.2 degrees, respectively. This dimension
FEMALE NORMAL OCCLUSION
SERIES 40

FIGURE 38
FIGURE 39

FEMALE NORMAL OCCLUSION
SERIES 40

- 9-9
- 12-3
Female Normal Occlusion Series 40

(NAP)
ANGLE of FACIAL CONVEXITY
FIGURE 40
for this individual followed the subgroup mean, except at the 17-9 age-level, when the angle of facial convexity was more straight than the subgroup mean represents. The angle decreased slowly with very few fluctuations from the 5-9 to the 17-9 age-level.

b. The Angle Formed by the Intersection of the Zella-Nasion Plane and the Gonion-Gnathion Planes

This angle was below the subgroup mean for the 12 years studied. The angle was very low at the 17-9 age-level. This angle (NS-GoGn) for the 5-9 and the 17-9 age-level was 28.8 and 22.0 degrees, respectively. The greatest angular decrease for 1 year was between the 8-9 and the 9-9 age-level. This 1-year decrease was 1.3 degrees.

c. The Maxillary Incisor Angle (1 to SN)

At the 5-9 and the 17-9 age-levels the angle (1 to SN) was 90.0 and 103.0 degrees, respectively. The individual was below the subgroup mean for this angular dimension. This angle was at its maximum procumbency at the 7-9 age-level, when it reached 110.8 degrees. The angle showed a constant decrease from the 7-9 to the 13-9 age-level. From the 13-9 to the 17-9 age-level the angle increased very slowly.

d. The Mandibular Incisor Angle (1 to GoGn)

At the 5-9 age-level the mandibular incisor was
lingually inclined to 76.0 degrees. The angle (T to GC0n) increased from the 5-9 to the 10-9 age-level. At the 10-9 age-level the angle was 94.5 degrees. The angle decreased to 89.3 at the 12-9 age-level and then had a constant increase to the 17-9 age-level. This angle was below the subgroup mean for this individual. The maxillary and mandibular incisors followed the same general trends.

3. The Interincisal Angle

At the 5-9 and the 17-9 age-level the interincisal angle was 165.0 and 143.4 degrees, respectively. From the 5-9 to the 7-9 age-level the angle decreased 30.0 degrees. From the 7-9 to the 11-9 age-levels the angle was relatively stable at 130.0 to 136.0 degrees. From the 11-9 age-level the angle increased to 147.0 degrees at the 13-9 age-level. From the 13-9 to the 17-9 age-level the angle decreased 3.6 degrees.

3. Linear Measurements

a. Sella-Nasion Plane

The Sella-Nasion plane at the 5-9 and the 17-9 age-levels was 60.5 and 69.5 millimeters, respectively. This dimension was similar to the subgroup mean. Growth acceleration increments are observed at the 5-9 to the 6-9 age-level and at the 11-9 to the 12-9 age-levels. From the 12-9 to the 17-9 age-level the dimension increased only 1.4 millimeters. A "spurt" is
observed during and after the circumpuberal maximum height age.

b. Sella to the Maxillary First Molar (3-6)

At the 5-9 and the 17-9 age-levels the linear dimension was 28.0 and 37.2 millimeters, respectively. This individual dimension was above the subgroup mean. The age-levels where a change of rate in the increase in length of this dimension were noted were: 5-9 to 6-9, 7-9 to 8-9, and 10-9 to 11-9. After the circumpuberal maximum this dimension became stable and fluctuated very little. These growth accelerations were related to the growth of the maxilla.

c. Nasion to the Maxillary First Molar (N-6)

This dimension was 32.5 millimeters in length at the 5-9 age-level and 32.2 millimeters at the 17-9 age-level. This was below the subgroup mean. The length showed increases with growth and decreases because of mesial movement of the molar. The over-all decrease in length was 0.3 millimeters. Growth accelerations were recorded between the 8-9 to 9-9 age-levels and a smaller acceleration between the 12-9 and 13-9 age-levels.

d. "Ja" Plane ("Ja" to 11)

At the 5-9 and the 17-9 age-levels the length of this plane was 30.0 and 39.0 millimeters, respectively. This individual was similar to her subgroup mean. With the eruption of the
permanent incisors, this plane increased in length 3.6 millimeters. Between the 11-9 and the 12-9 age-levels the length of this "Ja" plane increased 1.2 millimeters. For this individual the facial growth acceleration started at or before the circumpuberal maximum height age-level and continued 6 to 9 months after the circumpuberal maximum height age.

I. Summary

(1) The tracings reveal a square straight face with a prominent nose.

(2) The angle of facial convexity was below the subgroup mean and had a constant steady decrease with age.

(3) The angle (NS to GoGn) was below the subgroup mean and showed a constant decrease during growth.

(4) The maxillary incisor angle (1 to SN) was below the subgroup mean, increased with age, and fluctuated considerably.

(5) The mandibular incisor angle (1 to GoGn) was below the subgroup mean, increased with age, and showed some fluctuation of increasing, decreasing, and then increasing again.

(6) The interincisal angle decreased with age and fluctuated from one age-level to the next age-level.

(7) The sella-nasion plane length was similar to the mean and had a growth acceleration later than the circumpuberal maximum height age-level.
(8) The dimension (8 to 6) was above the subgroup mean and showed numerous growth rate increases.

(9) The dimension (N to 6) was below the subgroup mean.

(10) The "Ja" plane length was similar to the mean and continued to increase in length up to the 16-9 age-level.

(11) General trends recognized show that the individual dimensions tended to show a change of rate at and after the circumpuberal maximum height. After the circumpuberal maximum height the growth curves were not as irregular.

F. Female Normal Occlusion--Individual Number 53

1. Tracings (see Figures 44 and 45)

The tracings reveal a convex profile with procumbent tooth and a square short mandible. Supramentale is almost as prominent as pogonion.

2. Angular Dimensions (see Figures 44 and 45)

a. The Angle of Facial Convexity

The angle of facial convexity at the 5-9 and the 17-9 age-level was +12.0 and +9.0 degrees, respectively. The angle (NAP) changed 3.0 degrees for the 12 years studied, but was relatively stable from the 8-9 to the 17-9 age-level. This individual was above the subgroup mean for this angular dimension. From the 5-9 to the 7-9 age-level the angle (NAP) was +12.0 degrees. The angle decreased to +9.0 degrees at the 8-9 age-level.
FEMALE NORMAL OCCLUSION
SERIES 53

FIGURE 42
FEMALE NORMAL OCCLUSION
SERIES 53

FIGURE 43
Female Normal Occlusion
Series 53

(NAP)
ANGLE of FACIAL CONVEXITY

FIGURE 44
increased to +11.0 degrees at the 9-9 age-level, and increased to +8.0 degrees at the 10-9 age-level. From the 11-9 to the 17-9 age-level the angle fluctuated from +10.0 degrees ± 1.0 degree.

b. The Angle Formed by the Intersection of the Nasion-Sella Plane with the Sionion-Gnasion Plane

This angle (NS-GoGn) at the 5-9 and the 17-9 age-levels was 28.8 and 23.7 degrees, respectively. There was a total 12-year change of 5.1 degrees. The angle increased to 29.0 degrees at the 7-9 and 8-9 age-levels and then showed a constant steady decrease. This is an extremely low angle and indicates an excellent growth pattern.

c. The Maxillary Incisor Angle (L to SN)

This angle (L to SN) at the 5-9 and the 17-9 age-levels was 96.0 and 101.5 degrees, respectively. The angle was below the subgroup mean at the 17-9 age-level. The angle decreased to 93.0 degrees at the 6-9 age-level and then from the 7-9 to the 12-9 age level it was 107 ± 1.0 degree. At the 13-9 age-level the angle decreased slowly until it reached 101.5 degrees at the 17-9 age-level. The angle for this individual decreased with growth. It is obvious that the angle showed considerable fluctuation before becoming relatively stable. It is interesting to note that this angle is less than the mandibular incisor angle (I to GoGn).
d. The Mandibular Incisor Angle (I to GoGn)

The angle (I to GoGn) for the 5-9 and the 17-9 age-level was 101.0 and 111.7 degrees, respectively. This was above the subgroup mean. From the 5-9 to the 7-9 age-level the mandibular incisor angle was 101.0 degrees and then it started to increase through the 14-9 age-level. From the 14-9 to the 17-9 age-level the angle became less, but fluctuated considerably.

e. The Interincisal Angle (I to l)

The interincisal angle was 131.0 degrees at the 5-9 age-level, increased to 136.0 degrees at the 6-9 age-level, and then started to decrease so that at the 8-9 age-level the angle was 117.0 degrees. The angle continued to decrease so that at the 12-9 age-level it was 111.0 degrees. From the 12-9 to the 17-9 age-level the angle increased to 118.0 degrees. The downward concave curve from the 7-9 to the 17-9 age-level was typical for this angle.

3. Linear Dimensions

a. Sella-Nasion Plane

The Sella-Nasion plane had an absolute length of 61.0 millimeters at the 5-9 age-level and 68.7 millimeters at the 17-9 age-level. This is below the subgroup mean for this dimension. From the 12-9 to the 13-9 age-level a 2.0 millimeter yearly increment of growth on this plane was observed. From the 13-9 to
the 17-9 age-level the sella-nasion plane was very stable.

b. Sella to the Maxillary First Molar

This linear dimension was 25.0 millimeters at the 5-9 age-level and 35.0 millimeters at the 17-9 age-level. The total 12-year increment for this dimension (5 to 6) was 10.0 millimeters. These figures are similar to the subgroup mean for this dimension. A large increase in the length of this dimension was seen between the 5-9 and the 7-9 age-levels. The increment for this age-span was 6.0 millimeters. Between the 10-9 and the 11-9 age-levels we have a 1-year increment of 2.5 millimeters. The reading at the 13-9 age-level was probably an error. Excluding the 13-9 age-level (error), the 12-9 to 16-9 age-level reading was a constant 34.0 millimeters.

c. Nasion to the Maxillary First Molar (N-6)

At the 5-9 and the 17-9 age-levels the length of this dimension (N to 6) was 36.0 and 33.7 millimeters, respectively. This is very similar to the subgroup mean for this dimension. The dimension fluctuated between increasing and decreasing because of growth. However, the over-all 12-year trend showed a 2.3 millimeter decrease.

d. "Ja" Plane ("Ja" to 11)

This linear dimension was 31.5 millimeters at the 5-9 age-level and 38.7 millimeters at the 17-9 age-level. This
dimension was similar to the subgroup mean. A growth acceleration was observed between the 5-9 and 7-9 age-levels. The total increase for this 2-year span was 3.5 millimeters. The length of this dimension showed very insignificant changes from the 12-9 to the 17-9 age-levels.

4. Summary
(1) The tracings aid the reader to visualize an individual who had a short square mandible with procumbent incisors and a convex profile. Pogonion was not appreciably prominent in the facial profile.

(2) The angle of facial convexity was stable, below the subgroup mean, and convex.

(3) The angle (NS-GoGn) showed a constant decrease, and was below the subgroup mean.

(4) The maxillary incisor angle was below the subgroup mean, and decreased with growth.

(5) The mandibular incisor angle (I to GoGn) was above the subgroup mean, very procumbent, and tended to remain stable.

(6) The interincisal angle was below the subgroup mean and increased with age.

(7) Sella-nasion plane is similar to the subgroup mean and showed no significant increase from the 13-9 to the 17-9 age-levels.
(3) The "Ja" plane length was similar to the subgroup mean, had large growth spurts associated with the eruption of permanent incisors, and showed very little increased length after the 13-9 age-level.

Female Class I Occlusion—Individual Number 87

1. Tracings (see Figures 46 and 47)

This individual had a prominent chin; with a receding forehead and maxilla. The lower lip was more protrusive than the upper lip.

2. Angular Dimensions (see Figures 48 and 49)

a. The Angle of Facial Convexity

The angle of facial convexity was +13.2 degrees at the 5-9 age-level and +6.7 degrees at the 17-9 age-level. The angle (NAP) fluctuates from a decreasing trend at the 10-9, 11-9, and the 13-9 age-levels. Other than those 3 years the angle decreased continuously.

b. Angle Formed by the Intersection of the Sella-Nasion Plane and the Gonion-Gnathion Plane

The angle (NS-GoGn) at the 5-9 and the 17-9 age-levels was 42.8 and 42.1 degrees, respectively. Thus this angle had no significant change through the 12 years studied. The angle varied 0.7 degree for the 12 years investigated.
FEMALE CLASS I OCCLUSION
SERIES 87

FIGURE 46
FEMALE CLASS I OCCLUSION
SERIES 87

FIGURE 47
Female Class I Occlusion
Series 87

N
S

5-9

A

Po

17-9

(NAP)

ANGLE of FACIAL CONVEXITY

FIGURE 48
c. The Maxillary Incisor Angle (I to SN)

The angle was 83.3 degrees at the 5-9 age-level and 112.8 degrees at the 17-9 age-level. This dimension was above the subgroup. The angle has been classified as stable, because from the 13-9 to the 17-9 age-level the angle showed no significant change. The angle had a steady increase from the 5-9 to the 13-9 age-level.

d. The Mandibular Incisor Angle (I to GoGn)

The lower incisor at the 5-9 and the 17-9 age-levels was 67.3 and 87.1 degrees, respectively. The angle was stable but fluctuated each year during the study. This angle is below the subgroup mean.

e. The Interincisal Angle

The interincisal angle at the 5-9 age-level was 155.5 degrees; at the 17-9 age-level it was 119.1 degrees. The angle decreased from the 5-9 to the 12-9 age-level. From the 12-9 to the 17-9 age-level the angle was relatively stable.

3. Linear Dimensions

a. The Sella-Nasion Plane

The sella-nasion plane at the 5-9 and the 17-9 age-level was 60.2 and 67.2 millimeters, respectively. This was below the subgroup mean. From the 5-9 to the 7-9 age-level,
and from the 12-9 to the 13-9 age-level, growth accelerations were observed. After the 13-9 age-level the increase in this linear dimension was negligible.

b. Sella to the Maxillary First Molar (S to 6)

This dimension was 21.3 millimeters at the 5-9 age-level and 31.2 millimeters at the 17-9 age-level. This is below the subgroup mean. From the 12-9 to the 13-9 age-level a 2.5 millimeter growth acceleration was observed.

c. Nasion to the Maxillary First Molar (N to 6)

At the 5-9 and the 17-9 age-levels the length of the dimension (N to 6) was 38.9 and 35.8 millimeters, respectively. The total decrease for the 12 years studied was 3.1 millimeters. This dimension fluctuated considerably during the 12 years studied.

d. "Ja" Plane ("Ja" to 11)

At the 5-9 age-level the length of this dimension was 33.5 millimeters. The length increased 10.9 millimeters during the 12 years studied. This dimension was above the subgroup mean. Growth accelerations were seen between the 6-9 and 7-9 age-levels, the 12-9 and 13-9 age-levels, and the 14-9 and 15-9 age-levels.
II. Summary

(1) The angle of facial convexity decreased with growth, was above the mean, and represented a procumbent face.

(2) The angle (NS to GoGn) was fluctuating but stable for the 12 years studied.

(3) The maxillary and mandibular incisor angles fluctuated during the 12 years studied, but they were stable the last 4 years of the investigation.

(4) The interincisal angle showed a constant stable trend after the 12-9 age-level.

(5) The linear dimensions studied were all below the subgroup mean except the "Ja" plane. The sella-nasion plane, the N-S plane, and the S-S plane all tended to remain stable after the 13-9 age-level.

(6) All growth acceleration and all angles were complete, with few exceptions, after the 13-9 age-level.

(7) From the 13-9 to the 17-9 age-level the dental angles were stable for this individual.

III. Female Class I Occlusion--Individual Number 79

1. Tracings (see Figures 50 and 51)

The tracings reveal a well-developed maxilla, anterior teeth with a 4.0 to 5.0 millimeter vertical overbite and a well-developed lower lip.
FEMALE CLASS I OCCLUSION
SERIES 79

FIGURE 50
FEMALE CLASS I OCCLUSION
SERIES 79

FIGURE 51
2. Angular Measurements (see Figures 52 and 53)

a. The Angle of Facial Convexity

The angle of facial convexity at the 5-9 and the 17-9 age-levels was +10.0 degrees and +7.2 degrees, respectively. The angle for this individual was above her subgroup mean. The angle showed considerable fluctuation, as it decreased from the 5-9 to the 8-9 age-level, increased from the 8-9 to the 11-9 age-level, decreased to +6.9 degrees at the 14-9 age-level, and then remained stable for the last 3 years of the investigation. After the circumpuberal maximum height age-level this angle remained stable.

b. The Angle Formed by the Intersection of the Nasion Sella Plane with the Gonion-Gnathion Plane

At the 5-9 and the 17-9 age-levels the angle (NS-GoGoN) was 38.5 and 36.4 degrees, respectively. From the 5-9 to the 13-9 age-level the angle slowly decreased to 35.1 degrees. From the 13-9 to the 17-9 age-level the angle slowly increased to 36.4 degrees. The angle fluctuated during the 12 years investigated.

c. The Maxillary Incisor Angle (1 to SN)

At the 5-9 and the 17-9 age-levels the angle (1 to SN) were 87.0 and 102.2 degrees, respectively. This angle was below the subgroup mean. The angle increased from 87.0 degrees at the
Female Class I Occlusion
Series 79

(NAP)

ANGLE of FACIAL CONVEXITY

FIGURE 52
5-9 age-level to 104.2 degrees at the 10-9 age-level. The angle decreased to 100.6 degrees at the 14-9 age-level and then showed a constant increase to the 17-9 age-level. The angle (AN to SN) was very stable after the circumpuberal maximum height age-level.

d. The Mandibular Incisor Angle (I to GoSn)

The mandibular incisor was 87.0 degrees at the 5-9 age-level, and increased to 98.5 at the 17-9 age-level. This angle was above the subgroup mean. The greatest angular change for 1 year was between the 8-9 and the 9-9 age-levels, when the 1-year increment was 4.0 degrees. The angle was relatively stable after the circumpuberal maximum height age-level.

e. The Interincisal Angle

This angle was 114.0 degrees at the 5-9 age-level and 120.2 degrees at the 17-9 age-level. The angle fluctuated from one year to the next, but was decreasing steadily. The angle was relatively constant and stable after the circumpuberal maximum height age-level.

2. Linear Measurements

a. Sella-Nasion Plane

At the 5-9 age-level the sella-nasion plane was 62.0 millimeters in length and at the 17-9 age-level it was 70.0 millimeters in length. This was above the subgroup mean. The sella-
nasion plane increased 3.7 millimeters from the 9-9 to the 11-9 age-level. The length of this plane does not change after the 11-9 age-level, which means that the length is complete at the circumpuberal maximum height age-level.

b. Sella to the Maxillary First Molar (5 to 6)

At the 5-9 and the 17-9 age-levels the length of this dimension was 21.5 and 29.2 millimeters, respectively. This was below the subgroup mean for this dimension. A maximum increase in length of 2.0 millimeters, for 1 year, was seen between the 5-9 and the 6-9 age-levels. From the 10-9 to the 17-9 age-level the length of this plane increased only 1.0 millimeter.

c. Nasion to the Maxillary First Molar (N to 6)

At the 5-9 and the 17-9 age-levels the length of this plane was 40.5 and 40.8 millimeters, respectively. This was 4.0 millimeters greater than the subgroup mean. There was considerable fluctuation in the length of this plane.

d. "Ja" Plane ("Ja" to 11)

At the 5-9 and the 17-9 age-level the length of this plane was 35.5 and 44.6 millimeters, respectively. This was above the subgroup mean for this dimension. The individual had a constant increase in the length of this plane. Two growth accelerations are seen at the 6-9 and at the 9-9 age-levels. The 14-9 age-level was not consistent with the trend of this dimension.
4. Summary

(1) The tracings revealed a procumbent denture and procumbent profile.

(2) The angle of facial convexity was rather stable, above the subgroup mean, and represented a convex facial profile.

(3) The angle (NS to GoGn) was above the subgroup mean, fluctuated with growth, but the over-all trend was a decrease in this angle.

(4) The maxillary incisor angle increased with growth, was below the subgroup mean, and was relatively stable after the circumpuberal maximum height was reached.

(5) The mandibular incisor angle increased with growth and was above the subgroup mean.

(6) The interincisal angle decreased with growth and was below the subgroup mean.

(7) The sella-nasion plane was above the subgroup mean, and growth along this plane terminated by the 11-9 age-level.

(8) The dimension (S to 6) was below the subgroup mean, and the dimension (N-6) was above the subgroup mean.

(9) The "Ja" plane was 4.0 millimeters greater than the subgroup mean for the 5-9 to the 17-9 age-levels.

(10) The general trend was that after the circumpuberal maximum height age-level the angular and linear dimensions were relatively stable.
CHAPTER IV

DISCUSSION

The present study on growth is integrated to the changes of the dental and skeletal facial profile and is based on a longitudinal analysis of serial cephalometric roentgenograms. Each year of the life of forty individuals has been studied, starting at the five-year age-level and extending to the eighteen-year age-level. A total of twelve years of each individual's life was studied. It was hoped that by correlating odontological traits to osteological traits, an explanation could be conceived of how growth can create an anatomical balance for the face of different individuals. With such information anticipatory consideration could be given for each individual during the orthodontic analysis of the individual case, the treatment stage, and the retention stage.

Certain limitations are placed on this investigation. Only six individuals are in the female normal occlusion subgroup. This was not as complete a sample as the other three subgroups were. The second limitation is based on experimental error. The experimental error is relatively small for both angular and linear dimensions, but the angles involving dental organs contained the largest amount of error. The linear dimensions
(II to I and II to II) are not discussed in the findings because it was observed that their variance and their standard deviations were extremely large. Any changes taking place during growth were insignificant because of the wide variability of these dimensions. Another limitation on the investigation is placed on the Class I occlusion group. This group was not separated into divisions. Thus the intensity and degree of severity of the class I occlusions varied.

This investigation is the broadest in scope and the most inclusive study that has been attempted using serial cephalometric roentgenograms. In order to characterize the total group, the male and female group, and the differences in occlusion for males and females, statistical means, standard deviations, and the 99 per cent confidence limit were calculated. Nine separate means for groups and subgroups have been calculated for each dimension in order to characterize each group and subgroup. In the discussion we shall take up the means, the individual trends, the individual dimensions, and the integration of all the dimensions in order to better appreciate each single variant and its interplay in the total facial profile.

Linear Measurements

The individuals as individuals had linear measurements which seemed to follow subgroup means much closer than the angular
measurements did. This is probably due to the reduced effect that the environment could have on the linear measurements investigated. The angular measurements were more closely affected by environmental changes.

Sella-Tasion

This dimension in the literature is also referred to as the anterior cranial base. The total group means show a constant increase for this dimension. Only very small growth accelerations are seen for this dimension. The growth accelerations observed for the total group mean are not prominent growth rate changes. Nanda (1955), in a previous investigation, referred to this as a skeletal-neural growth acceleration. The total group means appear to confirm this conclusion. However, many individuals do have growth accelerations which are typical of the skeletal accelerations. The male means are larger than the female means for this dimension. The female and male means have a similar increment from the 5 year 9 month age-level to the 14 year 9 month age-level. It is before the 5 year 9 month age-level and after the 14 year 9 month age-level that the male means show a greater yearly increment than the female means do. Coben (1955) and Brodie, Jr. (1955) have reported a significant difference between males and females for this dimension. This is confirmed by the present investigation, but it is further shown that the
yearly increment is the same for both females and males from the 5 year 9 month age-level to the 11 year 9 month age-level. The female means show very insignificant changes in this dimension after the 11 year 9 month age-level. The yearly increment before the 5 year 9 month age-level must have been different for males than for females. This conclusion is confirmed by Brodie, Jr.'s investigation. The fact that the males increase in length along this dimension after the 11 year 9 month age-level while the females are showing only minor changes will be used to explain the facial profile of the male and female. For this dimension the normal occlusion group means are similar to the Class I occlusion means. It is observed that the normal occlusion means show a yearly increment which is greater than the Class I occlusion means after the 11 year 9 month age-level. At the circumpuberal age-level this dimension shows a growth acceleration in the majority of the individuals. After this paracircumpuberal growth acceleration the growth along this dimension slowly decelerates.

During the study of individuals it was observed that if this dimension stops growing early, before the circumpuberal age-level, the face tends to have a convex facial profile. The correlation of this linear dimension to the angle of facial convexity is discussed with the angular dimensions.

The importance of the anterior cranial base cannot be appreciated by studying just this one plane, but this one plane
has allowed us to speculate and pyramid our knowledge concerning
changes in the facial profile. This dimension was necessary to
study why the facial profile changes were different for different
individuals. It also allowed us to understand the reason for the
differences between male and female facial profiles.

Point **sella to the Maxillary**
**First Molar** (8 to 6)

This dimension has not been studied by investigators
as we have utilized it in this investigation.

This dimension represents changes which can be produced
by a combination of the maxilla growing downward and forward and
the mesial drift of the maxillary first molar. Very few inter-
pretations are made for this dimension because of the multiple
factors which may cause changes in this dimension. However, there
are some interesting observations between male and female means
and between normal and Class I occlusion means. For the most
part, increase in length of this dimension is similar to the in-
crease in length from sella to subspinale, which was studied by
Nanda using the same records. However, during the mixed dentition
stage this length increased more than the linear measurement of
sella to subspinale. This is to be expected as the leeway space
described by Nance allows the molar to drift mesially while the
maxilla is not necessarily growing.

The total group means show a total increase for this
dimension of 10.5 millimeters. The male means have a total linear dimension which is two millimeters larger than the female means at the 5 year 9 month age-level and 3.5 millimeters larger than the female means at the 17 year 9 month age-level. This greater difference between the males and females does not appear until after the 14 year 9 month age level. This would be similar to the findings of Nanda for the dimension sella to subspinale. The molar shows very little mesial drift which would be of significance after the 14 year 9 month age-level. With this information it can be observed that changes along this dimension, after the mixed dentition stage, are really changes occurring due to the forward downward growth of the maxilla.

It is interesting to observe that each individual has a growth acceleration which occurs shortly before the eruption of the first and second molars. This would indicate that arch length is needed for the eruption of the molars, a growth acceleration accommodates for this need. The normal occlusion means and the Class I occlusion means are similar at the 5 year 9 month age-level, but at the 17 year 9 month age-level the normal occlusion means is 2 millimeters larger for this dimension than the Class I means. This would indicate that during the twelve years investigated the maxilla-molar complex moves forward more for the normal occlusion group than for the Class I occlusion group. What significance is placed on this observation is
not known. More work would have to be done on this complexity to distinguish changes due to growth, error, and mesial drift of the molar.

Section to the Maxillary First Molar (N-6)

Summarizing the findings for the twelve years studied, we have observed that the total group mean decreases two millimeters, male and female means represent decreases in length for this dimension, and the normal occlusion mean represents a one-millimeter greater decrease for this dimension than the Class I group means represent. The fact that the normal occlusion group decreases one millimeter more than the Class I group means would indicate that more room is available for the molars to move forward by mesial drift for this normal occlusion group, or that the maxilla grows forward one millimeter more.

Some of the individuals showed an increase in length for this dimension, some showed no change, and most showed a decrease in the length. An increase in length would indicate that either compensatory growth was taking place between 6 and nasion or possibly this growth between 6 and nasion was greater than the forward growth of the maxilla. Series 92 were the tracings of an individual who showed an increase in this plane during growth. The maxilla appeared to be growing at about the same rate as the forehead. As a result the facial profile became straight.
The error involved in marking the mesial contact of the molar in a cephalometric roentgenogram might make any small change for this plane insignificant. The author does not rely on this plane to correlate the linear dimensions and the angular dimensions.

"Ja" Plane ("Ja" to II)

The total group mean for the "Ja" plane shows a change which represents a growth acceleration from the 5 years 9 months to the 7 years 9 months age-level. This acceleration at this age is seen in all group and subgroup means. This is correlated to the eruption of the permanent mandibular incisors. The Class I male and female group at the 17 years 8 month age-level is 45 and 40.4 millimeters, respectively. This is comparable to the findings of Braun.

This plane has been drawn in many different ways by different authors. Coben has referred to a similarly constructed plane as the mandibular incisor height. The male means are greater than the female means at the 5 year 9 month age-level and they show a greater increment rate than the females. It is observed that the Class I means for males and females are greater than the normal occlusion group. The question is "Does the greater vertical height for the "Ja" plane for the Class I subgroups affect the vertical overbite and cause an unbalanced
equilibrium between the maxillary and mandibular incisors?"
This question can only be presented and not answered because one
dimension is very insignificant by itself. The "Ja" plane fol-
lowa a similar curve as the sella-nasion plane, but it has more
prominent growth accelerations than the sella-nasion plane.
Fer reported that the lower facial height increased signifi-
cantly in length into the third decade of life for males. At the
end of the 17 year 9 month age-level, these dimensions are still
increasing in length during this investigation. The male is
growing at a faster rate than the female along the "ja" plane.
The conclusion would be that not only does the mandible
of the male grow in an anterior posterior direction at a differential rate of growth which is greater than the females', but that
the male mandible grows in a vertical direction at a greater
rate and for a longer time than the female mandible does.
The male exceeds the female in the total height of the
lower face, with a greater increment of growth during the twelve
years studied. The "Ja" plane shows an increment of growth para-
circumpuberal age-level and then the growth decelerates but
shows a steady increase. By observing just this one dimension
the observer will be impressed by the amount of variability
within subgroups and between sexes. Any and all combinations of
the dental angles the dental angles exist with a long or a short
"Ja" plane. The variability and unpredictability of the individual dimension is observed. The directional growth and the increment of growth appears to separate the males from the females.

The females and males have shown that they appear to be different from other males and females for one, two, three, or more dimensions. However, as a total individual they tend to follow a pattern which is striving for anatomical balance between all structures. The uniqueness of the individual can only be studied by the total integration of the linear and angular dimensions for that individual.

The Dental Angles

In discussing the dental angles (I to GoGn, l to SN, and the interincisal angle) the author will first compare each of the angles to the findings of other investigators. Then the three dental angles will be integrated and a discussion of individual trends will aid in elucidating the reasons for such trends seen during growth.

The Mandibular Incisor Angle (I to GoGn)

The mandibular incisor decreased, increased, or remained stable during growth. These three trends were observed only when individuals were studied. The total group means indicate that this angle increased to the 10 year 9 month age-level and then decreased with growth. This is not a true picture of
what individuals are doing, because the opposite but equal changes of specific individual trends have neutralized the mean values. The male mean values at the 17 year 9 month age-level compare favorably to the means established by Bjork and Palling (1955). The female group means at the 17 year 9 month age-level are two degrees greater than those female means observed by Noyes, Rushing, and Sims (1943). The male means at the 17 year 9 month age-level are similar to those reported by Noyes, Rushing, and Sims. Scheffer (1949) reported mean values for a group of mixed occlusions and sexes in a longitudinal cephalometric study involving the 8, 12, and 18 year old age-levels. His findings are 4 to 6 degrees greater than this investigation shows for each of the age-levels.

Within this sample we have observed that the female ranges from 3.6 to 5 degrees more protrusive than the male means. This would indicate that the male incisors are more vertically positioned on their supporting bone, while females have more procumbent incisors. This concurs with the findings of Noyes, Rushing, and Sims (1943). Janusz (1952) found no significant difference between males and females having Class I occlusions. Perhaps because of the statistical analysis method applied by Janusz, a significant difference did not appear to exist between sexes.

The author observed in his findings that the male mean mandibular
incisor angle was consistently three to five degrees smaller than the female for the twelve years studied. This trend for twelve years would appear to be of significant value. The normal occlusion group mean represented mandibular incisors which were upright on their supporting bone. The Class I group means were three to four degrees more procumbent than the normal occlusion group. This difference between the Class I and normal occlusion group only became prominent after the 10 year 9 month age-level. The males with a normal occlusion have lingually inclined incisor teeth which have a mandibular incisor angle of 87 degrees. This subgroup differed from the other subgroups studied. The male Class I group and females with Class I and normal occlusions were more procumbent than the male normal occlusion subgroup. From this observation the author feels that the mean values for Class I occlusions represent procumbent incisors because of a lack of arch length. With this lack of arch length the incisors have become labially inclined and finally have broken contacts between teeth to compensate for the lack of arch length.

It was interesting to observe that the mandibular angle for females tended to be stable or increasing with age. The male individuals have an angle (I to GoGn) which tended to be stable or decreasing with growth. This tendency is probably due to an earlier female deceleration of growth which allowed the female
mandibular incisor angle to reach an equilibrium state at an earlier age than the males. The mean circumpuberal age for females was 12.1 years while the males' circumpuberal mean age was 14.4 years. It is obvious that if the axial inclination of the mandibular incisor shows irregular fluctuations because of growth, then the female would tend to become stable at an earlier age-level than the male.

The irregular fluctuations of this angle from one age-level to the next age-level can be explained by the differential rate and the differential time at which the maxilla and the mandible grow. This difference in rate and time of growth of these two bones upset the equilibrium of the teeth in relation to each other, and therefore vertical compensatory changes take place. This will be explained in further detail when we discuss the integration of these three dental angles.

The eight individuals studied by integrating all of the dimensions showed that not one out of the eight individuals had a SN to C0Gn angle which could be correlated to changes of the (T to C0Gn) mandibular incisor angle. While the angle (SN-C0Gn) showed a decrease with growth, the mandibular incisor angle was increasing, decreasing, or remaining stable. When the angle (SN-C0Gn) remained stable or increased (exceptional cases) with growth, the mandibular incisor angle (T to C0Gn) varied from increasing, decreasing, or remaining stable. Furthermore, these
eight individuals (2 males and 2 females of Class I and 2 males and 2 females with normal occlusions) showed no correlation between the sizes of these two angles (I-CoGn and SN-CoGn). An individual with a large SN-CoGn angle could have a large, average, or small mandibular incisor angle (I to CoGn). An individual with a small SN-CoGn angle could have a large, average, or small mandibular incisor angle. Not only are the previous statements true for the eight individuals studied individually, but it is also true for the total forty individuals investigated. This would seem to be of utmost clinical importance. The orthodontist has made a correlation between the mandibular incisor angle (I to CoGn) and the SN-CoGn angle to aid in arriving at a treatment plan. This would not be justified if the previous findings are true. These findings suggest that a specific axial inclination of an incisor does not determine the stability of teeth for a group of individuals. The findings suggest that for an individual the axial inclination has a tendency to be stable at a specific angle but that this angle is different for different individuals.

The interest in the incisor teeth as a single variation must include an interest in the interrelation of the bone, the teeth, and the muscle complexes.

Variation is caused by a combination of hereditary, congenital, and environmental factors. Skeletal and dental
variation may be due to the effect of additive and interactive factors such as muscle changes, skeletal growth, and aging processes, any one of which may upset the equilibrium of the anatomical balance.

The Maxillary Incisor Angle (1 to SN)

In observing the means for this angle (1 to SN) we see that the total group means increase with age. Again this is not a true picture of what individuals are doing. The female means are 4 to 5 degrees more than the male means for the twelve years studied. This trend would appear to show a significant difference between sexes. Seidel (1947), Freeman (1953), and Janusz (1954) reported no significant sex differences between Class I and Class II occlusions. Janusz reported the mean for the maxillary incisor angle (1 to SN) as 103.2 and 105 degrees for Class I males and females, respectively. This investigation at a comparable age-level of that used by Janusz shows the differences between these two sexes as 100.7 for males and 105.5 degrees for females. The Northwestern University analysis uses 103.2 degrees as a mean for this angle.

This angle (1 to SN) also showed three trends for individuals. The angle could increase, decrease, or remain stable during growth. This confirms the observations of Shaeffer (1949). Both female and male individuals are distributed within these
three trends. The female tends to have more individuals who have a stable angle (l to SN). The males do not show this tendency for stability. Again this stability of the females can be explained by the earlier deceleration and termination of growth. Growth appears to cause a constant changing of the axial inclination of the incisors. These growth changes upset the positional stability of the maxillary incisor in their environment. With the termination of growth the changes upsetting the equilibrium of the teeth become less intense and this is the reason for a comparatively stable position for these teeth. It was also observed that dental angles seldom follow the means for the groups or subgroups.

The irregular curves observed for individuals is interpreted as the instability of the incisor due to compensatory changes caused by the changes in the oral environment of the tooth. After the circumpuberal maximum height age-level, the maxillary incisor angle may show slight changes. Shortly thereafter there is a tendency for the pattern to become constant and the angle either increases, decreases, or remains stable. The variability and the unpredictability of the angulation of these teeth is considered by the author to be due to an upset equilibrium caused by a differential growth rate and differential time of growth of the bones which house these teeth. The vertical
eruption of the mandibular and the maxillary incisors at the five year 9 month age-level confirms similar observations made by Brodie. If we are to orient this study to clinical orthodontics, we must question certain procedures of orthodontic treatment. It is questionable whether females and males should be treated so that their incisors are at similar axial inclinations. Since the males and females do not follow the same growth pattern trend, it is obvious that treatment compensations must be in keeping with the individual morphogenetic pattern. The females appear to have more procumbent incisors than the males.

The changes in the axial inclination of the maxillary incisors are at a later age-level for the males than for the females. Perhaps by treating individuals to a normal average angle or to a procumbent axial inclination, we are aging the denture with our orthodontic therapy.

The Interincisal Angle

The interincisal angle is changed by changes in the axial inclination of the mandibular or the maxillary incisor and by changes in the inclination of the bones which house these teeth. The interincisal angle from the 5 year 9 month age-level to the 8 year 9 month age-level decreases. This is in complete agreement with Brodie's findings because both the maxillary and mandibular incisors erupt vertically and then tip labially.
After the 9 year 9 month age-level the total group means are representative of a stable angle. Although this angle does not vary in degrees, this is not indicative that the component parts which affect this angle are not changing. They are changing, but it appears that when one part causes what would be a change in this angle, other component parts affecting this angle change to compensate for these changes. This is true for group means, but for individuals there are some irregular fluctuations from one year to the next year.

In order to compare these findings with other investigations we must compare them to many different investigations because few authors have reported more than one or two age-levels. Bjork and Palling (1955) reported the interincisal angle for males twelve years old and twenty years old, at 128 and 130 degrees, respectively. This investigation at comparative age-levels shows the means for this angle to be 133 and 139 degrees. This is a logical difference because the Swedish population investigated by Bjork and Palling tends to have a greater dental procumbency than the group this investigations studied. Sheaffer (1955), Lindegard (1956), and Reidel (1947) have reported approximately similar means of 130-3 degrees. They reported no significant differences between children and adolescents. The author’s findings are two degrees greater than the findings of
these three investigators. The findings of Noyes, Rushing, and Sims (1943) on 14 males and females between the ages of 22 and 34 years was 129.3 degrees. The findings of this investigation at the 17 year 9 month age-level for the total group mean was 132 degrees. Downs reported a mean of 135 degrees for individuals between 12 and 17 years of age. A comparative age-level to Downs' sample, taken from this investigation, has an angle of 132 degrees.

The male and female means at the 17 year 9 month age-level were 135 and 128.5 degrees, respectively. These are similar to the findings of Janusz (1956). By utilizing Fisher's "T" test, Janusz showed no significant differences between Class I males and females for this angle. The twelve-year growth trends show a difference between males and females, and between normal and Class I occlusions. These statements are based on general trends only.

An interesting observation is that this angle may increase, decrease, or remain stable. This is similar to the previous two dental angles discussed, and is in full agreement with Shaeffer's conclusions.

The divergent opinions reported for the dental angles would at first appear to be confusing. Always the thought arises, "Are we testing homogeneous populations?" The question then is
more than just an application of numbers to a statistical method.
The question is, "Can skeletal disharmonies be diagnosed by occlusion or are occlusal disharmonies only manifestations of deep significant differences between the upper and lower facial skeleton? If occlusal disharmonies are measurements of degrees of severity of skeletal disharmonies, then statistical analysis of such a heterogeneous conglomeration of skeletal patterns is most conflicting. There are five different divisions of Class I malocclusion. There may be many different skeletal disharmonies in individuals of any one class of malocclusion. The Analysis of Variance and Fisher's "t" test state that we assume a homogeneous population, and the author did not use these statistical tests because of the heterogeneous conglomeration of skeletal patterns being investigated. No such tests have been used to test significant differences between sexes and occlusion, and only means, trends, and specific individual analysis have been used to study this material.

The interincisal angle for females is less than it is for males. This would indicate that the female has a greater dental procumbency than the male. The Class I group means are also representative of a greater dental procumbency than the normal occlusion means. The males with normal occlusions have a subgroup mean which indicates that they have the least dental
Procumbency of any of the subgroups investigated. For this subgroup the angle of facial convexity and the dental procumbency (measured by interincisal angle) appears to follow significant parallel trends. Thus an individual with a large interincisal angle (dental procumbency is not prominent) also appears to have an angle of facial convexity which is representative of a flat straight facial profile. This is true only for the male subgroup with normal occlusions. It is apparent that the female interincisal angle becomes more stable at an earlier age-level than the males. Reason for this earlier stability has been discussed with the two previous dental angles.

Integration of the Three Dental Angles

By integrating and studying these three angles, we may observe (Tables 9 and 10) that thirteen possible combinations could exist for any individual pattern of growth. This would mean that an individual could have a mandibular incisor angle which was increasing, decreasing, or remaining stable, while the two other angles were changing along these three trends and independent of what the other angles were doing. Any combination of these thirteen possibilities can and did exist within our sample of forty individuals. This is similar to the findings of Shaeffer (1949). From a clinical examination of the headplate tracings and by superposition of the tracings from the 13 year 9 month age-level and the 17 year 9 month age level, it would
appear that the incisors moved to a more posterior position on their supporting bone at the later age-levels. This finding has been reported by Bjork and Shaerfer. Although this might be true in part, it is also partially an optical illusion. The apposition of bone at and around pogonion at these late growth stages gives the appearance that the teeth are moving more posteriorly than they actually are. The author does not dispute the fact that alveolar bone does not keep pace with the so-called "basal bone" of the mandible, but he feels that this is partially an illusion and that apposition of bone at pogonion gives the appearance that the incisors are moving posteriorly on their supporting bone, more than they really are.

The most interesting observation was that the teeth's axial inclinations seemed to fluctuate from one year to the next. The irregularity of the curves for each of the angular dimensions and the different trends for each individual was rather confusing until the total growth pattern was analyzed for each individual. The axial inclination of the teeth could be stable for one or two years and then fluctuate from an increase to a decrease in the axial inclination. The teeth of opposing jaws could act just the opposite of each other. Fluctuations of the axial inclination of the teeth appeared to be part of the individual's pattern. The only explanation for this fluctuation was that the oral
environment that keeps a tooth in a stable position was altered. The factors which could upset this stability are numerous. It could be skeletal growth, muscle changes, habits and manerisms, or possibly aging processes. When these changes in the axial inclination of the teeth were taking place, it was observed that they were associated with growth accelerations. It is the author’s opinion that the irregularity and fluctuations for these angles was caused by growth upsetting the stability of the teeth in the oral environment, and thus compensatory vertical changes took place in the axial inclination of these teeth in order to re-establish an equilibrium. The recognition that there is a differential growth rate of different bones and also a differential time of growth for different bones would, in theory, explain why one jaw may have stable axially-inclined teeth, while the opposing jaw may have incisor teeth which are decreasing or increasing their axial inclination. There are other factors which might upset this equilibrium. Loss of arch continuity, closing of the bite with age, mutilation of the dental arch, or occlusal mannerisms could upset the stability of the teeth by changing the vertical overbite and the horizontal overbite (overjet). Sicher and Schneider (1957) have reported on a histological investigation concerning labio-lingual changes of single-rooted teeth after growth has ceased. This histological investigation is in full agreement with the author’s cephalometric observations other than
the factor which upset the stability of the denture in this inves-
tigation was growth. This investigation correlated to the pre-
viously-mentioned histological study would indicate that the
axial inclination of the incisors is showing constant changes
throughout life.

The fact that there are thirteen possible combinations
of these three dental angles during growth, would indicate that
the mandibular arch is not as contained by the maxillary arch in
the anterior teeth region as it is often thought to be. This
does not mean that after growth has ceased the mandibular arch
would not be contained by the maxillary arch.

Whatever the factors are that cause an angular fluctua-
tion of the axial inclination of the tooth, these factors are
additive and interact to produce compensatory changes in the
axial inclination.

Clinically, these facts would indicate that the teeth
do not, in all cases, become more upright because of growth.
The orthodontist must treat his cases to completion and not de-
pend upon growth to have an advantageous aesthetic effect upon
the anterior teeth. Once the teeth have been positioned to what
the orthodontist considers a stable aesthetic position, it is his
obligation to observe his patients through the retentive and
growth periods. If growth appears to be upsetting the denture
stability established during treatment, further retention or occlusal and interproximal equilibration may be indicated and should be part of the complete orthodontic service.

**Angle of Facial Convexity**

A distinction must be made between group trends and the trends of an individual. Both may be similar to each other or they may be just the opposite of each other. In order to discuss the angle of facial convexity a short summary of observations is indicated. This investigation showed that the total group mean angle decreased with age, that the facial profile of males was less convex than that of females, that individuals with a normal occlusion tended to have a less convex facial profile than individuals with a Class I occlusion, and that despite group characteristics individuals followed their own pattern. Therefore, this angle could increase, decrease, or remain stable during growth.

The total group means represent a decrease in the convexity of the face during growth. This is similar to the findings of Lande (1951), Bigley (1947), and Bjork (1947). The individual means for the males and females at the four-year and eight-year age-level are similar to the means reported for these age-levels by Bigley. The male means at the seven-, twelve-, and eighteen-year age-levels represent a less convex facial profile than those reported by Lande for individuals at those same age-levels. The
total group means at the twelve-year age-level are similar to the means reported by Bjork and Palling (1955). The greatest significant differences that the findings show and which do not concur with other investigations are the irregular patterns of this angle for any one specific individual. Hunts recognized only a trend showing that this angle decreases with growth. The fact that this angle may decrease, remain stable, or increase with growth is significantly different from previous findings.

The irregular curves observed for specific individuals is best explained by the different times at which the growth of the maxilla (subspinale), the mandible (pogonion), and the anterior cranial base (nasion) take place. When the term "staggered" is used, it refers to time periods when one point (for example, subspinale) is moving forward due to growth, while the other two points (for example, nasion and pogonion) are remaining stable or moving forward at a different rate of growth than the first point. Any combination of these three points may be remaining stable or moving forward because of growth. It must be remembered that essentially these three different points change position by different types of growth. Sutural growth, condylar growth, and appositional growth are not necessarily taking place at the same time and at the same rate for each of these bones. If we examine Series: 24, 28, 32, 36, 40,
44, 48, and 52 we can observe that at different age-levels the landmark points forming the angle of facial convexity seem to be stable or moving forward. It is obvious that at any specific age-level these three points may be changing position because of different growth rates. Each point may be stable, moving forward rapidly or moving forward slowly. These differences in growth of these three points at any different age-level causes the irregular fluctuations of this angle from one year to the next. This differential time of growth and rate of growth also determines if the angle of facial convexity is increasing, decreasing, or remaining stable during the twelve years studied. If we look at the figures for the angle of facial convexity, we realize that if nasion grows forward and subspinale and pogonion grow slower or are stable, then the angle of facial convexity decreases. If subspinale moves forward because of growth while nasion and pogonion are stable, then the face becomes more convex. If pogonion moves forward while nasion and subspinale are stable then the facial profile becomes more straight or even concave. It is seen that a combination of the time at which bone growth takes place for each bone and the differential rate of growth of each bone can cause changes in the facial profile. It has been reported that the facial profile becomes more straight during the growth of an individual because of the differential rate of growth.
of the condyle of the mandible and the sutural growth of the maxilla. This is not always true in every individual case. First, because many individuals (14 out of 40 in this investigation) do not have an angle of facial convexity which decreases with age. The second reason is that not only is it condylar growth that appears to make the facial profile straighter, but it is appositional growth at pogonion which also aids in producing a straighter profile during growth. Appositional growth in the area of pogonion is probably greater than we have thought it was. The fact that facial areas do show rapid changes in late adolescence cannot be denied. The small nose of the child grows rapidly after menarche for females and during adolescence for males. The nose is no longer small, but becomes very prominent in the late teens. The voice change of the male during adolescence is nothing more than rapid growth of cartilage which is not compensated for by the vocal cords. These differential growth rates and the time of growth are probably associated with hormonal secretions. It is evident from the examples shown that the differential time of growth, differential rates of growth, and the direction of this growth may cause changes in the size of the bone, changes in the proportions of the bones, and changes in the spatial relation of bones to each other. The author has also attempted to show that changes in the second decade do occur which alter the facial profile. All or any one of these changes
may affect the angle of facial convexity and also the inclination of the dental organs. Again we only have to look at individuals to see that we are still speaking in the correct perspectives. Series 40, 87, 89, and 92 all represent individuals whose angle of facial convexity decreased with growth. It is obvious that the mandible (pogonion) is moving forward at a greater rate than is the maxilla (subspinale) and the forehead (nasion). Although all four of these individuals have an angle of facial convexity which decreases during growth, it is apparent that each has its own amount of change and each has a different facial profile. Individual 89 had the greatest amount of change, and it is obvious that the mandible (pogonion) is growing forward more than the maxilla and nasion. Nasion and subspinale did continue to move forward for a longer time than in most of the individuals, and if it were not for this fact, this face would have a severe concave facial profile. This fact only points out that this total individual growth pattern is normal for this individual, but this one dimension would be abnormal for many other individuals. In those individuals that the angle decreases and yet the profile remained convex it was because nasion either stopped growing sooner or nasion moved forward less than the maxilla (subspinale), while the mandible did not have as great a differential rate of growth (appositional and condylar growth) to position pogonion anteriorly enough to produce a straight or concave
profile. In those individuals where the angle of facial convexity was stable, the three points (N-A-Po) moved forward in synchrony so that the angle did not change. If one of the points showed no change of position due to growth, the other two points must compensate in relation to each other to produce a stable angle. The angle of facial convexity increased with age for the individual in Series 85. It is obvious from Figure 36 that the sella-nasion plane showed an early deceleration of growth, while the maxilla continued growing for a longer time and at a greater rate than nasion. The maxilla (subspinale) also appeared to grow at the same rate as the mandible and in the last two years of the study the rate of growth for the maxilla was greater than the growth rate of the mandible. Thus this angle of facial convexity increased for this individual. The male individuals as a group tend to be less convex than the females. This is because the female has an early deceleration and an early termination of growth at the condyle of the mandible and at pogonion. This conclusion confirms the sex differences observed by Braun and Schmidt on other dimensions of the face. Baer (1956) observed significant changes in the male up to the third decade. The female, according to Baer, had significant growth changes to the middle of the second decade of life.

The irregular patterns observed, where at one age-level the angle might be +10 degrees, at the second age-level the angle
might be +7 degrees, and at the third age-level the angle might be +13 degrees, are easily explained by asynchronous growth accelerations of these three different bones which make up landmark points for the angle of facial convexity. Each was growing at an asynchronous rate, and at an asynchronous time in relation to the others.

Growth accelerations are related to the circumpuberal maximum age-levels. When we group together age-levels of different individuals on a chronological age basis and not on a biological age basis, we group together age-levels which are nonsynchronous in relation to growth accelerations, and this incorrect grouping often offsets mean values. Growth is not only a matter of differential rates of change, but it is time linked for each individual, and in order to gain more useful mean values we should synchronize age-levels on a biological basis to avoid placing asynchronous growth age-levels into the same age-level.

After adolescent growth and the circumpuberal maximum height age-level, we often see an accelerated growth change. After this change there is usually a spontaneous recovery so that most structures begin to fit into a stable face, and both the angular and the linear dimensions show only small fluctuations. The word "stable face" is like "a bone." In reality neither one exists. The face becomes stable only because the
changes are showing less fluctuations. With the angle of facial convexity it is emphasized that a single variant deviating from mean values is not meaningful. There are many avenues of growth and growth adjustments for the individual facial pattern.

The values obtained in this study show the malleability of the facial profile and the dental angles. Both the dental angles and the facial profile change throughout life because the congruous relation of parts may be changed by growth, the environment, and aging processes. These conclusions agree with Erdlicka, Hooton, Hellman, Duportius, and Suchi when they reported that the face is continuously changing. Not only is the facial profile changing, but it appears that the three dental angles are changing due to an altered environment.

The orthodontist should remember in treatment planning that the normal facial profile for a male is not the normal facial profile for a female. The female has the more convex face, while the male tends to have a straight or slightly concave facial profile with a more prominent chin. Also of utmost importance is the fact that all growth is not necessarily going to improve the esthetic appearance of the individual. In one-third of the individuals studied the facial profile did not become more straight. This would indicate that the orthodontist should not depend upon the "magic of growth" to finish the esthetic appearance of an individual. Fortunately, two-thirds of the individuals studied
showed that the face does become more straight. Not only should the orthodontist treat his patients to an esthetic facial profile, but he should position the teeth at as stable a position as the case dictates. Realizing that changes will take place during growth, it is the obligation of the orthodontist to plan a treatment and a retention stage which will allow for possible growth changes. Each individual has an uniqueness all his own, and only by knowing the individual can one treat that individual.

The Application of the Investigation to the Clinical Study of Orthodontics

Growth is certainly a factor in orthodontics. Case diagnosis and analysis, treatment planning, and the retention stages of orthodontics are all based on an understanding and an intelligent prognosis of growth. Perhaps the previous statements are not always adhered to, but they should be.

Many orthodontists have based their case analysis and treatment plan on the correlation of the mandibular incisor angle (\(\overline{Y}\) to \(\overline{GoGn}\)) and the \(\overline{SN}\) to \(\overline{GoGn}\) angle (actually Frankfort Mandibular Angle). This study has shown that there is no such correlation during growth. The mandibular incisor angle is not predicated on condylar growth or mandibular ramus growth. Usually the \(\overline{SN}\) to \(\overline{GoGn}\) angle decreases during growth, but the mandibular incisor angle (\(\overline{Y}\) to \(\overline{GoGn}\)) may be increasing, decreasing, or remaining stable during growth. If the \(\overline{SN}\) to \(\overline{GoGn}\) angle
is large, the mandibular incisor angle may be small, intermediate in numerical value, or very large. If the SN to GoGn angle is very small the mandibular incisor may assume one of three positions: it may be procumbent, vertically upright, or lingually inclined. These observations on each of the forty individuals point out the fact that there is no correlation between the SN to GoGn angle and the mandibular incisor angle during growth. Therefore the treatment of an individual in orthodontics should not be to a mean angle, but to the individual's optimum angle for that age-level. This, of course, means that some way must be determined by which an individual's optimum dental angles may be determined for any specific age-level of that individual. This is a problem of the future investigations and investigators.

The statement often seen in the literature is that teeth and bone seem to have a "physiological clock." They know when to grow and when to stop growing. Teeth appear to know at what age-level to erupt. Bone seems to anticipate the future needs of an individual. We know that teeth seem to follow irregular, fluctuating, angular patterns for an individual. These irregular, fluctuating, angular patterns also seem to follow a time schedule set by the "physiological clock." Is it not possible to advance the hands of this physiological clock by orthodontically treating the axial inclination of the incisors to an average angle, or to a correlation of different angles.
which are not true correlations? Yes, orthodontic treatment can
age this denture and can advance this "physiological clock" if
abnormal inclinations of the teeth are our treatment plan for an
individual. Orthodontic treatment may upset the stability of the
oral environment and thus indirectly produce compensatory
changes after the bands are removed.

The results of this investigation show that in one-half
of the cases studied, the incisors did not become more upright
with growth, and to depend upon growth to aid and to correct
abnormally procumbent incisors would be wishful but unintelligent
thinking. The convexity of the face does not always become
straighter during growth. One-third of the forty individuals
studied did not have a straighter profile due to growth. Here
again the orthodontist must realize that growth is not always
favorable and that if he perceives a good esthetic facial profile
as being a straight profile, then he should treat to these end
results and not depend upon too much of the "growth magic."

Of course, the orthodontist must realize that the
facial profile and the axial inclination of the teeth of the
female and the male are not alike. Because of this, his concept
should be that what is normal for the male is not necessarily
normal for the female. The female has a more procumbent denture
and a more convex profile than the male. Treatment planning
should consider this, but again it is best to remember that the
treatment should be such that the orthodontist treat to the optimal for the individual.

This investigation does hint at a most favorable time of treatment for the individual. Many orthodontists feel that early treatment (mixed dentition) invites relapse and fatigues the patient. Other orthodontists feel that the teeth move more, and faster, and that the patient co-operates better during the earlier age periods (early mixed dentition). The findings of this investigation would indicate that, because of the fluctuations, irregular patterns, and unstable positions of the bone and the teeth before the circumpuberal maximum height age-level, early treatment is contra-indicated. This does not mean that all kinds of malocclusions should be treated at a later stage than the mixed dentition stage. Some malocclusions require early treatment. If we desire a comparatively stable occlusion, then it would appear from the growth interpretations of this investigation that individuals should usually be treated in the permanent dentition stages with treatment and retention through the growth stages, and especially past the circumpuberal maximum height age-level. If individuals are treated at any earlier age-level than advocated, then it is the responsibility of the orthodontist to retain and observe the individual through the growth stages. There can be no doubt that problems of retention and relapse are often caused by the changes of the oral environment.
because of growth. Because females stop growing at an earlier age-level than males, it would appear that growth has stopped upsetting the equilibrium of the denture at an earlier age-level for females.

This indicates that the orthodontic treatment for females can be initiated at an earlier age than for males, and that retention is not necessary at as late an age-level for females.

Growth can be useful or harmful to the orthodontist. It is a matter of corroborating treatment at the optimum time age-level of the individual so that growth aids in the treatment. The harmful effects of growth are prevented during retention by careful observations and with a well-planned retention stage.
CHAPTER V

SUMMARY

This investigation utilized serial cephalometric roentgenograms to study growth of forty individuals, starting when they were five years old and ending when they were eighteen years old. The individuals studied consisted of two types of occlusions: Angle's Class I occlusion and those within the range of having a normal occlusion. The roentgenographic records were obtained from the Child Research Council in Denver, Colorado. The error for making the tracings and measuring the dimensions were calculated and recorded. The findings were divided into three parts and these three parts were based on three different methods of handling the data. The first part of the findings investigated and studied growth by characterizing the total group, the occlusions, and the sexes by utilizing means and the 99 per cent confidence limit. Realization that means were not truly representative of any individual directed the second part of the investigation toward individual trends. These trends revealed more knowledge than the mean values, but did not tell us about the total individual. The third part of the findings dealt with the study of individuals as an entity. By the integration of all
of the linear and angular dimensions of one individual and by studying the interrelation and the correlation of these different linear and angular dimensions, it was felt that growth patterns, irregularities, and growth fluctuations could be explained.

There are many different methods of studying dental and skeletal facial growth. If these methods are applied and used wisely, they can answer many questions which are as yet unanswered. No one single method can give us all of the answers concerning growth. Cephalometric roentgenography can be used to tell us how much growth there was; it may show us relative changes because of growth; but it does not tell us what kind of growth was and is taking place.

A basic question is "Does an individual follow a pattern which is established at an early age?" The answer is probably "Yes and No." Yes, the individual has a tendency to follow a basic pattern. This means that an individual who has small dimensions at five years of age tends to have comparatively small dimensions at eighteen years of age. The answer must also be No, the individual does not follow a basic growth pattern established at an early age, because growth accelerations do occur which produce changes in the proportionate size of bones and changes in the spatial relations of different bones. This is the reason why an individual not only grows, but he also grows up.
The first part of the investigation is concerned with means. The means are used only to characterize the individuals within the population studied. Means are not to be interpreted as normal values for an individual, because what is a normal value for one individual, could be abnormal for another individual.

Most dimensions for an individual will vary and few, if any, will be exactly the mean value. All structures appear to have a definite variation in size, form, and growth "tempo." Variation of one, two, three, or more dimensions does not necessarily upset the anatomical balance necessary for a good esthetic dental and skeletal facial profile. Causes of individual variation are hereditary, congenital, and environmental. Some variations are unperceivable; these are called discrete variations by the geneticists. Visible variations may result from the additive effect and interaction of discrete variations. There is something about an individual's pattern of growth which makes him an individual. Growth for an individual has the attribute of being variable and unpredictable. It is factual that to produce anatomical balance of structures the dynamics of biological variability must balance the teeth, the muscles, and the bone within a single environment. After means had been investigated it was recognized that variations were often in opposite and equal directions. It became obvious when the individual was studied that all angular
dimensions could increase, decrease, or remain stable during growth. This seemed to limit any value that was placed on the group means and the subgroup means. It was recognized that growth accelerations of facial skeletal structures are related to the circumpuberal maximum height age-level. We were using chronological age and not biological age to determine our mean values. This meant that grouped together were the same age-levels of different individuals whose growth acceleration rates were not synchronous. This would offset much of the value of means for groups and subgroups. The fact that Class I malocclusions are of different degrees of severity might indicate that we are dealing with a heterogeneous conglomerate of skeletal patterns. With this knowledge, it was decided not to apply statistical significant tests and to limit ourselves to mean values and individual trends.

In order to find key traits of an individual it was necessary to integrate and correlate the odontological and the osteological patterns of that individual. From such integration it was immediately concluded that the avenues of growth differed for individuals and that the malleability of the dental and facial skeletal profile was constantly changing.

Theory is often what we have not learned to put into clinical practice, and growth must fall into the category of mostly theory when the application of growth is made to clinical
orthodontics. It appears that the three dental angles and the angle of facial convexity may increase, decrease, or remain stable during growth. These angles can in no way be correlated to each other. The author feels that the irregular patterns, the fluctuations from one year to the next, and the differences in dental and skeletal facial profiles, can be explained by differential growth rates and by the differential time of growth of different bones. Females and males seem to show significantly different growth patterns. The normal occlusion individuals and the Class I occlusion individuals have significant trend differences. For most linear and angular dimensions, there appears to be major fluctuations before the circumpuberal maximum height age-level, a growth acceleration parasubcircumpuberal age-level, and then there is usually a spontaneous recovery so that the structures begin to fit into a more stable face. Each individual is a unique dental and skeletal facial complex, and for an orthodontist to treat an individual he must know that individual by using all diagnostic means available.
CHAPTER VI

CONCLUSIONS

1. Nine means have been established and recorded for each dimension at each of the age-levels studied. These nine means characterize the sample into total group means, female and male group means, Class I and normal occlusion group means, and the four subgroup means composed of females with Class I occlusion, males with Class I occlusion, females with normal occlusion, and males with normal occlusion.

2. The angle of facial convexity may increase, decrease, or remain stable during growth.

A. What is a normal facial profile for males is not a normal facial profile for females.

B. The female group and the Class I occlusion group have a more convex facial profile than the male group and the normal occlusion group.

C. The angle of facial convexity has an irregular pattern from one age-level to the next age-level, because of the differential rate and the differential time of the growth of the bones involved.

D. The mandible tends to become more prognathic (due to condylar growth and appositional growth at pogenion) in
relation to nasion, while the maxilla remains comparatively stable, grows at a slower rate than the mandible, or grows at a faster rate than the mandible.

3. The mandibular incisor angle (I to GoGn) may decrease, increase or remain stable during growth.

A. There is no correlation between the mandibular incisor angle and the angle formed by the intersection of the sella-nasion plane with the gonion-gnathion plane (SN-GoGn).

B. The posterior positioning of the mandibular incisors on the supporting bone during growth is partially caused by the failure of alveolar bone to grow forward as fast as the supporting bone, and partially due to an illusion created by the apposition of bone at pogonion.

4. The maxillary incisor angle (I to SN) may increase, decrease, or remain stable during growth.

5. The interincisal angle (I to I) may increase, decrease, or remain stable during growth.

6. There is no correlation between the three dental angles studied. What one of these angles is doing at any specific age-level does not determine what the other two angles are doing. They may increase, decrease, or remain stable.

7. The three dental angles show irregular fluctuation changes from one age-level to the next age-level, and these appear to be
compensatory changes, which are caused by growth changes up-
setting the equilibrium of the oral environment of the teeth.

8. The three dental angles for female means and for Class I means
represent a more dental procumbent denture than the male group
and the normal occlusion group do.

9. The linear dimensions, nasion to the maxillary first molar,
may increase, decrease, or remain stable during growth.

10. The linear dimension, sella to the maxillary first molar,
increases during growth and is due to a combination of forward
growth of the maxilla and mesial drift of the molar.

11. The linear dimension, sella-nasion, usually shows a constant
slow growth increase from the 5-9 age-level until the circum-
puberal age-level, then a growth acceleration at that age-
level, followed by a slow gradual deceleration.

A. The sella-nasion plane has a growth acceleration which
is a combination of a skeletal neural growth pattern.

B. Males have an absolute length for this dimension which
is greater than females.

12. Individuals have growth accelerations which change the pro-
portions of the dental and skeletal facial profile, but the
individual does have a tendency to follow his own basic
pattern.

13. Females have an increment rate of growth that is less than
males and their growth decelerates and terminates at an
earlier age-level than males; therefore they become comparatively stable for angular and linear dimensions at an earlier age-level than males.

14. The "Ja" plane has a total absolute length and a yearly increment rate of growth which is greater for males than females. There appears to be a wide range of variation for this linear dimension.

15. After the paracircumpuber al growth acceleration all linear and angular dimensions appear to become comparatively stable and the structures making up the facial complex begin to fit into a more stable face.

16. Growth trends and avenues of growth were different for males and females.
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APPENDIX
# SSELLA TO -1

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APPROVAL SHEET

The thesis submitted by Dr. Donald C. Hilgers has been read and approved by four members of the Departments of Anatomy and Oral Anatomy.

The final copies have been examined by the director of the thesis and the signature which appears below verifies the fact that any necessary changes have been incorporated, and that the thesis is now given final approval with reference to content, form, and mechanical accuracy.

The thesis is therefore accepted in partial fulfillment of the requirements for the Degree of Master of Science.

5-11-61

DATE

Signature of Adviser