CEPHALOMETRIC ANALYSIS OF THE TRISOMY 21 SYNDROME (DOWN'S SYNDROME)

Abstract of a Thesis

Presented to

The Faculty of Graduate Studies and Research

University of Manitoba

In Partial Fulfillment

of the Requirement for the Degree

Master of Science

---

by

Fredrick Allen Ghiz

Department of Dental Science

September, 1968

CEPHALOMETRIC ANALYSIS OF THE TRISOMY 21 SYNDROME (DOWN'S SYNDROME)

by

Fredrick Allen Ghiz

ABSTRACT

Past investigations have indicated that there are marked differences in the craniofacial skeletal pattern of individuals with Down's syndrome as compared with normal individuals. It has also been generally accepted that individuals with Down's syndrome, determined by clinical diagnosis, have a particular phenotype. This study was undertaken to evaluate the craniofacial complex in individuals with the Trisomy 21 syndrome and to determine whether there are specific phenotypes for various age groups.

The sample consisted of a Trisomy 21 group and a control or normal group. Each group consisted of 121 individuals varying in age from 4 to 48 years with a relatively equal number of males and females. Each individual in the Trisomy 21 group had a cytogenetic analysis performed by a cytogeneticist and was found to possess an extra chromosome number 21.

Lateral and postercanterior cephalometric radiographs were taken of both groups utilizing the Broadbent-Bolton cephalometer and a portable cephalometer. A cephalometric analysis consisting of both angular and linear measurements was used to evaluate and compare the two groups. An analysis of variance was performed on the data to determine the significance of the results.

The significant findings were as follows:

1. The overall size of the craniofacial complex of the Trisomy 21 syndrome was definitely smaller than that of the control group.
2. The growth retardation that was exhibited in the Trisomy 21 group was present at the age of four. However, growth from this age to the adult appeared to be occurring at equal rates among the two groups.
3. Differences existed in the craniofacial components between the sexes in the Trisomy 21 syndrome, but these differences were similar to the differences in the control group.
4. The cranial base angle, NSBa, of the Trisomy 21 group continued to become more obtuse with increasing age which resulted in a flexion of the posterior cranial base.

5. The anterior and posterior facial height as well as the facial depths were significantly smaller in the Trisomy 21 syndrome.
6. The characteristic mandibular prognathic appearance of individuals with Trisomy 21 syndrome appeared to be due to a mandibular basilar prognathism in conjunction with a normal positioning of the maxilla.
7. The prominence of the frontal bone in the adult individual with the Trisomy 21 syndrome may have an influence in counteracting the mandibular protrusion to help bring about a normal profile.

ACKNOWLEDGEMENTS

To my advisor, Dr. J. F. Cleall, Department of Orthodontics, University of Manitoba, I wish to express sincere appreciation for his generous contribution of time in guidance, instruction, and supervision of this research work. Also my sincere thanks to Dr. L. Melosky, Department of Orthodontics, University of Manitoba, for his helpful suggestions and encouragement.

I wish to acknowledge Dr. I. Uchida, Director of Genetics, Winnipeg Children's Hospital, for the cytogenetic work and for her generosity in allowing the use of her records in obtaining the pure Trisomy 21 sample.

I would like to thank the staff of the St. Amant Ward of the St. Boniface Sanitorium and the staff of the Manitoba School for the Mentally Retarded for their interest and assistance in working with the Trisomy 21 individuals.

Various individuals have assisted me in obtaining the records of the two sample groups and I would especially like to express my sincere appreciation to the following: Dr. K. Braithwaite, Dr. W. Frostad, Miss C. Brown, Miss D. Rohr, Mrs. J. VanDale, and Miss B. Walker.

I wish to thank Mr. F. Chebib for his statistical assistance and evaluation of the raw data and to Mr. A. Domokos, Mr. A. Scott and Mr. B. Casper for the photography and art work.

To the Department of National Health and Welfare I am grateful for the Federal Health Research Grant No. 606-7-147 that was awarded for the support of this research project.

Finally, my sincere appreciation goes to my wife for her kind consideration and understanding.

TABLE OF CONTENTS

LIST OF TABLES

TABLE PAGE

LIST OF FIGURES

FIGURE PAGE

CHAPTER I

INTRODUCTION

The growth and development of the cranium and the face is a complex process because this area is associated with many important and vital systems of the body. Variations exist from one individual to another so that it is difficult to ascertain exactly what normal growth and development of the craniofacial area is. If a better understanding of the abnormal can be acquired, then a more precise definition of what is normal can be established.

There exist certain abnormal conditions that exhibit marked changes in growth and development. One such condition is the Trisomy 21 syndrome or Down's syndrome. Individuals with this condition have faces which are oriental in appearance. They also have an abnormal skull morphology and possess disturbances in the bones and joints.

A review of the literature shows that a few studies have been done on individuals with Down's syndrome using roentgenographic cephalometry. This is an excellent method for studying the face and cranium of a living human being because it allows for a comparison and analysis of one film with another due to the standardization of each radiogram. These studies have helped to clarify questionable patterns, but there is still much to learn about the growth of the cranial base and the growth of the maxilla and mandible.

Moreover, these studies involved a sample of Down's syndrome determined only by a clinical diagnosis and these studies do not mention cytogenetic determination of any chromosomal aberration.

The Down's syndrome sample used in this study was accumulated by Dr. Irene Uchida and her staff of the Genetics Department of the Winnipeg Children's Hospital. This Department has on file one of the largest collections of Down's syndrome in North America. They have performed a cytogenetic analysis on the chromosomes of all the individuals in the collection and have recorded the various chromosomal aberrations that existed. The work of this Department has given this study a large sample consisting only of proven Trisomy 21 individuals. No translocations or mosaics are included.

With the use of the roentgenographic cephalometric technique to study this sample, this project was undertaken to establish the phenotype of individuals with this specific karyotype and to supply additional knowledge for a better understanding of the abnormal and normal growth and development of the craniofacial complex.

The following points were considered while comparing the Trisomy 21 sample with the normal or control sample:-

1. To compare and analyse the craniofacial morphology of the various age ranges of the Trisomy 21 group with the same age ranges of the control group.

2. To compare and analyse the craniofacial morphology of one age range of the Trisomy 21 group with other age ranges of the Trisomy 21 group.
3. To analyse the growth of the cranial base and its relationship to the morphology of the face.
4. To study the growth of the maxilla and mandible and determine the cause of mandibular protrusion.
5. To determine the reasons why the facial appearance of many adult individuals with the Trisomy 21 syndrome becomes less characteristic of their younger appearance.

CHAPTER II

REVIEW OF THE LITERATURE

I. DOWN'S SYNDROME

History

Down's syndrome was first described by J. Langdon Down in 1866 from his investigations at the Eastwood Asylum in England. Although some of his observations were inaccurate and his theory of etiology erroneous, he correctly described the more characteristic abnormalities of the condition. Since this time, the inappropriate term "mongolism" has been used to denote Down's syndrome because of its resemblance to the characteristics of the mongolian race. The connotation of the word "mongolism" will be avoided in this review and this condition will be referred to as Down's syndrome or Trisomy 21 syndrome except where other investigators are referred to or quoted.

General Considerations

The syndrome is characterized by physical and mental retardation with the physical variations varying from slight anomalies to gross malformations. Fraser and Mitchell in 1876 called attention to brachycephalia, Shuttleworth in 1886 classified this abnormality as one of the "unfinished children", Jones in 1890 reported characteristics of the mouth, Oliver in 1891 reported on characteristics of the

eyes, Smith in 1896 reported on the hands, Garrod in 1898 called attention to the frequency of congenital heart disease and Thompson in 1907 reported on the tongue.

Modifications such as Kalmuch idiocy, mongolian idiocy, unfinished children, mongolian deformity, congenital acromicria and general fetal dysplasia constituted most of the designations given to this condition in which resemblance to the mongolian race was only superficial and where mental deficiency ranged from feeble-mindedness to deep idiocy.

There is considerable variance between one Down's syndrome individual and another and consequently, investigators, in order to diagnose the condition, have selected what they regard as cardinal symptoms. Oster in 1933 stated that: "Mongolism is a complex of signs comprising several physical abnormalities, chiefly developmental defects, in association with mental deficiency". He investigated 526 individuals with Down's syndrome in Denmark and stated ten cardinal signs: (1) four-finger line; (2) short, crooked fifth finger; (3) short, broad hands; (4) hyper-flexibility; (5) oblique palpebral fissure; (6) epicanthus; (7) furrowed tongue; (8) irregular and abnormal teeth; (9) high narrow palate; and (10) flat occiput (brachycephalia). Oster states that "Taken as a whole we may say that mental defectives with four or more cardinal signs, in all probability,

are mongols".

Penrose in 1961 listed seven diagnostic features: (1) intelligence quotient between 15-29 inclusive; (2) cephalic index of 0.83 or higher; (3) epicanthic fold on either eye; (4) fissured tongue; (5) conjunctivitis at time of examination; (6) transverse palmar line on either hand; and (7) one crease only on minimal digit of either hand. He said "Any defective with four or more of these characters is almost certainly a mongol". He did not suggest that these characters were necessarily the best to select and he stated that others have served the same purpose.

Gustavson (1964) in a survey of over 100 cases used Oster's criteria and also reported other signs, including Brushfield spots, congenital heart disease and a gap between the first and second toes. He found an average of 6.7 of Oster's cardinal signs per patient and 12.9 of the cardinal signs he used himself.

Gibson and his colleagues in 1964 examined the interrelation between 13 common entities of Down's syndrome. They found few significant connections and felt that each individual must be diagnosed independently. The syndrome could thus be determined by observing the number of microsymptoms present, regardless of what the particular symptoms were.

Older individuals with Down's syndrome are more difficult to recognize. Richards in 1965 stated several of the characteristics that resulted with age. The slant of the palpebral fissures was less, if at all noticeable; the head was not unusually round; the complexion was not ruddy; and the chin appeared to be almost pointed, possibly due to sunken cheeks resulting from loss of teeth.

Incidence

Penrose in 1963 estimated the incidence of Down's syndrome as 1.6 to 2.5 per thousand live births. Breg in 1962 found similar incidence in that it occurred about once in every 600 live births and that it accounted for approximately 10% of all institutionalized mentally retarded patients. Penrose also found the incidence of Down's syndrome to increase with maternal age, and he stated that a sharp increase was noted after 35 years of age. In a previous study, Penrose (1939) found no significant factor in paternal age.

Gustavson (1964) found the incidence of premature births to be twice the normal rate, or about 20% of the Down's syndrome births. McIntire, et al. in 1965 reported that 48% of these mothers reported complications with bleeding, spotting, toxemia and intrauterine disease during their pregnancies. They reported that 80% of these mothers

had other normal pregnancies while 20% had previous miscarriages or abortions. All had normal labour during delivery of the child with Down's syndrome. They also stated that 7% of these deliveries were breech births compared to 3% of the normal population.

Mortality

Record and Smith (1955) in a study of mortality estimated that nearly 40% of the individuals with Down's syndrome were dead by the end of the first month of life. They found that almost 10% more failed to survive the first year and, only 40% of the original total were alive after five years of age. They found that females showed a higher mortality rate in infancy and early childhood.

They stated that death among the Down's syndrome individuals was chiefly due to infection of the respiratory tract and less frequently to congenital malformations and gastrointestinal infections.

Etiology (Non-Genetic)

The etiology of Down's syndrome has been a subject of discussion since its first description. The underlying cause is still unknown though many theories have been proposed.

Warkany in 1960 reported that there have been 39 theories proposed in the past to explain the etiology of

Down's syndrome. He reviewed these theories and categorized them into four groups: (1) reversion to a primitive ancestral type;(2) a genetic origin involving one or more genes, mutations, injury to germ cells, or interaction of the embryonic genetic constitution with uterine conditions; (3) disturbances in the environment, including accidents during gestation, disease states, aging of the mother, or aging of the ovum; (4) changes within the child, especially endocrine deficiencies.

Genetics

Initial discoveries. Wardenburgh in 1932 was the first to suggest that Down's syndrome might be associated with an extra chromosome, but for several years this theory was not accepted due to the lack of substantial evidence.

Lejeune, et al. in 1959 were the first to report the findings of 47 chromosomes instead of the normal 46 in patients with Down's syndrome. Lejeune felt that the extra chromosome was number 21. Jacobs, et al. later in 1959, reported the same findings in six individuals with Down's syndrome. Ford, et al. and Book in two separate investigations in 1959 also had similar results and were able to identify the extra chromosome as a small acrocentric.

Polani, et al. (1960) and Fraccaro, et al. (1960) both found such individuals with a normal number of 46 chromosomes but with an extra chromosome translocated to another acrocentric chromosome. This results in a normal chromosomal number but with extra chromosomal material.

Karyotypes

Richards (1964) stated that various karyotypes of Down's syndrome have been reported and he listed them as the following:

21 Trisomy

13 - 15/21 Translocation (D/G)

21/21 Translocation (G/G)

21/22 Translocation (G/G)

2/21 Translocation (A/G)

21 Trisomy following pericentric inversion

21 Isochromosome (possible)

Extra partially deleted number 21

Various types of mosaicism

Double or multiple aneuploidy

(e.g. Trisomy 21 and Klinfelter's, Turner's, Tripo-X or Trisomy D group in the same subject).

As a result of these past investigations, three main types of Down's syndrome were established - Trisomy 21, Mosaics and Translocations.

Trisomy 21 - The normal human somatic cell contains 22 pairs of autosomes and one pair of sex chromosomes. When an additional autosome is present so that there are three matched autosomes, the individual has a trisomy of that chromosome. The trisomy involves either chromosome 21 or 22 in Down's syndrome, but most authorities agree with Lejeune (1959) and refer to this condition as the Trisomy 21 syndrome.

According to Smith's interpretation (1964), the production of trisomics is the result of a type of meiotic malfunction which results in the failure of chromosomes to segregate properly at anaphase. The result of this failure, or non-disjunction, during meiosis is that both members of a particular chromosome pair are included in one gamete, leaving no representative of this pair in the other gamete. Thus n +1 and n - 1 gametes are formed which upon fertilization yield 2n + 1 and 2n - 1 zygotes (trisomics and monosomics). The monosomic zygote, when it involves an autosome, is apparently not capable of continued intrauterine development. The trisomic zygote might continue to develop depending on which autosome is in triplicate and how severe the effect is upon the developing embryo and fetus.

Smith added that trisomy can also arise after the

formation of a genetically balanced zygote. Faulty distribution of an autosome during the first cleavage division could lead to one daughter cell being monosomic and the other trisomic. The trisomic cell would likely survive and develop into an individual.

Mosaic - If this same malfunctioning occurs such later in cleavage then three cell types would result - a normal number of chromosomes or 2n, a greater number or 2n + 1 and a smaller number or 2n - 1. The monosomic cells would not develop, but the others, in all probability, would develop to result in the second type of Down's syndrome or mosaicism. The mosaic type of Down's syndrome, therefore, has some somatic cells as Trisomy 21 while others are normal.

Translocation - The third type, or translocation, is characterized by the fact that the extra chromosome is not free in the cell, but is attached to another chromosome. Penrose (1961) stated that there was a loss of a small portion of both chromosomes, followed by the translocating of the two chromosomes to each other. The translocation usually involves either the 13 - 15 group or the 21 - 22 group with the former being the most common. Carter, et al. in 1960 found the translocation to the 13 - 15 group in families with more than one case

of Down's syndrome. They stated that it was important to note that the translocation chromosome was carried by the normal parents and may pass through several generations.

Karyotype-phenotype relationship. The various karyotype that were described earlier result in a change in the phenotype of the individual. Many different theories have been mentioned in regard to the reasons why the defect in the phenotype is produced. Brandt, et al. in 1963 felt that the extra chromosome creates a surplus of one or more enzymes produced by the genes located on the extra chromosomes. He suggested the enzyme is galactose-1-phosphate uridyl transferase. This enzyme will disturb cell differentiation, possibly in those cells where the blocking of an enzyme synthesis is necessary in order for normal morphogenesis to take place.

Schmid (1963) felt that the extra chromosome was late in the DNA synthesis and possibly may go through some form of lyonization. Hall (1964) felt that the extra chromosome was either completely or partly inactive but still disturbed cell division and affected normal morphogenesis in some unspecified way.

Only one major work is found in the literature involving a correlation between phenotype and karyotype.

Gustavson in 1964 stated that one could not tell the phenotypical difference between the Trisomy 21 types of Down's syndrome and the translocation type. He concluded this from results involving mental retardation plus four or more of Oster's ten cardinal signs. It is important to note, however, that he did not conclude this from any skeletal malformations.

II. CEPHALOMETRIC ROENTGENOGRAPHY

History

Broadbent in the United States and Hofrath in Germany independently introduced cephalometric roentgenography to orthodontics in 1931 by utilizing a cephalometer and a standardized roentgenographic technique. This work made it possible to study growth and development of the craniofacial complex on a living person instead of skulls, which had been the only means of study to that date. This standardized technique would allow for longitudinal as well as cross-sectional studies.

Since that date many men, such as Griffen and Hoffman (1936), Higley (1936), Margolis (1940) and Weingart (1948), have modified the technique, but basically the original technique of Broadbent is used today.

Definition and Analysis

Salzman describes cephalometrics as a means of measuring, describing and appraising the morphological configuration and growth changes in the skull by ascertaining the dimensions of lines, angles and planes between anthropometric landmarks established by physical anthropologists and between points selected by orthodontists.

Salzman also points out that various analyses of lines, planes and angles have been devised by Bjork, Sassouni, Downs, Steiner, Margolis, Moorrees, Koski and Ricketts. Important contributions by Wylie and Riedel have also helped to establish a means of analysing the cephalometric radiograms. With these various analyses many studies have been done to evaluate craniofacial growth and development.

Errors

Various investigators have studied, in addition to growth studies, the inherent errors in cephalometric films and tracings. Adams (1940) pointed out the importance of a painstaking technique so that accurate measurements may be obtained.

The problem of magnification and its correction has been reported by many investigators. Adams (1940) and Thurow (1951) suggested the use of a metal gauge on the

midsagittal plane, while Broadbent (1931) and Hofrath (1931) utilized maximum anode-object distance.

Hallett in 1959 pointed out the errors due to movement of the patient, or the tube, and the loss of definition. He suggested methods of overcoming these problems by using a stabilized cephalostat, well constructed and solid mountings of the X-ray machine and the use of intensifying screens within the cassette.

Broadway, et al. in 1962 studied errors involved with cephalometric tracings and found that greater accuracy occurred when a single individual duplicated tracings of a subject. They also stated that one should use discernible points of measurements and that angles involving the teeth were the most inaccurate.

III. NORMAL GROWTH AND DEVELOPMENT

General Craniofacial Growth

Investigation of normal growth and development of the craniofacial complex has been greatly advanced by the use of roentgenographic cephalometry. It began in 1937 when Broadbent published a composite pattern of facial growth establishing the facial pattern at the completion of the eruption of the permanent dentition with the exception of third molars.

Brodie in 1941, using Broadbent's records, studied the growth and development of the craniofacial complex from three months to eight years of age. He concluded that growth of this area occurred in gradual increments of consistent growth. Although his conclusions were based on mean trends, he still recognized individual variation. Brodie in 1946 established again the stability of the face but he stated that adjustments occurred within the teeth and alveolar process. Bjork in 1947 also pointed out the individual variations that exist in normal growth. Bjork (1955), using a cephalometric study aided by metallic implants, further showed the individual variations that existed in growth of the craniofacial complex.

Hellman (1935) showed the continuous increase in facial size without uniformity. He stated that, with growth, the face gradully drifted forward, thus changing its relation to the cranium.

Goldstein in 1936 established a pattern of facial growth whereby the length of the face grew more rapidly, followed by the face depth and the width grew the slowest. The lower portion of the face grew in depth more rapidly than that of the upper face. He also found spurts of growth to occur between 3 - 5 and 13 - 15 years of age.

Krogman in 1951 found interesting results in growth of the face in the three directions of height, breadth and

depth. He found that at birth, height was 40-45% of its final adult dimension, breadth was 55-60% and depth was 30-35%. Growth after birth occurred greatest in depth, second in breadth and least growth occurred in height.

Cranial Base

The cranial base results from cartilaginous growth involving the area of the ethmoid, sphenoid and occipital bones. Some studies included the frontal bone as part of the cranial base. Early studies by Schuller in 1918 and Keith and Campion in 1922 suggested that growth increase occurred at the sphenoccipital, sphenoethmoidal and frontal sutures.

Brodie, Jr. (1955) did a serial study of the cranial base between the ages of 3 and 20 and found that each part of the cranial base made constant growth contributions throughout the age period studied.

Brodie (1941) stated that the size proportion of the anterior and posterior cranial bases was established at three months and remained stable thereafter. Ortiz and Brodie in 1949 found the anterior cranial base longer at birth than the posterior cranial base.

Most researchers, such as Decoster (1952), Ford (1958), Scott (1954) (1958), Bjork (1955) and Sassouni

(1962), agreed that the sphenoethmoidal synchrondrosis closed early in life, and was usually complete by the seventh year. The anterior cranial base was, therefore, stable after this time. However, Bjork (1955) and Sassouni (1958) both stated that although the spheno-ethmoidal synchrondrosis closed early in life, the anterior cranial base was elongated ventrally by frontal apposition at the nasion area.

Sassouni (1962) found the sphenoccipital synchond-rosis to be relatively horizontal and its growth resulted in a continuous vertical growth at the clivus with some remodeling by appositional growth. He found this synchon-drosis to be active until adolescence.

Koni in 1964 studied 152 males and 162 females with midsagittal laminagrams. Laminagrams are radiographs resulting from a special technique to show, in detail, images of structures lying in a predetermined plane of tissue, while blurring or eliminating detail in images of structures in other planes. He found the sphenooccipital junction to show a consistency in initial fusion at the skeletal age of 10.1/2 years in females (± 6 months) and 12.1/2 in males (± 6 months).

Irwin in 1960 found through a radiological study that the sphenooccipital synchondrosis began closure

superiorly and moved inferiorly. He first noticed closure superiorly at the age of 11 and closure was generally initiated by 13 years of age. This closure, according to his findings, continued until the age of 18 and after this age he found solid closure.

Sassouni in 1958 stated that since the spheno-occipital synchondrosis was active until adolescence, the posterior cranial base would change in either angulation or length and both might alter the relationship between the lower face and midface.

Bjork in 1955 studied longitudinal growth changes in the cranial base and concluded that its shape remained stable with age. He observed a mandibular position influenced by the rotation of the cranial base and pointed out that individual variation showed changes in both directions but that the overall means were constant.

Ricketts (1955) agreed with Bjork (1955), concluding that an obtuse cranial base gave a more posterior positioning of the temporamandibular joint, while an acute cranial base gave a downward movement of the temporomandibular joint.

Senneville, et al. (1950) studied the cranial base angle from three months intrauterine to birth and found it to remain constant while Moss, in 1955, also found

the cranial base angle to remain constant at different age levels.

Scott (1958) found that most of the bending of the cranial base occurred during fetal life and it probably did so at the postsphenoid and presphenoid synchondrosis. The changes that occurred in later life were due to changes in nasion and changes in position of the spheno-occipital synchondrosis.

Nasomaxillary Complex

Brodie in 1941 concluded that the horizontal planes of the face, e.g. the palatal, occlusal and mandibular, grow in a parallel, orderly way. While working with Ortiz in 1949, he found that at birth the face began to grow downward and forward at a continuously smooth rate and the growth gradually diminished after adulthood.

Massler and Schour in 1944 used an alizarine red staining technique to study rats and monkeys and concluded that the growth of the face was in a downward and forward direction due to growth at the oblique sutures and the condylar heads. Moore (1946) used a vital staining technique for studying growth in monkey skulls and concluded that the sutures were the primary agents of growth.

Weinman and Sicher in 1947 also felt that the oblique position of the facial sutures brought about growth in a

downward and forward position in relation to the cranial base.

Scott (1954) found that growth at the facial sutures was secondary to a process of separation at the sutures which was produced by the proliferation of cartilage and expansion of such organs as the brain and orbital contents. He added that the active growth centre in the cartilage of the nasal septum was the pacemaker for early growth of the nasomaxillary area.

Scott in 1958 stated that the maxilla was closely related to the growth of the anterior cranial base. The sutures in the nasomaxillary area produced growth in a downward and forward direction and the growth was regulated by growth at the nasal septum during fetal life and early childhood. He found the growth of the maxilla to be in two steps. The first step was the early phase, in which, during fetal life and childhood to age seven, growth of the anterior cranial base pushed the facial bones downward and forward. The second step occurred after the age of seven, when facial sutures had ceased to cause growth and growth was due to apposition in conjunction with internal resorption to allow for an increase in size of the nasal cavity, the air sinuses and the oral cavity.

Selman and Sarnot in 1955 found that extirpation

of the frontal nasal suture in the rabbit had no effect on the longitudinal growth of the snout, and Moss in 1960, found that extirpation of several neural cranial sutures in the rat did not affect the length and breadth of the calvarium. Moss concluded that the shape of the calvarial bones was not predetermined by the location of the sutures.

A study of facial height and depth in 1946 by Brodie showed a high degree of constancy in nasal height, and he found nasal height (nasion to the anterior nasal spine) to be 43% of the total face height (nasion to gnathion). Wylie in 1947 also found 43% as the mean for a similar relationship.

Cobin in 1955 studied a group of males and females between the ages of 8 and 16 and found that the midfacial depth increased slightly in comparison to lower face depth and he found the facial height to increase more than the facial depth.

Mandible

Bjork (1955) found that rotation of the cranial base would alter the temporal bone, which in turn would move the glenoid fossa either downward and forward or backward and upward and, therefore, after mandibular position as well as maxillary position.

Sassouni (1958) found a correlation between the activity of the sphenooccipital synchondrosis and that of the head of the condyle. He observed concomitance between a long ramus and a long clivus and a square gonian and square cranial base angle. He suggested that both areas could be under the influence of some endocrine or genetic factor.

Sicher (1957) studied cartilage structures and found a significant difference between condylar cartilage and cranial base synchondrosis. A thick layer of connective tissue covered the condylar cartilage causing growth by apposition on the external surface of the ascending ramus of the mandible, while the synchondrosis grew by interstitial proliferation.

Most investigators, such as Bjork (1955), Scott (1958) and Sassouni (1958), stated that the anteroposterior and vertical growth of the mandible occurred primarily at the condyles. As the condylar cartilage grew, it was replaced by bone pushing the mandible downward and forward. They also mentioned that the ramus increased in width by appositional growth on its posterior border while resorption took place on the anterior border.

Sarnot and Engel (1951) did condylectomies on monkeys and found major interference with mandibular growth.

Removal of one resulted in an asymetrical deformity and removal of both caused a symetrical arrest of growth.

Bjork (1947) found that prognatism occurred in both jaws with the mandible or lower face showing the greatest prognathic change. This resulted in bringing about a straighter profile. He found that the gonial angle remained constant and that the greatest change occurred in the length of the ramus where it increased twice as much as the body of the mandible. Other researchers, such as Brodie (1941), Lande (1952), Williams (1953) and Nanda (1955), also showed changes toward a forward positioning of the chin while the midface showed an earlier arrest in growth.

Brodie in 1941 showed that the gonial angle did not change from three months of life onward. He felt that methods of measuring in the past accounted for the variations and changes that were seen. Later, Adams (1948) found no correlation between chronological age and the gonial angle.

Senneville, et al. found a great variance in the gonial angle from three months intrauterine to birth. During this period, they also noted that the body of the mandible grew proportionately more than the ramus of the mandible.

Jensen and Palling in 1954 showed that the gonial

angle could vary from 100° to 148° and they found a proportional association between facial height and ramus height. The angle was more obtuse with a greater facial height and less obtuse with a shorter facial height.

IV. GROWTH AND DEVELOPMENT IN DOWN'S SYNDROME

Institution Versus Non-Institution Environment

Many investigators have described growth and development of Down's syndrome from various types of studies. These studies have involved both the institutionalized and the home-reared individual. Stedman and Eichorn did a study in 1964 to determine if these two environments resulted in changes in the mental, social, motor and physical development. The home-reared group were significantly superior in mental test scores and social quotients, but no statistically significant differences in motor performance were found. In their study of physical development, they used 14 anthropometric measurements and found that only three; the leg length, leg width and calf circumference, were significantly larger in the home-reared.

Early Non-Cephalometric Roentgenographic Studies

Before the advent of cephalometric studies, many men investigated Down's syndrome. Muir in 1903, in his analysis of 26 cases, found that the occipito-frontal circumference was always diminished the same amount for boys and girls. He found the head to be flat and often depressed as a whole.

Timme in 1921 reported on the peculiar change of the anterior portion of the pituitary fossa. This consisted of an anterior excavation under the anterior clinoid process, communicating directly with the anterior portion of the fossa itself.

Cliff in 1922, in his roentgenographic study, found this same depression under the anterior clinoid process. He stated that the main departure from normal was a generalized delay of bony development. The cranium was small and the cranial bones uniformly thin. He mentioned that the suture lines were frequently separated and in many cases irregular. The nose and maxilla were also poorly developed. However, he found the size and shape of the sella turcia to be about the same as the normal.

Talbot in 1924 studied untreated "mongolian idiots", ranging in age from four months to ten years, by measuring the circumference of the head over the occiput and around

the frontal bones. He found a characteristic flattening of the posterior skull with consequent shortening of the anterio-posterior diameter.

Later Non-Cephalometric Roentgenographic Studies

Benda has done a great deal of work in evaluating the physical development of Down's syndrome. From studies conducted in 1940, 1941, 1956 and 1960, Benda observed growth disorders and abnormalities of the skull and found that the facial bones of the skull deviated from the normal in their proportions. He further stated that the body of the sphenoid bone did not form the normal angulation. It was either in an upright position or a slightly backward position. The cribiform plate was shorter and higher than normal and nasion was retracted. He found the posterior cranial base to have a smaller clivus, smaller frontal and sphenoid sinuses, and the frontal sinus was often absent.

Reporting on the sutures, he found them to remain permanently separated and the fontanelle closure was always delayed, whereas the metopic suture was always present.

There was a growth failure of the maxilla and the nasal portion of the face. He found the proportion between the forehead and the face was still fetal and the

deficiency of development of the maxilla placed the lower margin of the orbit near the alveolar crest. The distance from nasal spine to prosthion was as short as in a normal newborn. He found the body of the mandible to be underdeveloped and mandibular angulation was flat and definitely fetal in shape.

Ingalls (1947) considered the cranium of individuals with Down's syndrome to be brachycephalic with moderate microcephalia. He also stated that the basilar bones, nasal bones and the maxilla all showed some type of dwarfism.

Gosman (1951) studied the facial development in Down's syndrome of 22 individuals. Using anthropometric measurements, he showed underdevelopment of a rather severe nature. In some dimensions it was more noticeable than in others. Total face height was considerably smaller than normal and face depth shorter than normal. Ramus height was comparatively developed, but the length of the body of the mandible was smaller than normal. He suggested that the facial changes in Down's syndrome after 16 - 18 years of age were limited to progressive mandibular prognathism due to tongue size and habit.

Spittzer and Robinson in 1955 in a radiographic examination of 28 individuals with Down's syndrome found

that both frontal sinuses were absent in 93% of the cases and that the maxilla and mandible were both underdeveloped. The body of the mandible lacked vertical height, the mandibular angle was obtuse and the ascending rami were short. Triebsch in 1958, studying Down's syndrome in regard to age, reported that there was a marked reduction of the anterior cranial base. In addition to brachycephaly, he found more disturbance in the growth of the height of the nasomaxillary area than in the growth of its width.

Spittzer, Rabinovitch and Wybar in 1961, investigating the abnormalities in Down's syndrome, noted the cribiform plate to be abnormally low and the angle formed by the sphenoid bone steep. There was a hypoplasia of the maxilla segment of the face involving the maxilla and the nasal bones and, because of the hypoplasia, the diminutive maxilla remained retracted under the relatively protruding forehead.

They claimed that the abnormal development of the mandible had to be attributed to a deficient condylar development which was epiphyseal in character. Both the horizontal and ascending rami tended to be slender and the mandibular angle was often obtuse.

Roche, Seward and Sunderland in 1961, in a non-

metrical observation of cranial roentgenograms, noted that during early life sutures were more widely separated in children with Down's syndrome than in normal children. After the age of ten, a metopic suture was presented in 42% of the males. The frontal sinuses and the superciliary arches were absent in most cases. A study of the lateral cranial silhouette of white Australians with Down's syndrome by these same investigators showed total cranial height and length significantly below normal, but no departure from normal was detected in the posterior portion of the cranium.

Poszonyi, Gibson and Zarfas in 1964 studied skeletal maturation on 100 individuals with Down's syndrome and found that up to eight years of age there was bone growth retardation, but between 8 and 15 years of age bone growth accelerated in relation to normal rates of growth. They found no correlation between rate and early termination and maturation, birth weight, neonatal illness, nutritional status, sex or degree of imbecility. As a result of these findings they suggested an endogenous cause to this early aging process.

Cephalometric Roentgenographic Studies

Only in recent years have studies been performed on Down's syndrome with use of cephalometric radiographs.

Sassouni, et al. in 1964 and Kisling in 1966 have contributed the best studies.

Cranial base - Sassouni showed a shortness of the anterior cranial base but found no significant difference in the internal contour of the frontal bone. He suggested that the frontonasal suture was underdeveloped.

Kisling also showed a smaller cranial base with the anterior portion showing the greater reduction. There was a reduction in height of the cranial base with the greatest reduction at the posterior cranial fossa, followed by the middle and then the anterior.

Rezk (1964) studied 31 cases of Down's syndrome and showed a shorter anterior and posterior cranial base as well as an increase in the flexure of the cranial base angle.

Nasomaxillary complex. Sassouni and Rezk both observed the midface to be markedly underdeveloped both vertically and anterioposteriorly, while Kisling observed a shorter maxilla although the maxilla was positioned normally to the anterior cranial base.

Mandible. Sassouni showed a normal length and gonial angle and stated that there existed a pseudo-

mandibular prognathism. He felt that the prognathic appearance in these cases was due to an underdeveloped maxilla in relation to a normal mandible.

Kisling, however, found a smaller mandibular length than in his normal group, but the mandible was positioned forward in relation to the anterior cranial base, thereby creating the prognathic appearance. He found a greater reduction in height of the mandible than in total length.

Rezk also found a smaller mandible as well as a smaller ramus height. He also found the gonial angle to be significantly smaller among the Down's syndrome cases.

Face height. Sassouni studied the anterior face height from nasion to the palate to the chin and found it to be significantly smaller. His measurement of posterior vertical height from sella to the gonial angle was also smaller, except in the group of ten year old males. He found the differences between the sexes to be the same as for normals. Kisling and Rezk, using similar landmarks as Sassouni, both showed a significant difference in anterior and posterior facial height.

Karyotype-phenotype relationship. Davis (1965) has done the only cephalometric X-ray study comparing the phenotypes of different karyotype of Down's syndrome by studying the skeletal morphology. Based on ten cephalometric measures, he did not find any difference between the phenotype of the translocation karyotype and the Trisomy 21 karyotype. He pointed out, however, that this investigation was not sound in that his sample of translocation karyotype was too small for statistical analysis.

CHAPTER III

MATERIALS AND METHODS

I. SAMPLE

The sample consisted of two groups. One was a Trisomy 21 group and the other was a control, or normal group. The Trisomy 21 group was composed of 60 males and 61 females who lived within the Canadian Province of Manitoba. This group varied in age from 4 to 48 years and was broken down into six different age groups. The age groups were determined as follows: pre-permanent dentition (ages 4 - 5), early mixed dentition (ages 6 - 8), late mixed dentition (ages 9 - 11), early adolescence (ages 12 - 15), late adolescence (ages 16 - 19) and adults (age 20 and up). A complete survey of the Trisomy 21 group is seen in Table I.

Every subject in the Trisomy 21 group had had a cytogenetic analysis performed by a qualified cytogeneticist.* The peripheral blood technique was used and cells containing the chromosomes were obtained from the cultured white blood cells. Each person in this group was found to

---

*Dr. Irene Uchida and Staff, Winnipeg Children's Hospital, Winnipeg, Manitoba, Canada.

possess an extra chromosome number 21. All translocations and mosaics were eliminated.

TABLE I

AGE DISTRIBUTION OF THE TRISOMY 21 GROUP

Age	Male	Mean Age		Female	Mean Age	
		Yr.	Mon.		Yr.	Mon.
4 - 5	7	4	6	7	4	4
6 - 8	9	6	11	8	7	0
9 -11	10	10	1	5	9	8
12 -15	15	13	2	11	13	1
16 -19	6	17	7	7	17	3
Adult	13	28	2	23	29	10
Total	60			61		

Institutionalized subjects totalled 73% of the Trisomy 21 group. These individuals resided in two separate schools within the Province of Manitoba. The remaining portion of the Trisomy 21 group lived in private homes with their own families.

The control group was derived from a random collection of normal individuals, consisting of 60 males

and 61 females. This group was matched with the Trisomy 21 group in age and divided into the similar groups. Single individuals as well as entire families participated in making up the control group. All of these people lived in private residences and none of them had had any previous orthodontic therapy. A complete survey of the control or normal group is seen in Table II.

TABLE II

AGE DISTRIBUTION OF THE CONTROL GROUP

Age	Male	Mean Age		Female	Mean Age	
		Yr.	Mon.		Yr.	Mon.
4 - 5	7	4	5	7	4	6
6 - 8	11	7	1	12	7	1
9 -11	10	10	3	8	9	11
12 -15	14	13	4	7	13	3
16 -19	5	17	3	6	17	0
Adult	13	27	5	19	26	6
Total	60			61		

All the members of the Trisomy 21 group and the control group belonged to the caucasian race. The

various ethnic backgrounds represented were not completely determined. However, a similarity of ethnic origins existed between the Trisomy 21 group and the control group.

II. RECORDS

Lateral and posteroanterior cephalometric radiographs were taken of both groups utilizing the Broadbent-Bolton cephalometer and a portable cephalometer. Lateral radiographs were taken while the individual's mandible was in three different positions - occlusion, physiological rest position and wide open. The posteroanterior radiograph was taken in occlusion.

III. CEPHALOMETRIC EQUIPMENT

The standard Broadbent-Bolton cephalometer X-ray machine (Figure 1) was used according to the technique described by Broadbent (1931). This cephalometer was used on all the individuals of the control group and the portion of the Trisomy 21 group who resided in private homes.

A portable cephalometer (Figure 2) was necessary to obtain records on those people residing in the two institutions. The portable cephalometer was composed of

a standard General Electric X-ray head and arm* placed on a common mount with a standard cephalostat. The mountings were positioned in a pattern similar to the Broadbent-Bolton cephalometer.

The distance from the left ear rod to the film of both cephalometers was fixed so that a 5 feet 6 inch anode - film distance was established. Since the position of the mid-sagittal plane of the individual's head varied, a metal gauge was placed on the mid-sagittal plane in order to establish a magnification factor for each radiograph.

The magnification varied from 5% to 7% depending on the size of the individual, but most subjects show a 6% magnification error. All linear values were adjusted for their magnification and, therefore, the radiographs from the two cephalometers were definitely comparable.

IV. TRACING TECHNIQUE

The lateral radiographs with the teeth in occlusion were traced, using a hard lead or 4H pencil, onto the matt surface of acetate tracing paper. Whenever a double projection of lateral structures was present, in order to

---

* General Electric Co. of Canada Ltd., Toronto, Ontario.

approximate a midline structure, both images were traced and the bisection of the two lines was done.

Some degree of error is inherent in tracing films. However, care was taken in order to eliminate as much error as possible. In order to determine the degree of tracing error, eight radiographs were each traced four times on four separate occasions. These tracings were then subjected to a cephalometric analysis to determine the error.

Some of the data recordings from the analysis of the tracings showed a 1 - 2% error. A small number of recordings exhibited a 3% error. Basion and posterior nasal spine were the reference points most difficult to reproduce accurately. This small degree of error was not considered in the statistical results.

The posteroanterior films were not traced and were only used to subjectively determine the skeletal symmetry or assymmetry of the various individuals in the study.

V. CEPHALOMETRIC ANALYSIS

The work of several investigators, as sited in the Review of Literature, have shown that certain lines and angles are useful in the analysis of lateral cephalograms. A cephalometric analysis consisting of both angular and

linear measurements was used to evaluate and compare the two groups of the study.

Various landmarks and reference points were selected according to their visibility on the radiograph, uniformity in outline, and ease of tracing. The landmarks used allowed for valid quantitative measurements of lines and angles projected from them. The definitions and abbreviations of the various landmarks and reference points that were used, are found in the glossary.

The analysis in this study, as diagramed in Figure 3, (see pages 49 and 49a), was designed to reveal the relationship of the various portions of the craniofacial complex. A total of 50 variables consisting of 18 angles, 15 linear measurements, and 17 ratios of the linear measurements was used. The lines and planes have a significant relationship to the vectors of growth in specific areas and the measurements of the angles, lines, and ratios will help to show the respective relationships of the selected landmarks and reference points of these areas.

The angles, linear measurements, and ratios of linear measurements used to correlate the various areas of the craniofacial complex are listed below under the proper relationship.

Relationship of the anterior cranial base to the posterior cranial base.

Angle	Linear Measurements	Ratios
NSBa	SN	SN/SBa
	SBa	SN/NBa
	NBa	SBe/NBa

Relationship of the anterior cranial base to the maxilla.

Angles	Linear Measurements	Ratios
SNA	SN	SN/AnsPns
NOAns	AnsPns	

Relationship of the anterior cranial base to the mandible.

Angles	Linear Measurements	Ratios
SNB	SN	SN/GoGn
SNP	GoGn	SN/SGn
NSGn	SGn	
NSAr	SAr	
NSGo		
SGoGn		
NVGn		

Relationship of the posterior cranial base and the mandible.

Angles	Linear Measurements	Ratios
SArGo	SAr	SAr/ArGo
	ArGo	

Relationship of the maxilla to the mandible.

Angles	Linear Measurements	Ratios
ANB	AnsPns	AnsPns/GoGn
AnsTGn	GoGn	

Relationship of the ramus of the mandible to the body of the mandible.

Angles	Linear Measurements	Ratios
ArGoGn	ArGo	ArGo/GoGn
	GoGn	

Relationship of frontal bone prominence to facial countour as related to the anterior cranial base.

Angles	Linear Measurements	Ratios
SFN	SF	SN/SF
SFA	SN	
SFB	FX	
AFB		

Relationship of upper and lower facial height (Anterior).

Linear Measurements	Ratios
NW	NW/WM
WM	
NM	

Relationship of anterior facial height to posterior facial height.

Linear Measurements	Ratios
SGo	SGo/NM
NM	

Relationship of anterior cranial base to anterior and posterior facial height.

Linear Measurements	Ratios
SN	SN/NM
NM	SN/SGo
SGo	

Relationship of upper, middle, and lower facial depth.

Linear Measurements	Ratios
SN	SN/AG
AG	AG/GoGn
GoGn	SN/GoGn

Relationship of maxilla to the midface depth.

Linear Measurements	Ratios
AnsPns	AnsPns/AG
AG	

VI. STATISTICAL ANALYSIS

The error that resulted from the tracing and performing of the cephalometric analysis was measured by using four tracings and subsequent cephalometric analysis on eight different radiographs. The amount of error was found to vary from 1% to 3%. This amount of error is in accordance with the accepted techniques in the literature and was not considered in the statistical results.

The raw data which were obtained by direct measurement of the various angles and lines of the cephalometric analysis was recorded on computer data sheets. These data were submitted to a digital computer for the numerical procedures. The raw data of the linear measurements were corrected for the magnification error and the ratios of the linear measurements were computed from these corrected values.

Each of the 18 angular, 15 linear, and 17 ratio varieties were then independently subjected to an analysis of variance with the intention of detecting the significance of difference at the 1% and 5% levels among the groups, sexes, and ages, as well as the interaction of group and sex, group and age, sex and age, and group, sex, and age.

The 241 degrees of freedom available between the 242 subjects were partitioned as shown in Table III.

The student "t" test was used to determine the significance of difference between individual pairs of means for a portion of the sources of variation.

VII. POLYGONAL PROFILES

A portion of the mean values obtained from the statistical analysis was used to construct a polygon

TABLE III

DEGREES OF FREEDOM FOR EIGHT SOURCES OF VARIATION FOR THE 242 SUBJECTS

Source of Variation	Degrees of Freedom
Between Groups	1
" Sexes	1
" Ages	5
" Group x Sex	1
" Group x Age	5
" Sex x Age	5
" Group x Sex x Age	5
Error	218
Total	241

patterned after the one reported by Bjork (1954). The polygons were used to evaluate growth trends of the facial profile and comparisons were made between the two groups as well as between the various age ranges. Growth trends could be determined by superimposing the polygons on the line sella nasion with registration on sella. An example of the polygon is shown in Figure 4.

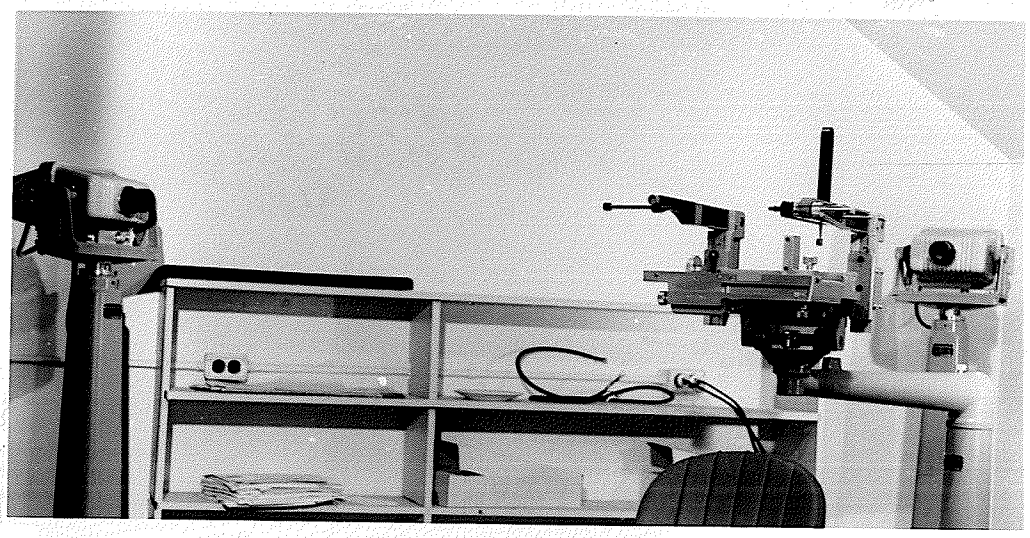


FIGURE 1

BROADBENT-BOLTON CEPHALOMETER

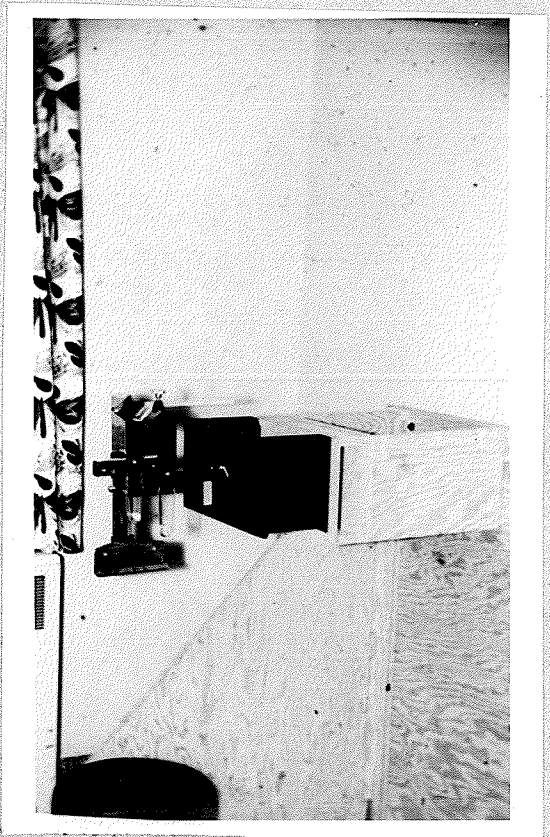


FIGURE 2

CEPHALOMETRIC HEADHOLDER USED WITH PORTABLE CEPHALOMETRIC SET-UP

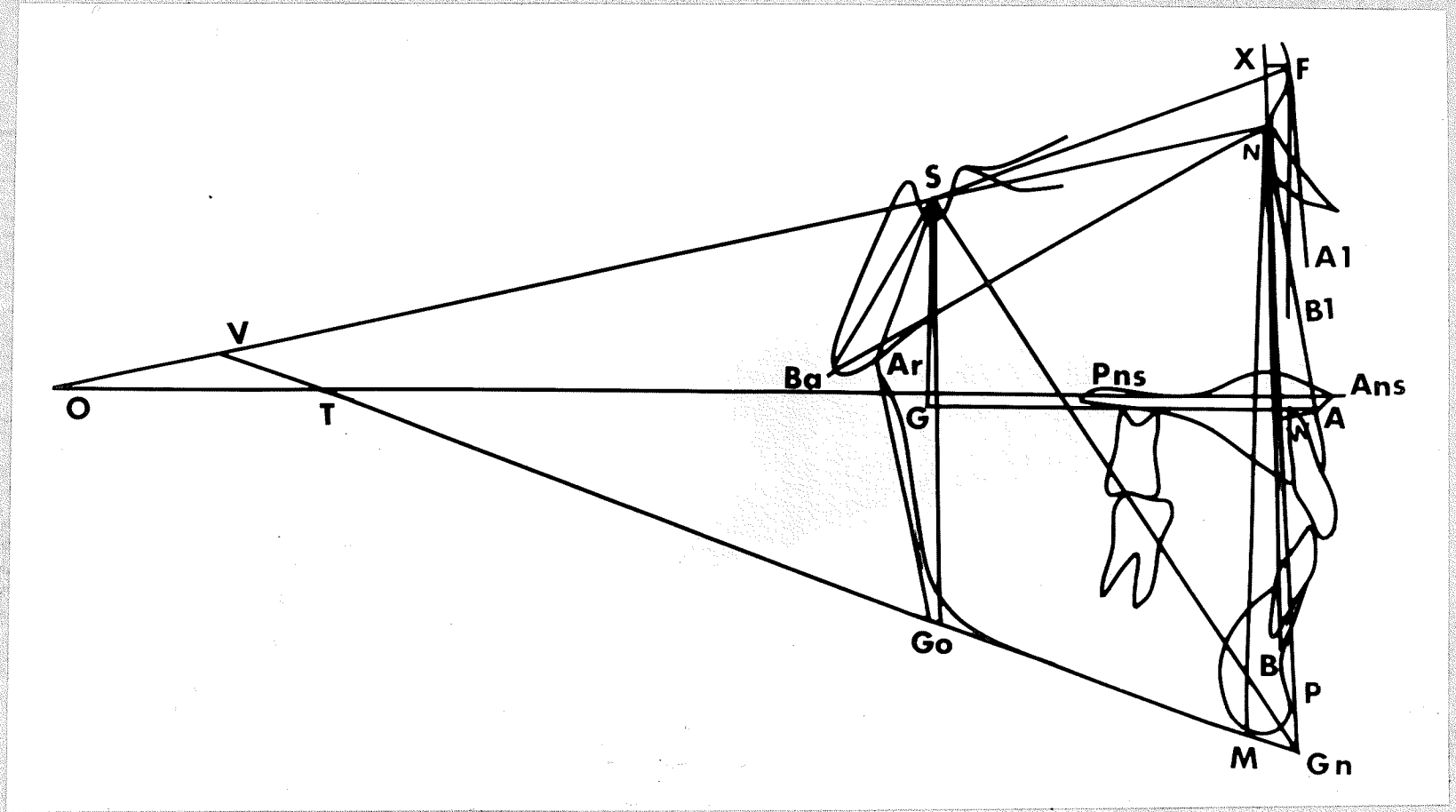


FIGURE 3

ILLUSTRATION OF THE CEPHALOMETRIC ANALYSIS
USED IN THE STUDY

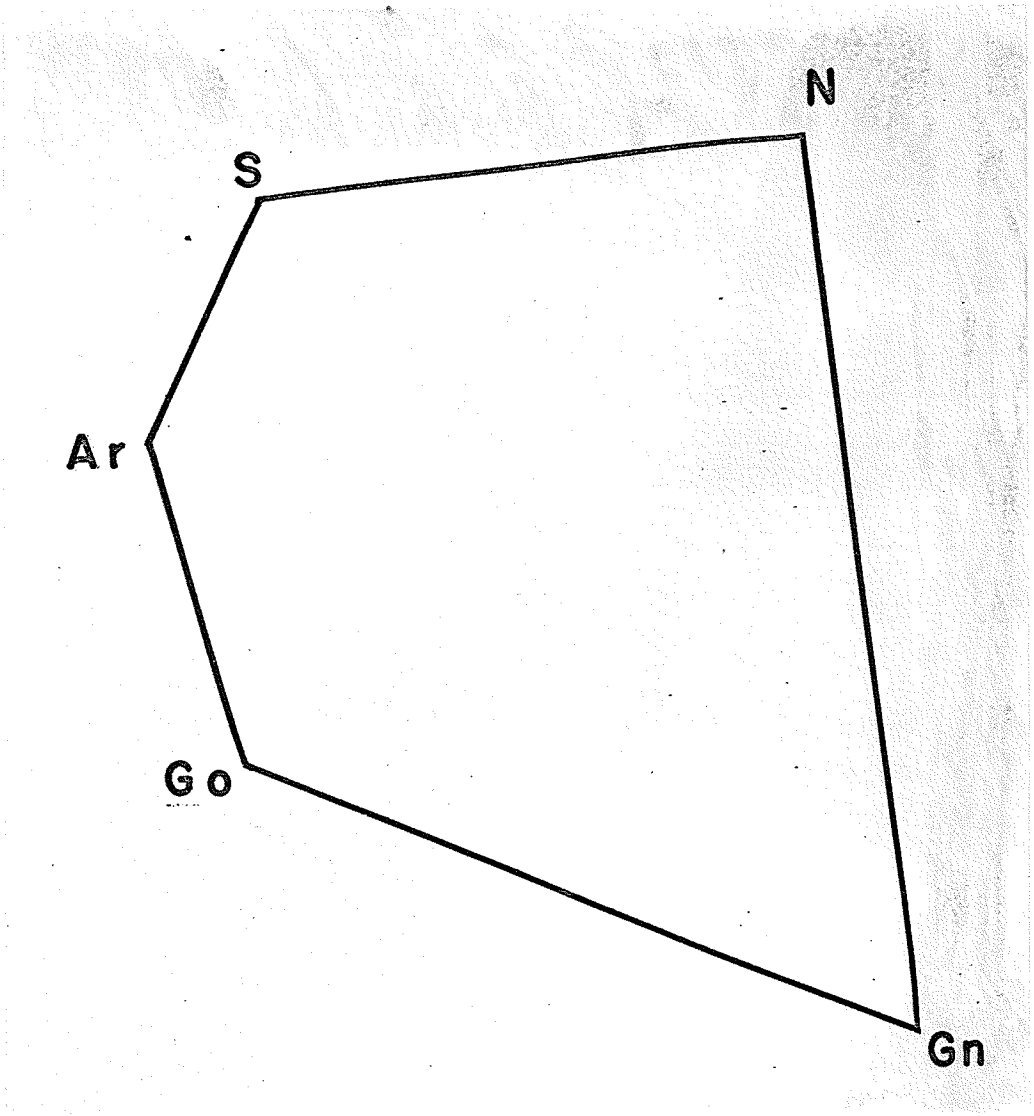


FIGURE 4

ILLUSTRATION OF POLYGON TO EVALUATE GROWTH TRENDS OF THE FACIAL PROFILE

CHAPTER IV

RESULTS

The findings based on the statistical analysis were organized into tables, graphs, and charts. The tables show the means and the significance of difference between the groups, sexes, and ages, and these tables are located in the appendix of this paper. The graphs and charts are found at the end of this chapter and will be referred to when required.

The discussion of the results will be divided into three sections. (1) The Trisomy 21 group versus the normal group (Group versus Group); (2) The Trisomy 21 group versus the normal group with reference to the sexes (Group x Sex versus Group x Sex); (3) The Trisomy 21 group versus the normal group with reference to the age ranges (Group x Age versus Group x Age).

I. THE TRISOMY 21 GROUP VERSUS THE NORMAL GROUP

The absolute linear measurements of the Trisomy 21 group after correction for magnification were found to be significantly smaller at the 1% level. This was evident in 14 of the 15 linear measurements taken. The values for the measurement FX of the Trisomy 21 group was found to be larger at the 1% level.

The cranial base angle NSBa was significantly greater in the Trisomy 21 group at the 1% level. The mean value of the Trisomy 21 group was 138.5° as compared to 131.5° for the control group. These values showed a greater flexion of the posterior cranial base in the Trisomy 21 group.

Within the cranial base, the ratio of the linear measurements comparing SN to NBa was significantly smaller at the 1% level in the Trisomy 21 group thus indicating that the anterior cranial base, SN, was proportionally smaller in the Trisomy 21 group.

The angle SNA, comparing the maxillary protrusion to the anterior cranial base, showed no significant differences between the two groups. However, the angle SNB, comparing the mandibular protrusion to the anterior cranial base, was significantly larger at the 1% level in the Trisomy 21 group. Similarly, angle SNGn was larger at the 5% level of significance in the Trisomy 21 group.

Angle ANB, comparing the maxilla to the mandible, was significantly different at the 1% level. The Trisomy 21 group exhibited the smaller mean value of 1.5° as compared to the control mean value of 3.0°.

The ratios of the linear measurements comparing the maxilla and the mandible to the anterior cranial base

showed significant differences with the ratio SN/AnsPns being larger in the Trisomy 21 group, the ratio SN/GoGn being smaller in the Trisomy 21 group, and the ratio SN/SGn being smaller in the Trisomy 21 group. These results showed the anterior cranial base to be larger in proportion to the maxilla but smaller in proportion to the mandible. When the maxilla and the mandible were compared in the ratio AnsPns/GoGn, there was a significance of difference at the 1% level with the Trisomy 21 group being the smaller. This indicated that the maxilla was proportionally smaller in the Trisomy 21 group in relation to the mandible.

The angle NOAns formed by the palatal plane and the plane of the anterior cranial base was significantly larger at the 1% level in the Trisomy 21 group, showing a steeper inclination of these two planes.

The gonial angle ArGoGn was significantly smaller at the 1% level in the Trisomy 21 group. The gonial angle for the Trisomy 21 group had a value of 123.5° while the control group had a value of 126.0°. However, the ratio ArGo/GoGn did not show any significance of difference, but the ratio SAr/ArGo was smaller at the 1% level of significance in the Trisomy 21 group. This indicated, that in the Trisomy 21 group, the ramus was larger in

relation to sella articulare than in the control group.

When the prominence of the frontal bone of the two sample groups was related to the anterior cranial base and the profile, the findings showed a significance of difference between the two groups. Both SFN and SFA were smaller at the 1% level of significance in the Trisomy 21 group, while SFB was smaller at the 5% level. These findings indicated a greater prominence of the frontal bone when compared to the profile. The angle AFB was significantly smaller at the 1% level in the Trisomy 21 group and this corresponded to the findings of angle ANB.

The linear measurement SF corresponded with the measurement SN in that it was also significantly smaller at the 1% level in the Trisomy 21 group. However, the linear measurement FX was larger at the 1% level in the Trisomy 21 group showing the greater prominence of the frontal bone when related to the profile.

The facial height was measured using the linear measurement NM for the anterior and SGo for the posterior facial height. The anterior facial height was further broken down into upper and lower facial heights by the measurements NW and WM. All linear measurements were smaller at the 1% level in the Trisomy 21 group indicating a definite difference in facial height. When the

upper facial height was compared to the lower facial height by the ratio NW/WM, the findings showed the ratio to be significantly smaller at the 1% level for the Trisomy 21 group thus indicating a larger, lower facial height than in the normal group. No significant findings were seen when the posterior and anterior facial heights were compared.

The facial depth was measured using the linear measurements SN, AG, and GoGn as well as the ratios between them. The facial depth of the Trisomy 21 group was smaller at the 1% level of significance and the ratios comparing the upper (SN), middle (AG), and lower (GoGn) facial depth showed the lower face height of the Trisomy 21 group to be significantly larger at the 1% level.

The midface depth, AG, was compared to the length of the maxilla by the ratio AnsPns/AG and the findings showed the midface depth of the Trisomy 21 group to be smaller in relation to the maxilla than the same relationship of the control group.

II. THE TRISOMY 21 GROUP VERSUS THE CONTROL GROUP WITH REFERENCE TO THE SEXES

The results showed that differences existed between the males and the females of the Trisomy 21 group. However, these differences were the same as those which existed between the males and the females of the control group.

Therefore no significant results can be reported.

The differences between the male Trisomy 21 group and the male control group, as well as, the differences between the female Trisomy 21 group and the female control group were significant at the 1% and 5% levels. However, the findings were the same as cited in the previous section and these results will not be repeated.

III. THE TRISOMY 21 GROUP VERSUS THE CONTROL GROUP WITH REFERENCE TO THE AGE RANGES

The absolute linear measurements of each age range of the Trisomy 21 group after correction for magnification were found to be significantly smaller at the 1% level when compared to the same measurements in the age ranges of the control group. Examples in graph form of some of the linear measurements are seen in Figures 5,6,7,8 and 9.

This size difference was evident in 14 of the 15 linear measurements. The values for the measurement FX of the Trisomy 21 group were found to be larger at the 1% level within each age range.

The cranial base angle NSBa (Figure 10) of the Trisomy 21 group was about 4^{o} larger than the control group in the 4-5 age range and with an increase in age the cranial base angle of the Trisomy 21 group continued to enlarge while the angle in the control group remained relatively constant. The cranial base angle in the adult

Trisomy 21 group was about 10° larger than the same angle in the adult control group. The angle was significantly larger at each age level but showed the greatest difference in the older age groups.

The angle SNA (Figure 11) was not significantly different, but a significant difference existed in most age ranges for angle SNB. Angle SNB (Figure 12) of the control was larger in the 4-5 age range, but the angle remained relatively constant with an increase in age. The same angle of the Trisomy 21 group continued to enlarge so that in the older age range it was larger at the 1% level of significance. This indicated that in the early age group, mandibular protrusion was similar between the two groups, but in the older age ranges, the mandible of the Trisomy 21 group showed a greater protrusion in relation to the anterior cranial base.

The angle SNGn (Figure 13) showed the same relationship during age changes as did angle SNB. The angle in the control group was larger in the 4-5 age range but remained constant with an increase in each age range, and in the adult, the angle SNGn of the Trisomy 21 group was significantly larger at the 1% level.

The findings of the changes in angle ANB (Figure 14) corresponded to the findings of the angles SNA and SNB.

The angle ANB of the Trisomy 21 group continued to decrease with age increase while angle ANB of the control group remained constant.

When the maxillary length (AnsPns) was compared to the mandibular length (GoGn), an important finding was noted. The ratio AnsPns/GoGn of the control group remained constant with increasing age, but the same ratio in the Trisomy 21 group increased with age indicating that growth of the mandible of the Trisomy 21 group was less in proportion to the maxilla, while in the control group, the maxilla and the mandible grew in equal proportion.

The posterior cranial base was compared to the mandible by the angle SArGo (Figure 15). This angle remained constant in the control group while it gradually decreased as the Trisomy 21 group ages. This corresponded to the greater flexion of the posterior cranial base. A change in the angle SArGo could also have been a result of the over closing of the mandible due to changes in the dentition or a result of tipping of the occlusal plane.

The gonial angle ArGoGn (Figure 16) of the Trisomy 21 group remained constant with increasing age while it decreased slightly in the control group. However, the gonial angle of the Trisomy 21 group was more acute in every age range.

The relationship of the ramus to the body of the mandible was shown in the ratio ArGo/GoGn. The ratio in the Trisomy 21 group increased a significant amount with the increase of age while it increased slightly in the control group. This indicated that the ramus of the Trisomy 21 group became larger in proportion to the body of the mandible than that of the control group.

The changes in the prominence of the frontal bone in relation to the profile was seen in each age range. The angles SFN, SFA, SFB, and AFB of both groups increased with age. However, the basic difference as discussed above was present in each age range. The linear measurement FX (Figure 17) of the Trisomy 21 group fluctuated with increasing age while the control group remained constant.

Facial height (Figure 18) within each age range was smaller in the Trisomy 21 group at a 1% level of significance. The lower facial height (Figure 19) increased with age to a greater degree in the control group. Facial depth was similar in that the Trisomy 21 group was smaller in all age ranges.

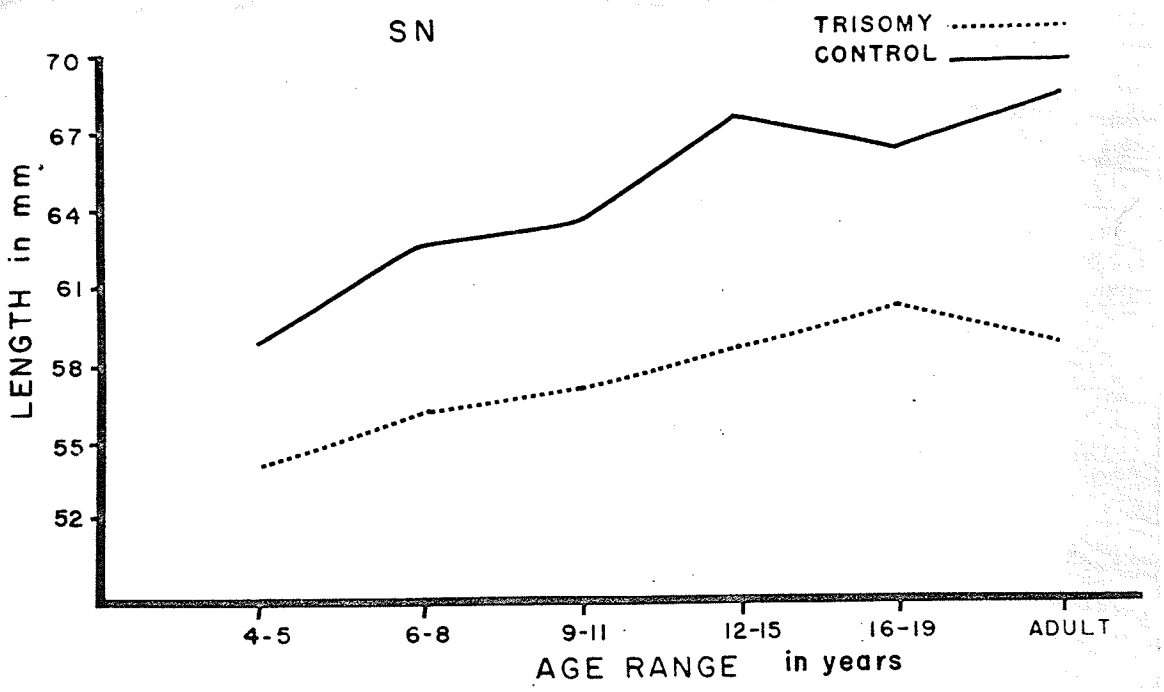
The linear values of SBa and SAr in the adult age range of both groups are low. This could indicate three things. 1. Difficulty in accurately locating basion; 2. Changes in the posture of the mandible, 3. Lowering of the sella turcia in the adult.

FIGURE 5

GRAPH SHOWING THE AGE CHANGES OF THE LINEAR MEASUREMENT SN IN THE TRISOMY 21 AND CONTROL GROUPS

FIGURE 6

GRAPH SHOWING THE AGE CHANGES OF THE LINEAR MEASUREMENT SBa IN THE TRISOMY 21 AND CONTROL GROUPS


SN
TRISOMY
CONTROL
LENGTH in mm
70
67
64
61
58
55
52
4-5
6-8
9-11
12-15
16-19
ADULT
AGE RANGE in years

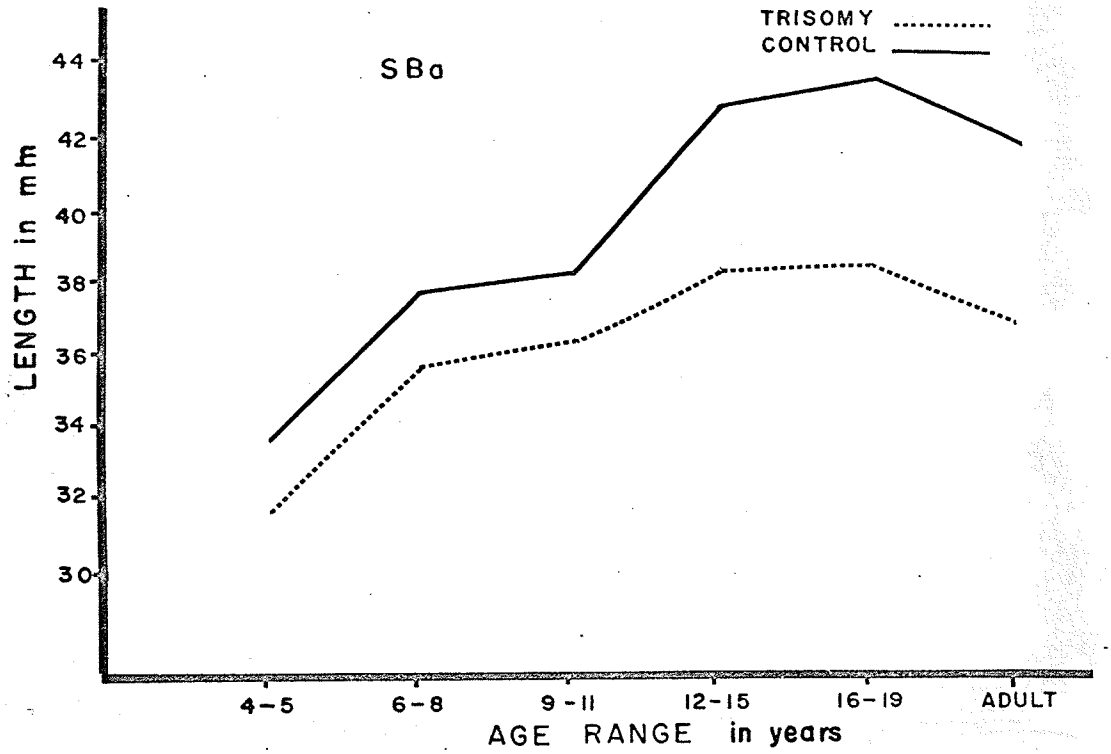
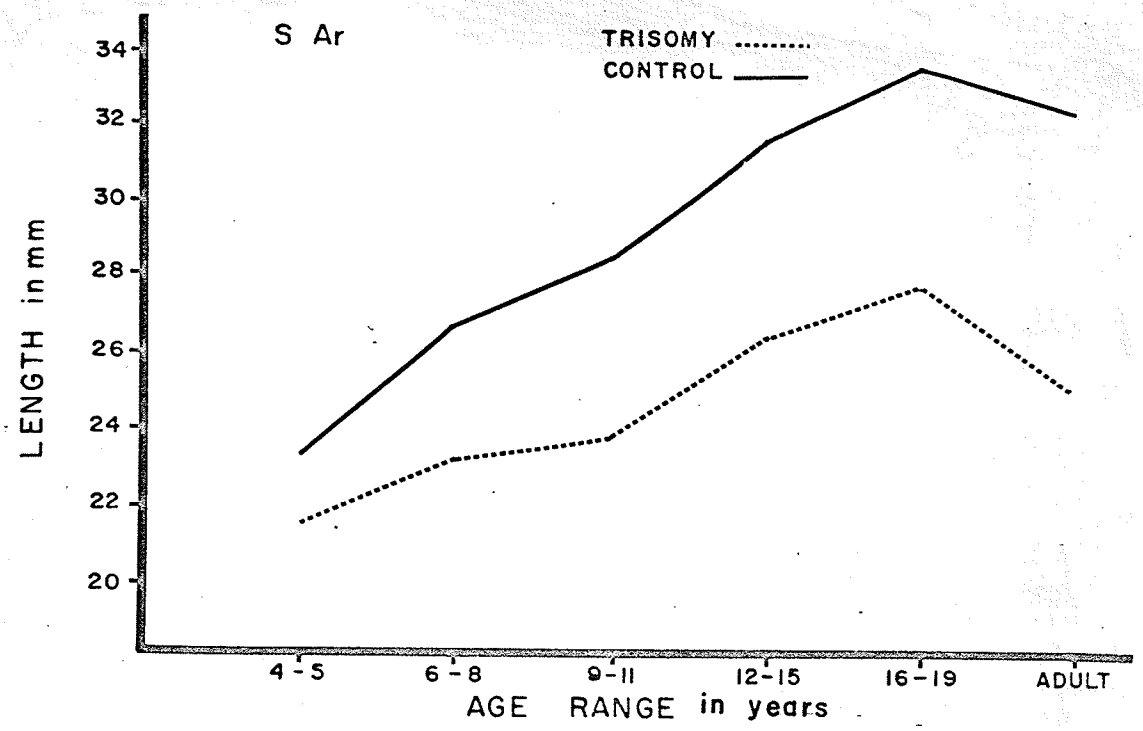

SBa
TRISOMY
CONTROL
LENGTH in mm
44
42
40
38
36
34
32
30
4-5
6-8
9-11
12-15
16-19
ADULT
AGE RANGE in years

FIGURE 7

GRAPH SHOWING THE AGE CHANGES OF THE LINEAR MEASUREMENT SAr IN THE TRISOMY 21 AND CONTROL GROUPS

FIGURE 8

GRAPH SHOWING THE AGE CHANGES OF THE LINEAR MEASUREMENT ArGo IN THE TRISOMY 21 AND CONTROL GROUPS


S Ar
TRISOMY
CONTROL
LENGTH in mm
34
32
30
28
26
24
22
20
4-5
6-8
9-11
12-15
16-19
ADULT
AGE RANGE in years

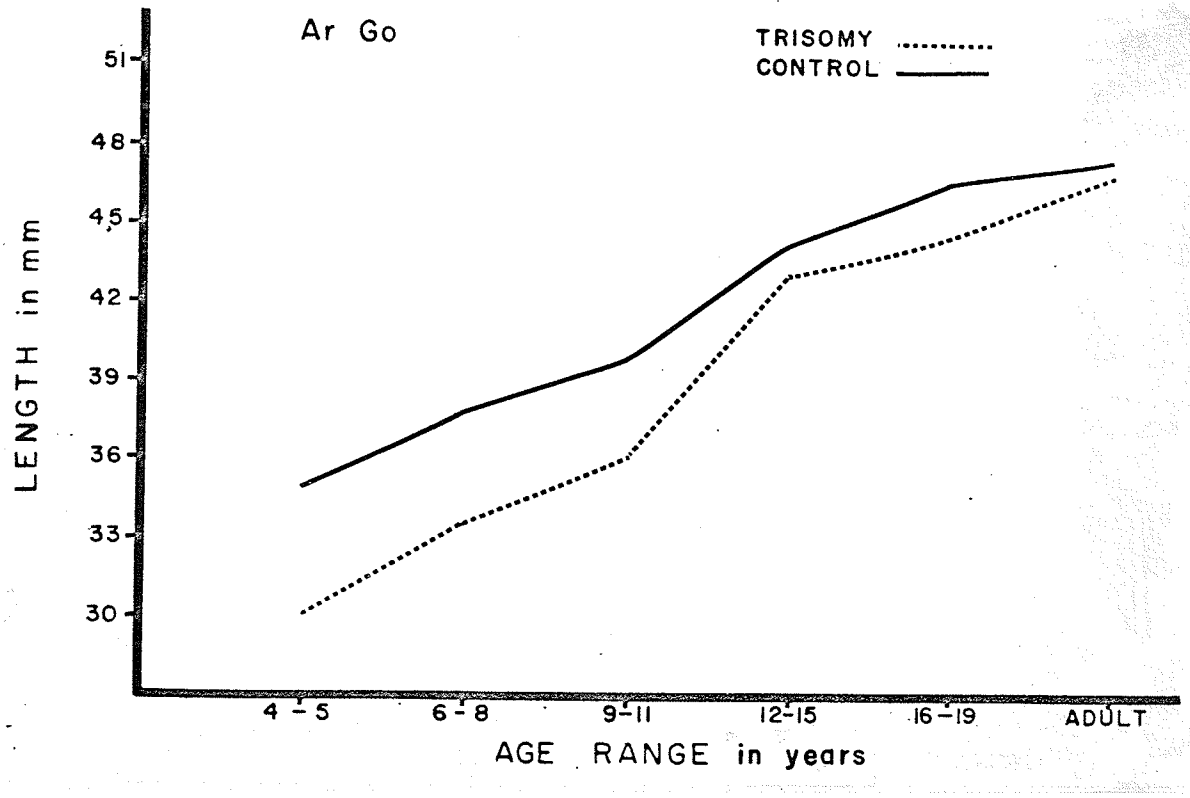
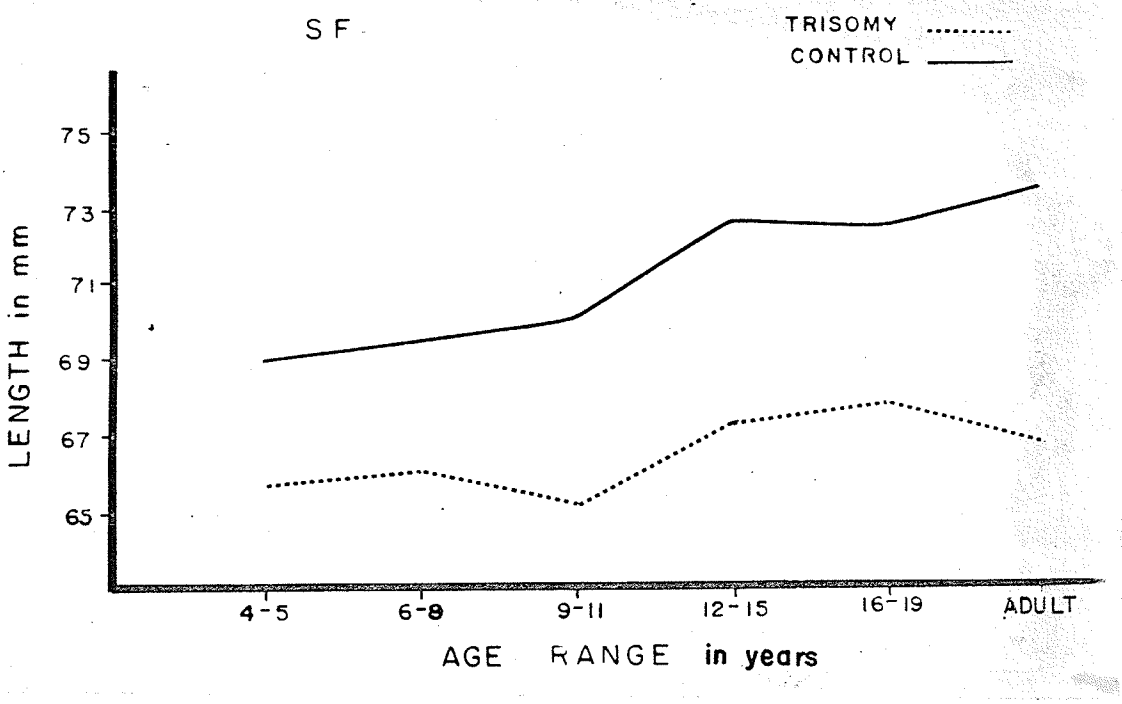

Ar Go
TRISOMY
CONTROL
LENGTH in mm
51
48
45
42
39
36
33
30
4-5
6-8
9-11
12-15
16-19
ADULT
AGE RANGE in years

FIGURE 9

GRAPH SHOWING THE AGE CHANGES OF THE LINEAR MEASUREMENT SF IN THE TRISOMY 21 AND CONTROL GROUPS

FIGURE 10

GRAPH SHOWING THE AGE CHANGES OF THE ANGULAR MEASUREMENT NSBa IN THE TRISOMY 21 AND CONTROL GROUPS


S F
TRISOMY
CONTROL
LENGTH in mm
75
73
71
69
67
65
4-5
6-8
9-11
12-15
16-19
ADULT
AGE RANGE in years

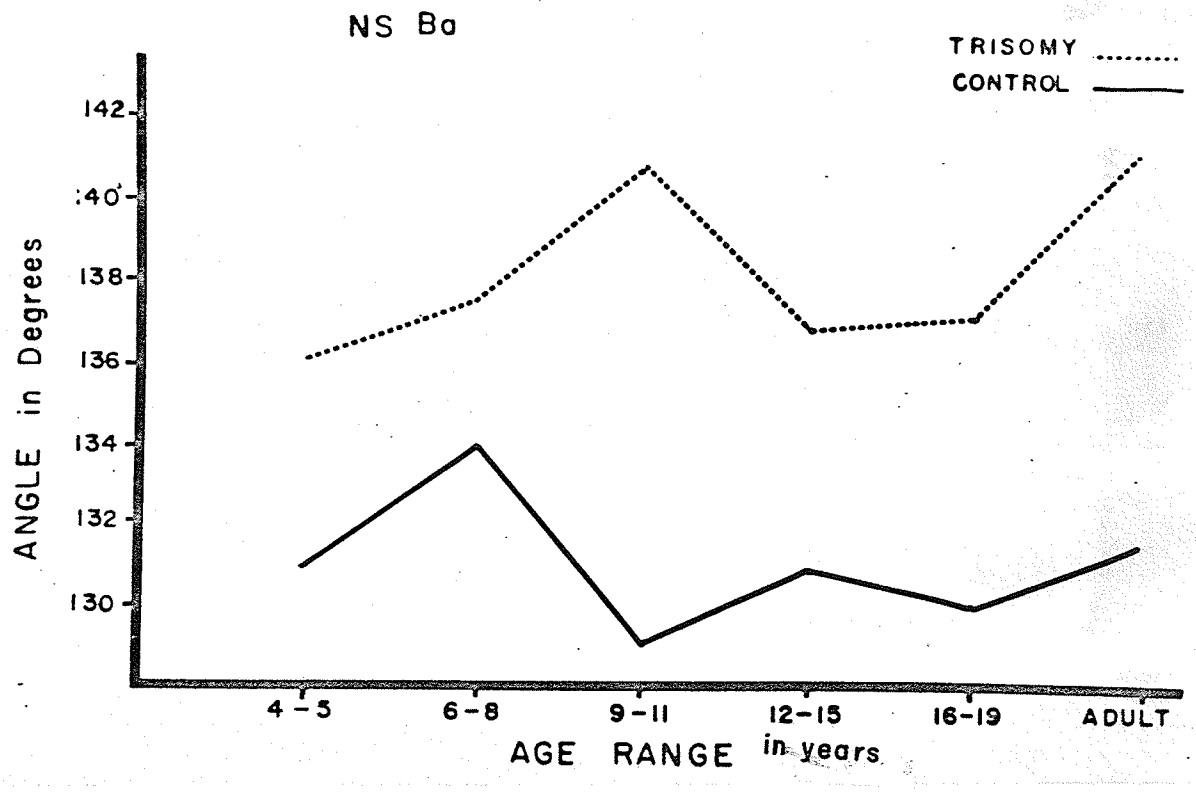
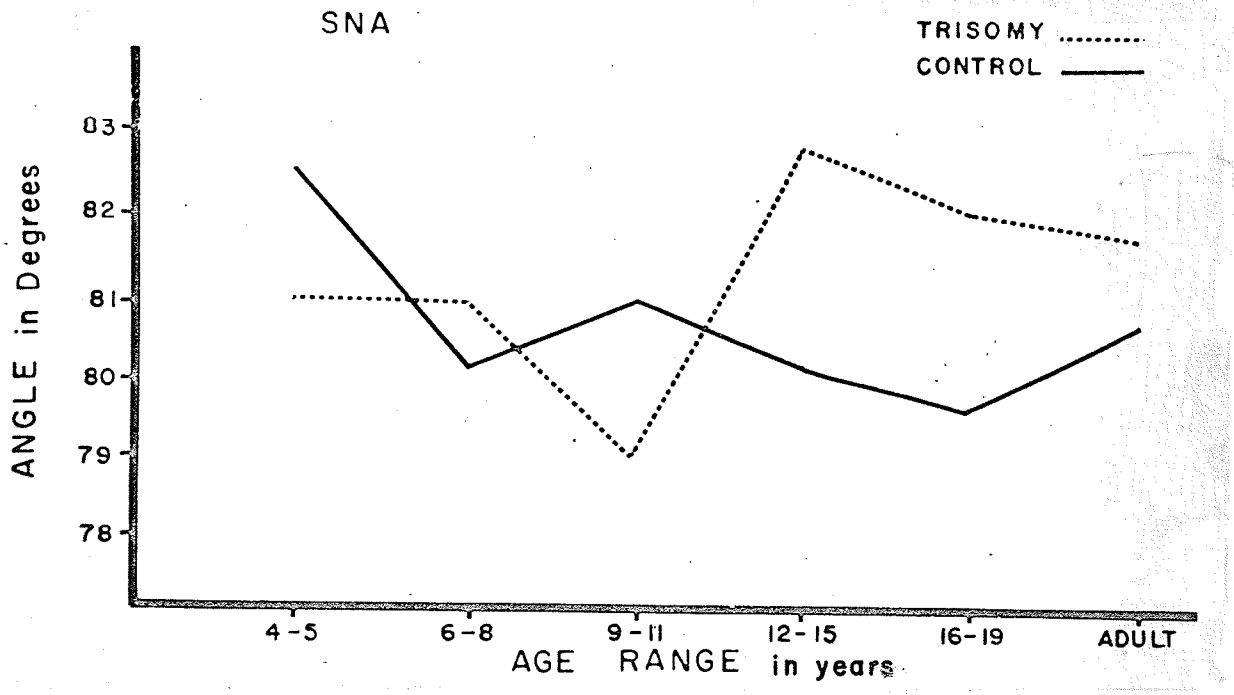

NS Ba
TRISOMY
CONTROL
ANGLE in Degrees
142
140
138
136
134
132
130
4-5
6-8
9-11
12-15
16-19
ADULT
AGE RANGE in years

FIGURE 11

GRAPH SHOWING THE AGE CHANGES OF THE ANGULAR MEASUREMENT SNA IN THE TRISOMY 21 AND CONTROL GROUPS

FIGURE 12

GRAPH SHOWING THE AGE CHANGES OF THE ANGULAR MEASUREMENT SNB IN THE TRISOMY 21 AND CONTROL GROUPS


SNA
TRISOMY
CONTROL
ANGLE in Degrees
83
82
81
80
79
78
4-5
6-8
9-11
12-15
16-19
ADULT
AGE RANGE in years

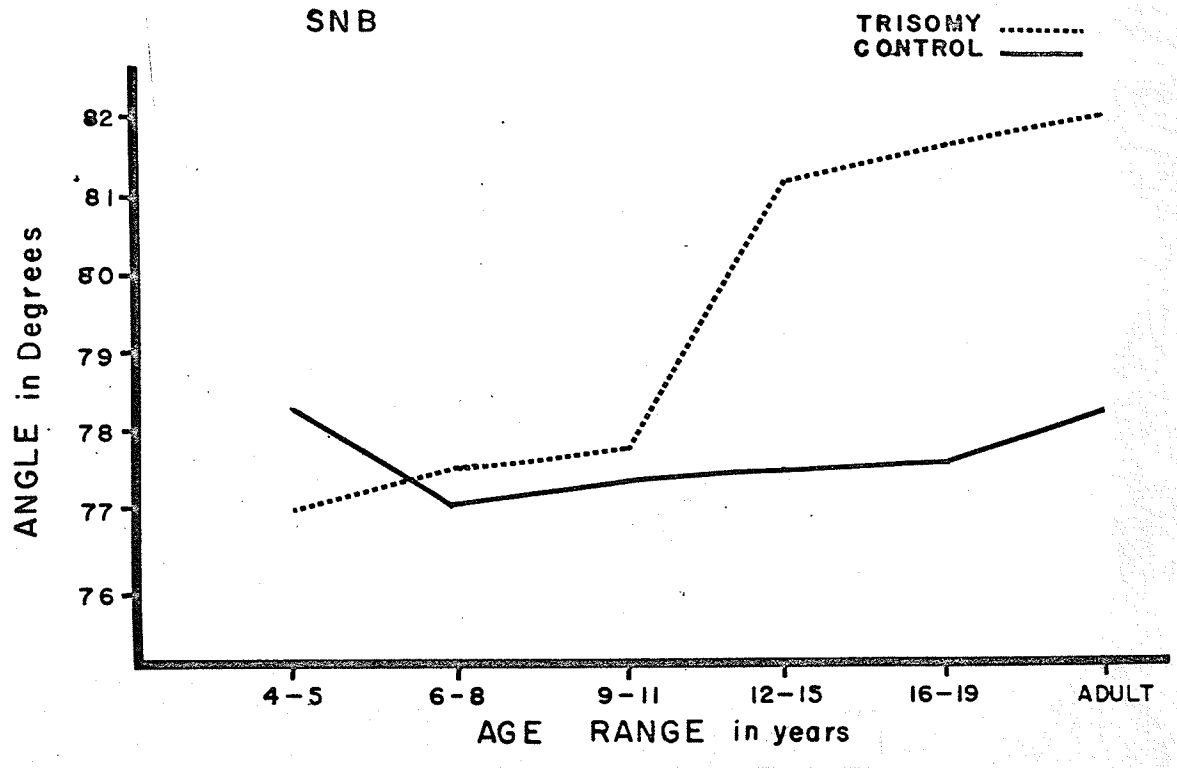
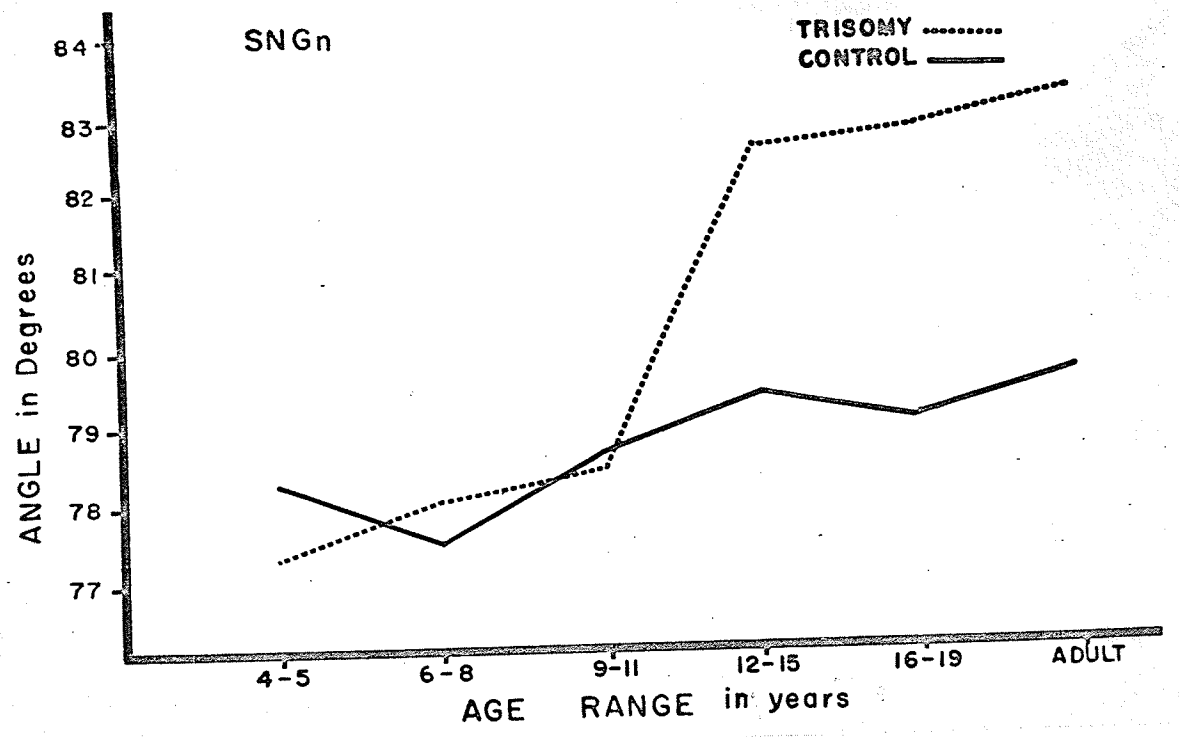

SNB
TRISOMY
CONTROL
ANGLE in Degrees
82
81
80
79
78
77
76
4-5
6-8
9-11
12-15
16-19
ADULT
AGE RANGE in years

FIGURE 13

GRAPH SHOWING THE AGE CHANGES OF THE ANGULAR MEASUREMENT SNGn IN THE TRISOMY 21 AND CONTROL GROUPS

FIGURE 14

GRAPH SHOWING THE AGE CHANGES OF THE ANGULAR MEASUREMENT ANB IN THE TRISOMY 21 AND CONTROL GROUPS


SNGn
TRISOMY
CONTROL
84
83
82
81
80
79
78
77
ANGLE in Degrees
4-5
6-8
9-11
12-15
16-19
ADULT
AGE RANGE in years

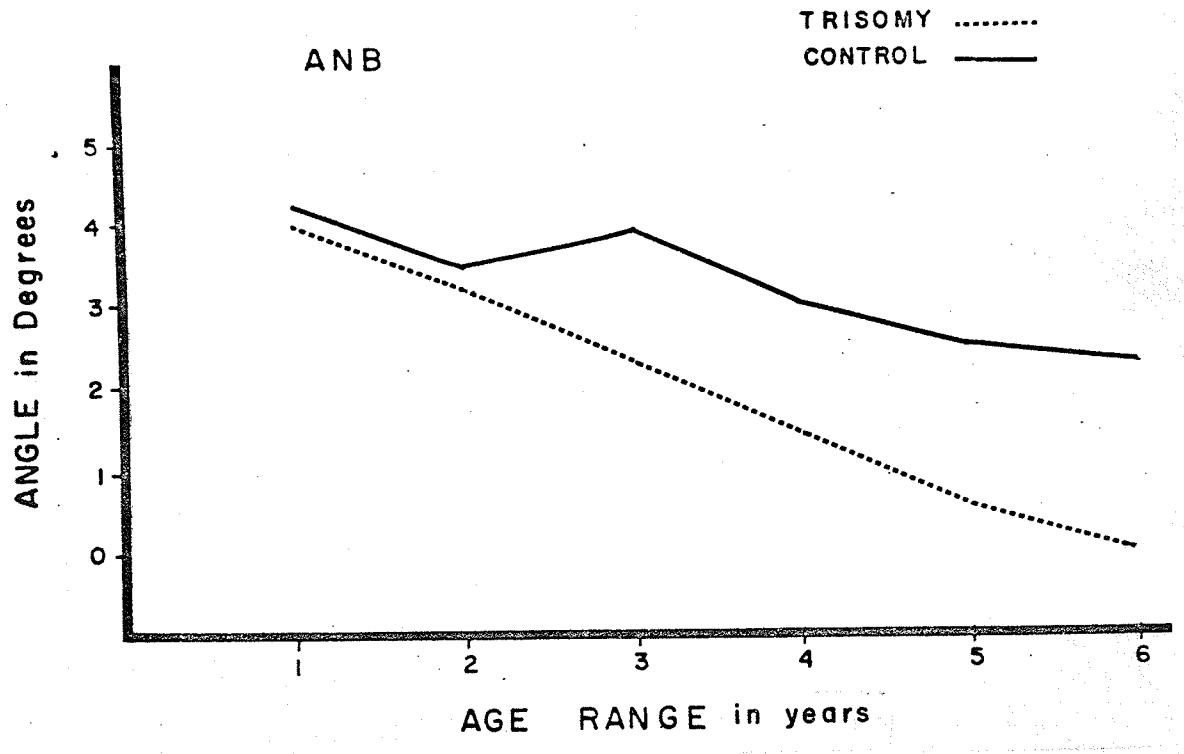
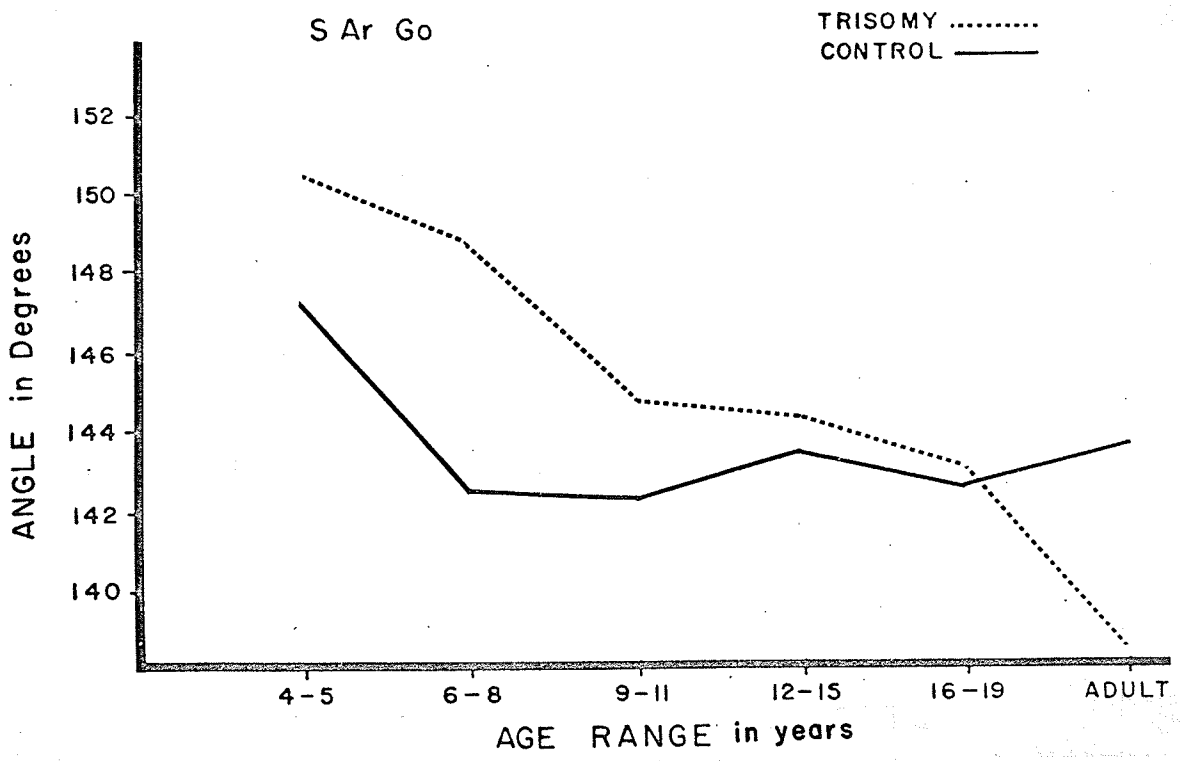

ANB
TRISOMY
CONTROL
5
4
3
2
1
0
ANGLE in Degrees
1
2
3
4
5
6
AGE RANGE in years

FIGURE 15

GRAPH SHOWING THE AGE CHANGES OF THE ANGULAR MEASUREMENT SArGo IN THE TRISOMY 21 AND CONTROL GROUPS

FIGURE 16

GRAPH SHOWING THE AGE CHANGES OF THE ANGULAR MEASUREMENT ArGoGn IN THE TRISOMY 21 AND CONTROL GROUPS


S Ar Go
TRISOMY
CONTROL
ANGLE in Degrees
152
150
148
146
144
142
140
4-5
6-8
9-11
12-15
16-19
ADULT
AGE RANGE in years

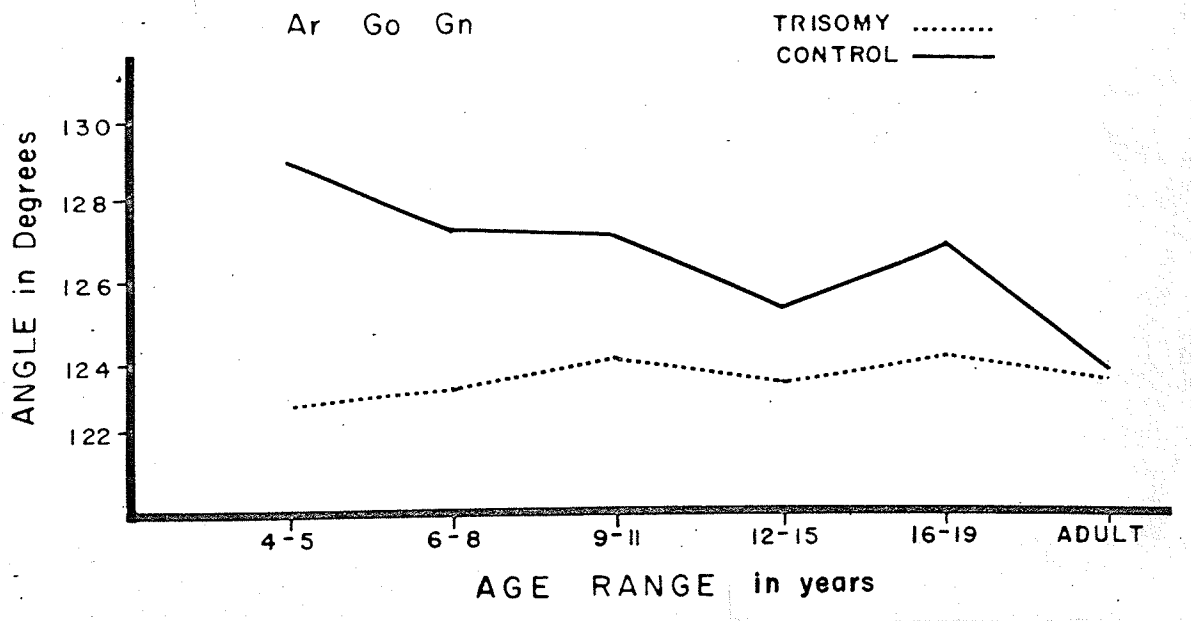
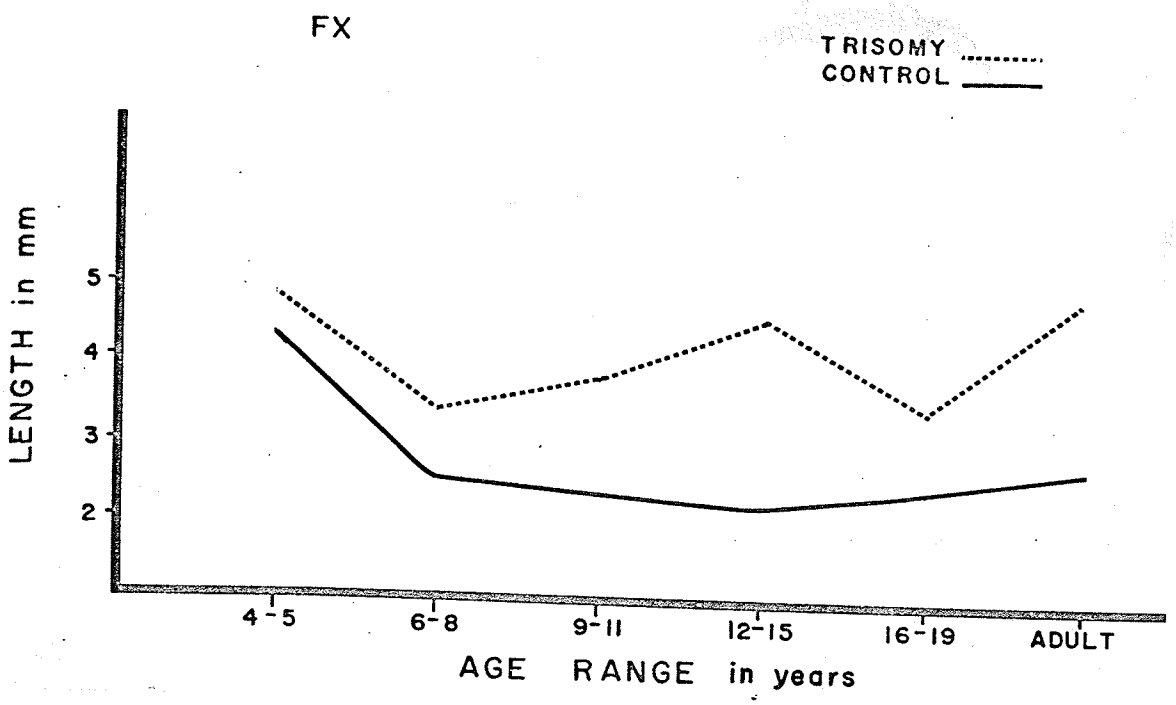

Ar Go Gn
TRISOMY
CONTROL
ANGLE in Degrees
130
128
126
124
122
4-5
6-8
9-11
12-15
16-19
ADULT
AGE RANGE in years

FIGURE 17

GRAPH SHOWING THE AGE CHANGES OF THE LINEAR MEASUREMENT FX IN THE TRISOMY 21 AND CONTROL GROUPS

FIGURE 18

GRAPH SHOWING THE AGE CHANGES OF THE TOTAL FACIAL HEIGHT, NM, IN THE TRISOMY 21 AND CONTROL GROUPS


FX
TRISOMY
CONTROL
LENGTH in mm
5
4
3
2
4-5
6-8
9-11
12-15
16-19
ADULT
AGE RANGE in years

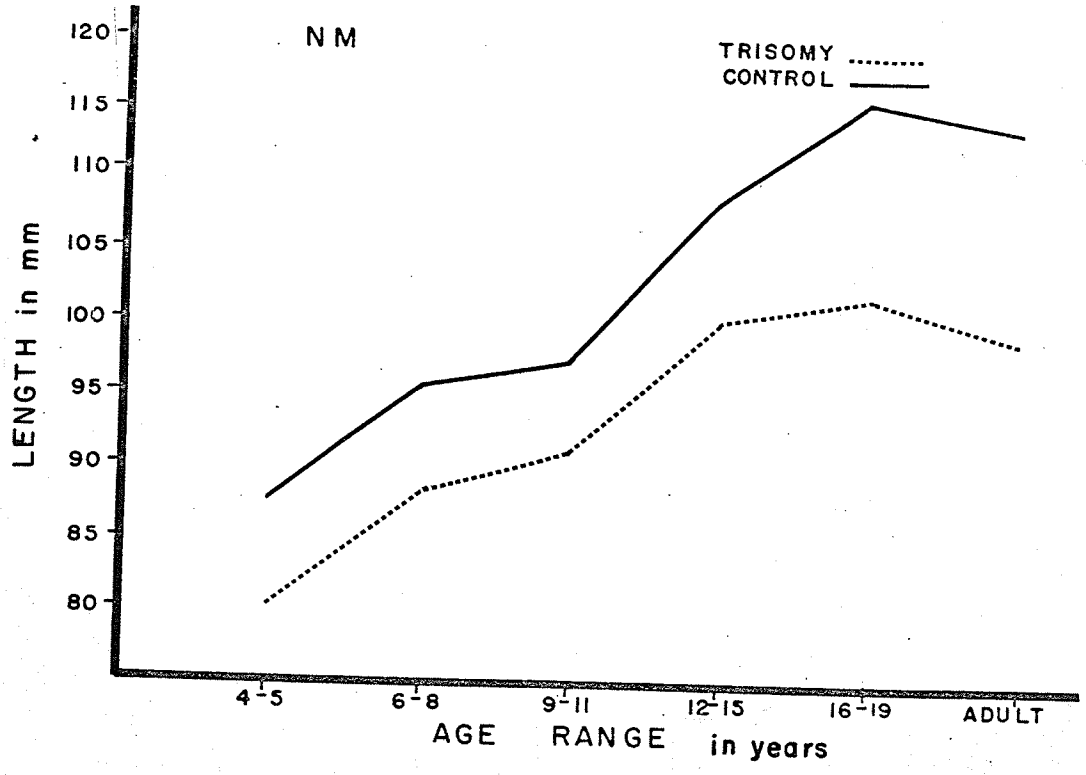
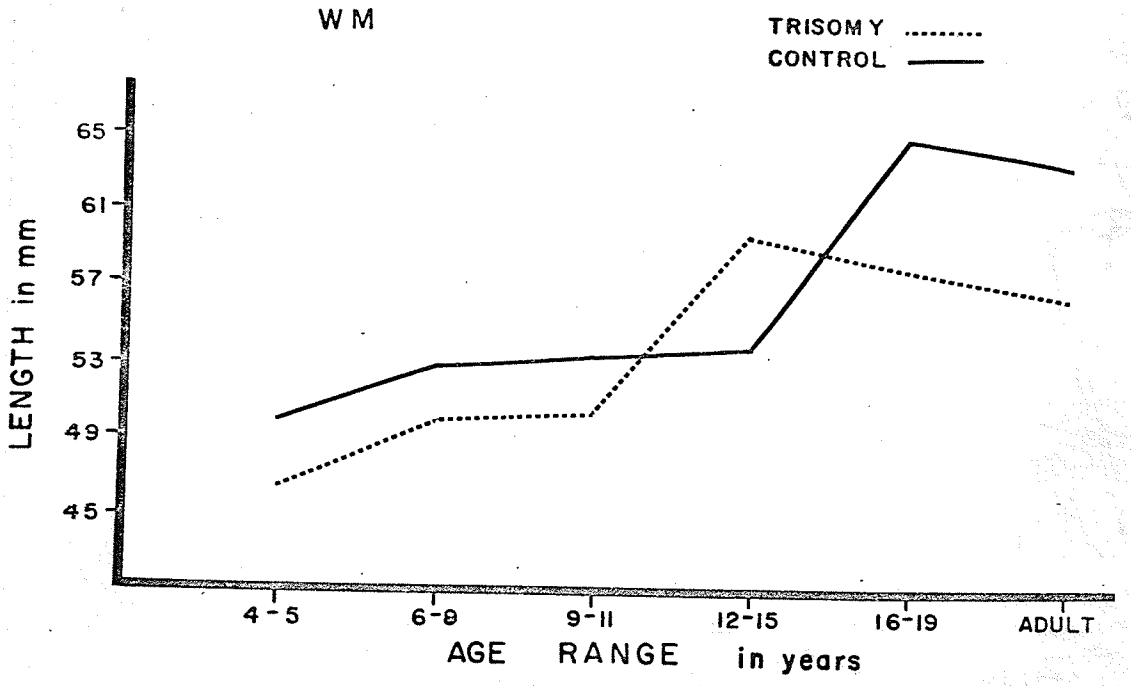

NM
TRISOMY
CONTROL
LENGTH in mm
120
115
110
105
100
95
90
85
80
4-5
6-8
9-11
12-15
16-19
ADULT
AGE RANGE in years

FIGURE 19

GRAPH SHOWING THE AGE CHANGES OF THE LOWER FACIAL HEIGHT, WM, IN THE TRISOMY 21 AND CONTROL GROUPS


W M
TRISOMY
CONTROL
LENGTH in mm
65
61
57
53
49
45
4-5
6-8
9-11
12-15
16-19
ADULT
AGE RANGE in years

CHAPTER V

DISCUSSION

I. OVERALL GROWTH

The craniofacial complex of the Trisomy 21 group was significantly smaller than the control, or normal group. Within every age range, this size difference was noted. The findings corresponded to most investigations concerning Down's syndrome. Thus, it is well documented that a definite effect of this syndrome is a retardation of the growth centres of the craniofacial skeleton.

Using angular and linear measurements to construct facial polygons, as seen in Figure 20, the size difference of these two groups can be seen in each age range. This size difference, or growth retardation, was present at the age of four and growth from this age to the adult stage appears to be occurring at equal rates within the two groups.

It has been previously felt that individuals with Down's syndrome appeared to exhibit a retardation of growth throughout their period of development. However, the results of this study on the Trisomy 21 syndrome appeared to point out an opposite concept. While growth retardation may occur up to the age of four, growth appeared to have undergone a normal rate after this age.

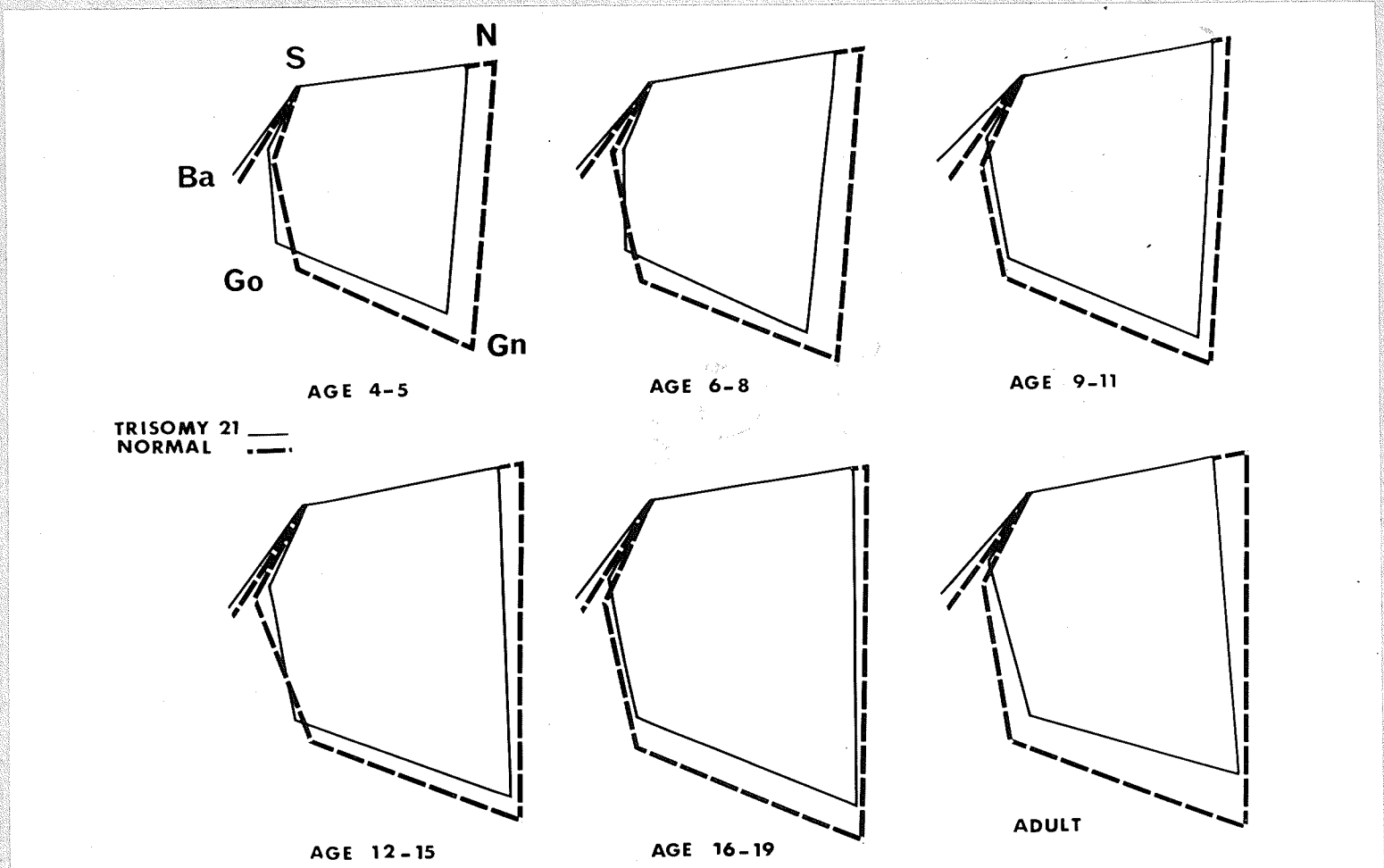


FIGURE 20

ILLUSTRATION SHOWING THE COMPARISON OF GROWTH TRENDS OF THE TRISOMY 21 GROUP AND THE CONTROL GROUP IN EACH AGE RANGE

The growth retardation that was present evidently occurred before the age of four and could possibly have been evident at birth. Oster (1953) in a study of newborns with Down's syndrome, found the weight of these infants to be less than the average weight of a normal newborn. With the use of an infant cephalometer, a study could be done on newborns with the Trisomy 21 syndrome to observe the results of intrauterine growth and development.

Sassouni, et al. (1964) showed that in Down's Syndrome the major portion of the adult face was formed by 10 years of age. However, this present study indicated strongly that the growth of the Trisomy 21 group continued into the 16-19 age range which is more comparable to the normal individual.

Although this study indicated a normal rate of growth after the age of four years in the Trisomy 21 group, there are certain changes in the cranial base and profile of these individuals. These changes will be discussed in the following sections.

II. CRANIAL BASE

The shortening of the cranial base in the Trisomy 21 syndrome, which has been reported for Down's syndrome by past investigators, was borne out in this study. The results

of the linear measurements and ratios of these linear measurements also showed that the anterior cranial base of the Trisomy 21 group shortened more than the posterior cranial base.

This shortening of the cranial base indicates a growth retardation or early closure of the sphenoethmoidal and sphenooccipital synchondrosis. Because of the greater shortening of the anterior cranial base, it can be assumed that the growth activity of the sphenoethmoidal synchondrosis was affected to a greater extent. Previous investigations have shown that the sphenoethmoidal synchondrosis closed during the seventh year of life while the sphenooccipital synchondrosis closed between 13 and 16 years of life. It cannot be determined by this study exactly when these two synchondrosis closed, but, since the size difference is apparent by the age of four and since growth appears to occur at a normal rate after this age, it may be assumed that these synchondrosis exhibit only a retardation in their activity.

The Trisomy 21 group showed greater flexion of the cranial base angle. At the age range of 4-5, the cranial base angles of the two groups were about equal, but with an increase in age, the angle gradually became larger in the Trisomy 21 syndrome.

The reason for more flexion in the Trisomy 21 group may

be attributed to two factors. One is the direction of growth of the sphenooccipital synchondrosis and the appositional growth patterns, and the second is a flattening of the cranial base due to the lowering of the sella turcia. This is indicated by a smaller SGo measurement, but because a shorter ramus can influence this measurement, it would be difficult to definitely state that the sella was lowered. Sassouni, et al. (1964) and Kisling (1966) found a lowering a sella as flexion of the cranial base angle occurred.

The flexion of the cranial base should influence the position of both the maxilla and the mandible by positioning them more posteriorly. However, in the sample of the Trisomy 21 syndrome, the maxilla and mandible did not move posteriorly with the flexion of the cranial base. The reasons for this were not brought out in this study and further investigation is required to determine the factors that influence this positioning.

III. NASOMAXILLARY COMPLEX

The maxilla of the Trisomy 21 group was found to be definitely shorter than that of the normal group. This shortening has been reported by other investigators of Down's syndrome. However, when the maxilla was related to the anterior cranial base by the angle SNA, it was found that a normal protrusion existed in the Trisomy 21 syndrome.

Kisling (1966) also found this same relationship of the maxilla to the anterior cranial base, but these findings were contrary to Sassouni, et al. (1964). These latter investigators found the maxilla to be in a posterior position in relation to the anterior cranial base.

Kisling (1966) found the maxilla to be more inclined to the anterior cranial base than was the maxillary occlusal plane to the anterior cranial base. He assumed that the atypical positioning of the tongue may account for this. This present study showed a greater inclination of the maxilla to the anterior cranial base, but its relationship with the occlusal plane was not investigated. It appeared that Kisling's finding was supported to some degree by the finding in this study.

IV. MANDIBLE

Spitzer and Robinson (1955) have described the mandible in Down's syndrome as being underdeveloped with a short ramus. This study confirmed this finding in that it showed smaller dimensions in length of the body and ramus of the mandible. Sassouni et al. (1964) and Kisling (1966) also showed similar results.

A study of the angle SNB and SNGn strongly indicated that the mandible of individuals with Down's syndrome was in a protrusive position when compared to the anterior

cranial base. Kisling (1966) also found a protrusive mandible, but Sassouni et al. (1964) found a normally positioned mandible.

All investigators of Down's syndrome agreed that a mandibular prognathic appearance was characteristic of the facial profile of these individuals. However, there was disagreement as to what factors create this mandibular prognathism. Sassouni et al. (1964) felt that the combination of a retruded maxilla with a normally positioned mandible caused the mandibular prognathic appearance. Kisling (1966) specified that the reason was a normally positioned maxilla with a protruded mandible. Raison, Lepoivre, and Ackermann (1956) found that in their study of Down's syndrome, an alveolar rather than a basal mandibular prognathism was present.

The results of angles SNA, SNB, and SNGn of this present study have been cited and the conclusions that have been drawn from these findings showed that the characteristic prognathism that is seen in individuals with the Trisomy 21 syndrome appeared to be due to a basilar mandibular prognathism while the maxilla was in a normal position when both were related to the anterior cranial base.

V. FACIAL HEIGHT AND DEPTH

The anterior facial height was represented by the line

NM and was referred to as the skeletal facial height. However, this measurement was dependent to some degree on the dental occlusion. Therefore, consideration must be given to this when reviewing the linear values.

The anterior face height was significantly smaller in the Trisomy 21 syndrome and a similar size difference was seen in the posterior facial height. The Trisomy 21 group showed a longer lower facial height when compared to the upper facial height. This was expected since there appears to be a prognathic mandible. The longer lower face adds to this characteristic mandibular prognathism.

The various measurements that determined the facial depth, showed the face of the individuals with the Trisomy 21 syndrome to be smaller in this dimension as well. It may be assumed that all growth centres of the face were retarded sometime in development.

VI. KARYOTYPE-PHENOTYPE RELATIONSHIP

Richards (1965) discussed several clinical changes in the phenotype of Down's syndrome that resulted as the individual aged. He stated that many adult individuals with Down's syndrome are less difficult to distinguish from the normal individual.

A cross sectional investigation of the various age ranges of this present study helps to substantiate the

remarks of Richards. The phenotype of the craniofacial complex of individuals with the specific karyotype of Trisomy 21 showed interesting changes with aging. The phenotype of the Trisomy 21 syndrome at ages 4-5 years was similar to the normal, except for the general retardation of growth. With an increase in age, the size difference was still present, but in addition, skeletal configurations began to change. The profile changes were the most noticable. The maxilla maintained a normal protrusive relationship with the anterior cranial base while the mandible developed a more anterior protrusive relationship than was seen in the normal individual. These changes resulted in the characteristic phenotype associated with Trisomy 21.

An area that is often overlooked in studies of this syndrome is the frontal bone. With an increase in age of the 21 Trisomics, there was a greater prominence of the frontal bone in relation to the profile. The greater prominence of this area in the adult would tend to balance the phenotypic effects of the mandibular protrusion. These findings, in addition to those of Richards, could simulate a normal phenotypic appearance to the adult face.

However, two areas of the profile have not been investigated at this time by any study. They are the nasal bone and the soft tissue profile. Once these areas have been studied and this information is added to what has been

established, then the phenotypic changes that occur with age in the Trisomy 21 syndrome will be more easily explained.

The results of this study differ somewhat from the findings of other investigators. This may be due to the fact that this study involved a sample of proven Trisomy 21 cases, while the other studies did not indicate a separation of translocations, mosaics, and Trisomy 21 syndromes.

CHAPTER VI

SUMMARY AND CONCLUSIONS

The present study was undertaken to evaluate the craniofacial complex of the Trisomy 21 syndrome and to ascertain if the phenotype of this group differs from the phenotypes established in the literature for Down's syndrome. The sample consisted of a proven Trisomy 21 group and a randomly selected control group. Each group contained 121 individuals varying in age from 4 to 48 years. Both groups were studied through the use of laterial and posteroanterior cephalometric radiographs.

A cephalometric analysis consisting of angular and linear measurements was used to evaluate and compare the two groups and an analysis of variance was performed to determine the significance of the results. The findings that were obtained from these computations and from subjective investigation of the results were as follows:

1. Almost all linear measurements of the Trisomy 21 syndrome are significantly smaller than the control group with the only exception being the linear measurement FX. Therefore, the overall size of the craniofacial complex of the Trisomy 21 syndrome is definitely smaller than that of the control group.

2. The growth retardation that was exhibited in the smaller linear measurements was present at the age of four. However, growth from this age to the adult appeared to be occurring at equal rates among the two groups.
3. Differences existed in the craniofacial components between the sexes in the Trisomy 21 syndrome, but these differences were similar to the differences in the control group.
4. The cranial base angle, NSBa, of the control group remained stable throughout the age ranges, but in the Trisomy 21 group it continued to become more obtuse with increasing age. This resulted in a flexion of the posterior cranial base.
5. The anterior cranial base of the Trisomy 21 group was proportionately shorter in relation to the posterior cranial base. This indicated that the growth activity of the sphenoethmoidal synchondrosis is retarded to a greater extent than the sphenooccipital synchondrosis.
6. When compared to the anterior cranial base, the maxilla of the Trisomy 21 syndrome was found to be in a normal anterioposterior position, while the mandible was in a forward position.

7. The gonial angle of the control group remained constant with growth of the face while the gonial angle of the Trisomy 21 group became more obtuse. However, the angular value in the Trisomy 21 was more acute than the control in each of the age ranges.
8. The anterior and posterior facial height were significantly smaller in the Trisomy 21 syndrome. The lower facial height of both groups was longer than the upper facial height, but in the Trisomy 21 group, the lower face showed an even greater length in proportion to the upper facial height.
9. The upper, middle, and lower facial depths of the Trisomy 21 syndrome were smaller than their respective facial depths of the control group.
10. The measurements involving the frontal bone indicated that in the Trisomy 21 syndrome there was an increase in frontal prominence with each increase in age.
11. A consideration of the various results indicated strongly that the characteristic mandibular prognathic appearance of individuals with Trisomy 21 syndrome was due to a mandibular basilar prognathism in conjunction with a normal positioning of the maxilla.

12. The prominence of the frontal bone in the adult individual with the Trisomy 21 syndrome may have an influence in counteracting the mandibular protrusion to help bring about a normal profile. However, no conclusion can be drawn on the profile without information on the development of the nasal bone and the overlying soft tissue of the face.

APPENDIX

TABLE IV

MEANS AND DIFFERENCE OF MEANS FOR ALL ANGULAR VARIABLES COMPARING THE TRISOMY 21 GROUP AND THE CONTROL GROUP

Angle	Trisomy 21	Control	Difference of Means
NSBa	138.53	131.57	6.96 ++
NSAr	126.53	125.12	1.41
NSGo	103.53	103.03	0.50 +
SNA	81.60	80.76	0.84
SNB	80.02	77.63	2.39 ++
ANB	1.58	3.14	1.56 ++
NSGn	66.47	67.30	0.83
SNGn	80.88	78.80	2.08 +
SArGo	143.74	143.29	0.45
SGoGn	109.58	110.54	0.96
ArGoGn	123.45	126.16	3.29 ++
NOAns	8.70	7.67	1.03 ++
AnsTGn	24.11	25.29	1.18
NVGn	32.26	32.93	0.67
SFN	51.94	56.94	8.00 ++
SFA	65.60	68.09	2.49 ++
SFB	65.94	66.48	0.54 +
AFB	- 0.34	1.64	1.98 ++

\+ = Significant at 5% level
++ = Significant at 1% level

TABLE V

MEANS AND DIFFERENCE OF MEANS FOR ALL LINEAR VARIABLES COMPARING THE TRISOMY 21 GROUP AND THE CONTROL GROUP

Line	Trisomy 21	Control	Difference of Means
SN	58.10	65.02	6.92 ++
SBa	36.56	40.13	3.57 ++
BaN	88.50	96.08	7.58 ++
SAr	24.91	29.68	4.77 ++
ArGo	40.75	42.38	1.63 ++
SGo	62.36	68.26	5.90 ++
NM	95.27	104.26	8.99 ++
NW	40.84	46.59	5.75 ++
WM	54.68	57.77	3.09 ++
AnsPns	37.84	43.28	5.44 ++
GoGn	66.68	69.79	3.11 ++
AG	57.00	62.62	5.62 ++
SGn	105.61	113.27	7.66 ++
SF	66.41	71.40	4.99 ++
FX	4.24	2.75	1.49 ++

\+ = Significant at 5% level
++ = Significant at 1% level

TABLE VI

MEANS AND DIFFERENCE OF MEANS FOR ALL RATIO VARIABLES COMPARING THE TRISOMY 21 GROUP AND THE CONTROL GROUP

Ratio	Trisomy 21	Control	Difference of Means
SN/SBa	1.61	1.63	0.02
SN/NBa	0.66	0.68	0.02 ++
SN/NM	0.62	0.63	0.01
SN/AnsPns	1.55	1.52	0.03 ++
SN/GoGn	0.88	0.94	0.06 ++
SN/AG	1.02	1.04	0.02
SN/SGn	0.55	0.58	0.03 ++
SBa/NBa	0.41	0.42	0.01
SAr/ArGo	0.63	0.70	0.07 ++
ArGo/GoGn	0.61	0.61	0.00
SGo/NM	0.65	0.65	0.00
NW/WM	0.75	0.81	0.06 ++
AnsPns/GoGn	0.57	0.62	0.05 ++
AnsPns/AG	0.66	0.69	0.03 ++
AG/GoGn	0.86	0.90	0.04 ++
SN/SGo	0.95	0.96	0.01
SN/SF	1.14	1.10	0.04 ++

+ = Significant at 5% level
++ = Significant at 1% level

TABLE VII

MEANS AND DIFFERENCE OF MEANS FOR ALL ANGULAR VARIABLES COMPARING THE FEMALE TRISOMY 21 GROUP AND THE FEMALE CONTROL GROUP

Angle	Trisomy 21	Control	Difference of Means
NSBa	138.84	131.48	7.40 ++
NSAr	126.52	124.93	1.59 ++
NSGo	103.04	103.16	0.12
SNA	81.79	80.93	0.86 ++
SNB	80.16	77.73	2.43 ++
ANB	1.63	3.20	1.57 ++
NSGn	65.65	67.16	1.51 ++
SNGn	81.17	78.80	2.37 ++
SArGo	143.39	144.44	1.05 +
SGoGn	108.80	110.43	1.63 ++
ArGoGn	122.61	125.43	2.82 ++
NOAns	8.38	8.02	0.36
AnsTGn	23.43	24.98	1.55 ++
NVGn	31.29	32.99	1.70 ++
SFN	52.42	57.93	5.51 ++
SFA	65.93	68.23	2.30 ++
SFB	66.29	66.39	0.10
AFB	- 0.37	1.91	2.28 ++

\+ = Significant at 5% level
++ = Significant at 1% level

TABLE VIII

MEANS AND DIFFERENCE OF MEANS FOR ALL LINEAR VARIABLES COMPARING THE FEMALE TRISOMY 21 GROUP AND THE FEMALE CONTROL GROUP

Line	Trisomy 21	Control	Difference of Means
SN	57.25	64.27	7.02 ++
SBa	35.39	39.44	4.05 ++
BaN	86.66	94.86	8.20 ++
SAr	33.91	28.97	4.94 ++
ArGo	40.35	41.05	0.70 ++
SGo	61.07	66.93	5.86 ++
NM	92.31	102.54	10.23 ++
NW	39.39	45.86	6.47 ++
WM	52.88	56.87	3.99 ++
AnsPns	37.43	42.50	5.07 ++
GoGn	65.21	69.51	4.30 ++
AG	56.17	62.36	6.19 ++
SGn	102.92	111.58	8.66
SF	65.27	70.30	5.03 ++
FX	4.20	2.51	1.69 ++

\+ = Significant at 5% level
++ = Significant at 1% level

TABLE IX

MEANS AND DIFFERENCE OF MEANS FOR ALL RATIO VARIABLES COMPARING THE FEMALE TRISOMY 21 GROUP AND THE FEMALE CONTROL GROUP

Ratio	Trisomy 21	Control	Difference of Means
SN/SBa	1.63	1.64	0.01
SN/NBa	0.66	0.68	0.02 ++
SN/NM	0.63	0.63	0.00
SN/AnsPns	1.54	1.53	0.01
SN/GoGn	0.88	0.93	0.05 ++
SN/AG	1.02	1.03	0.01 ++
SN/SGn	0.56	0.58	0.02 ++
SBa/NBa	0.41	0.42	0.01 ++
SAr/ArGo	0.61	0.71	0.10 ++
ArGo/GoGn	0.62	0.59	0.03 ++
SGo/NM	0.66	0.65	0.01 ++
NW/WM	0.75	0.81	0.06 ++
AnsPns/GoGn	0.58	0.61	0.03 ++
AnsPns/AG	0.67	0.68	0.01 ++
AG/GoGn	0.87	0.90	0.03 ++
SN/SGo	0.95	0.97	0.02 ++
SN/SF	1.14	1.10	0.04 ++

\+ = Significant at 5% level
++ = Significant at 1% level

TABLE X

MEANS AND DIFFERENCE OF MEANS FOR ALL ANGULAR VARIABLES COMPARING THE MALE TRISOMY 21 GROUP AND THE MALE CONTROL GROUP

Angle	Trisomy 21	Control	Difference of Means
NSBa	138.21	131.66	6.55 ++
NSAr	126.53	125.31	1.22 ++
NSGo	104.03	102.91	1.12 ++
SNA	81.40	80.93	0.47
SNB	79.88	77.53	2.35 ++
ANB	1.53	3.07	1.54 ++
NSGn	67.30	67.44	0.14
SNGn	80.59	78.80	1.79 ++
SArGo	144.11	142.11	2.00 ++
SGoGn	110.37	110.64	0.27
ArGoGn	124.32	126.91	2.59 ++
NOAns	9.02	7.30	1.62 ++
AnsTGn	24.80	25.61	0.81 +
NVGn	34.57	34.90	0.33
SFN	51.46	55.94	4.48 ++
SFA	65.27	67.94	2.67 ++
SFB	65.58	66.57	0.99 ++
AFB	-0.31	1.37	1.68 ++

+ = Significant at 5% level
++ = Significant at 1% level

TABLE XI

MEANS AND DIFFERENCE OF MEANS FOR ALL LINEAR VARIABLES COMPARING THE MALE TRISOMY 21 GROUP AND THE MALE CONTROL GROUP

Line	Trisomy 21	Control	Difference of Means
SN	58.97	65.78	6.81 ++
SBa	37.74	40.83	3.09 ++
BaN	90.37	97.31	7.06 ++
SAr	25.93	30.40	4.47 ++
ArGo	41.15	43.74	2.59 ++
SGo	63.67	69.62	5.95 ++
NM	98.28	106.01	7.73 ++
NW	42.30	47.33	5.03 ++
WM	56.51	58.69	2.18 ++
AnsPns	38.26	44.07	5.81 ++
GoGn	68.18	70.08	1.90 ++
AG	57.85	62.89	5.04 ++
SGn	108.36	115.00	6.64 ++
SF	67.57	72.52	4.95 ++
FX	4.28	2.99	1.29 ++

+ = Significant at 5% level
++ = Significant at 1% level

TABLE XII

MEANS AND DIFFERENCE OF MEANS FOR ALL RATIO VARIABLES COMPARING THE MALE TRISOMY 21 GROUP AND THE MALE CONTROL GROUP

Ratio	Trisomy 21	Control	Difference of Means
SN/SBa	1.58	1.63	0.05 ++
SN/NBa	0.65	0.68	0.03 ++
SN/NM	0.61	0.63	0.02 ++
SN/AnsPns	1.56	1.51	0.05 ++
SN/GoGn	0.87	0.95	0.08 ++
SN/AG	1.02	1.05	0.03 ++
SN/SGn	0.55	0.58	0.03 ++
SBa/NBa	0.42	0.42	0.00
SAr/ArGo	0.65	0.70	0.05 ++
ArGo/GoGn	0.60	0.62	0.02 ++
SGo/NM	0.65	0.66	0.01 ++
NW/WM	0.76	0.81	0.05 ++
AnsPns/GoGn	0.56	0.63	0.07 ++
AnsPns/AG	0.66	0.70	0.04 ++
AG/GoGn	0.86	0.91	0.05 ++
SN/SGo	0.94	0.96	0.02 ++
SN/SF	1.15	1.10	0.05 ++

+ = Significant at 5% level
++ = Significant at 1% level

TABLE XIII

MEANS AND DIFFERENCE OF MEANS FOR ALL ANGULAR VARIABLES COMPARING THE TRISOMY 21 GROUP AND THE CONTROL GROUP IN THE 4 - 5 YEAR AGE RANGE

Angle	Trisomy 21	Control	Difference of Means
NSBa	136.00	131.11	4.89 +
NSAr	122.50	119.43	3.07
NSGo	105.46	99.25	6.21 ++
SNA	81.04	82.46	1.02
SNB	77.00	78.21	1.21
ANB	4.04	4.21	0.17
NSGn	66.86	65.36	1.50
SNGn	77.29	78.14	0.85
SArGo	150.36	147.25	3.11
SGoGn	110.57	115.39	4.82 +
ArGoGn	122.57	129.00	6.43 +
NOAns	8.11	7.30	0.81
AnsTGn	26.68	27.50	0.82
NVGn	34.57	34.18	0.39
SFN	46.46	50.11	3.65
SFA	60.29	64.50	4.21 ++
SFB	59.75	63.04	3.29 +
AFB	0.54	1.46	0.92

+ = Significant at 5% level
++ = Significant at 1% level

TABLE XIV

MEANS AND DIFFERENCE OF MEANS FOR ALL LINEAR VARIABLES COMPARING THE TRISOMY 21 GROUP AND THE CONTROL GROUP IN THE 4 - 5 YEAR AGE RANGE

Line	Trisomy 21	Control	Difference of Means
SN	53.91	59.67	5.76 ++
SBa	31.54	33.69	2.15
BaN	79.41	85.95	6.54 ++
SAr	21.43	23.38	1.95
ArGo	30.02	34.87	4.85 ++
SGo	48.92	56.00	7.08 ++
NM	80.36	88.14	7.78 ++
NW	32.99	38.24	5.25 ++
WM	46.97	49.90	2.93
AnsPns	30.83	36.69	5.86 ++
GoGn	57.14	59.43	2.29
AG	51.55	58.29	6.74 ++
SGn	87.97	97.54	9.57 ++
SF	65.57	69.10	3.53 +
FX	4.75	4.25	0.50

+ = Significant at 5% level
++ = Significant at 1% level

TABLE XV

MEANS AND DIFFERENCE OF MEANS FOR ALL RATIO VARIABLES COMPARING THE TRISOMY 21 GROUP AND THE CONTROL GROUP IN THE 4 - 5 YEAR AGE RANGE

Ratio	Trisomy 21	Control	Difference of Means
SN/SBa	1.72	1.78	0.06
SN/NBa	0.68	0.69	0.01
SN/NM	0.67	0.68	0.01
SN/AnsPns	1.76	1.65	0.09 +
SN/GoGn	0.95	1.01	0.06 +
SN/AG	1.05	1.02	0.03
SN/SGn	0.61	0.61	0.00
SBa/NBa	0.40	0.39	0.01
SAr/ArGo	0.73	0.67	3.06
ArGo/GoGn	0.53	0.59	0.06 +
SGo/NM	0.61	0.64	0.03
NW/WM	0.71	0.77	0.06 +
AnsPns/GoGn	0.54	0.62	0.08 ++
AnsPns/AG	0.60	0.63	0.03
AG/GoGn	0.90	0.98	0.08 ++
SN/SGo	1.11	1.07	0.04
SN/SF	1.22	1.16	0.06 ++

\+ = Significant at 5% level
++ = Significant at 1% level

TABLE XVI

MEANS AND DIFFERENCE OF MEANS FOR ALL ANGULAR VARIABLES COMPARING THE TRISOMY 21 GROUP AND THE CONTROL GROUP IN THE 6 - 8 YEAR AGE RANGE

Angle	Trisomy 21	Control	Difference of Means
NSBa	137.50	134.22	3.28
NSAr	125.12	125.67	0.55
NSGo	105.85	102.83	3.02 ++
SNA	81.00	80.30	0.70
SNB	77.59	76.98	0.61
ANB	3.29	3.33	0.04
NSGn	67.59	66.67	0.92
SNGn	77.91	77.54	0.37
SArGo	148.65	142.33	6.32 +
SGoGn	109.85	111.37	1.52
ArGoGn	123.09	127.37	4.28
NOAns	10.41	7.30	3.11 +
AnsTGn	24.79	26.33	1.54
NVGn	35.18	33.59	1.59
SFN	51.97	56.07	4.10 +
SFA	63.12	66.76	3.64 ++
SFB	61.94	65.20	3.26 ++
AFB	1.18	1.74	0.56

+ = Significant at 5% level
++ = Significant at 1% level

TABLE XVII

MEANS AND DIFFERENCE OF MEANS FOR ALL LINEAR VARIABLES COMPARING THE TRISOMY 21 GROUP AND THE CONTROL GROUP IN THE 6 - 8 YEAR AGE RANGE

Line	Trisomy 21	Control	Difference of Means
SN	56.58	62.82	6.24 ++
SBa	35.60	37.76	2.16 +
BaN	86.10	92.99	6.89 ++
SAr	23.20	26.57	3.37 ++
ArGo	33.27	37.86	4.49 ++
SGo	54.16	61.26	7.10 ++
NM	88.15	95.65	7.50 ++
NW	37.96	42.74	4.78 ++
WM	50.06	52.95	2.89
AnsPns	35.38	39.85	4.47 ++
GoGn	63.01	65.08	2.07
AG	56.16	60.08	3.92 ++
SGn	96.70	104.03	7.67 ++
SF	65.70	69.54	3.84 ++
FX	3.39	2.63	0.76

\+ = Significant at 5% level
++ = Significant at 1% level

TABLE XVIII

MEANS AND DIFFERENCE OF MEANS FOR ALL RATIO VARIABLES COMPARING THE TRISOMY 21 GROUP AND THE CONTROL GROUP IN THE 6 - 8 YEAR AGE RANGE

Ratio	Trisomy 21	Control	Difference of Means
SN/SBa	1.60	1.67	0.07
SN/NBa	0.66	0.68	0.02 +
SN/NM	0.65	0.66	0.01
SN/AnsPns	1.61	1.59	0.02
SN/GoGn	0.90	0.97	0.07 ++
SN/AG	1.01	1.05	0.04 +
SN/SGn	0.59	0.60	0.01
SBa/NBa	0.41	0.41	0.00
SAr/ArGo	0.71	0.71	0.00
ArGo/GoGn	0.53	0.58	0.05 +
SGo/NM	0.62	0.64	0.02
NW/WM	0.76	0.81	0.05 +
AnsPns/GoGn	0.56	0.61	0.05 ++
AnsPns/AG	0.63	0.66	0.03
AG/GoGn	0.89	0.93	0.04
SN/SGo	1.05	1.03	0.02
SN/SF	1.16	1.11	0.05 +

+ = Significant at 5% level
++ = Significant at 1% level

TABLE XIX

MEANS AND DIFFERENCE OF MEANS FOR ALL ANGULAR VARIABLES COMPARING THE TRISOMY 21 GROUP AND THE CONTROL GROUP IN THE 9 - 11 YEAR AGE RANGE

Angle	Trisomy 21	Control	Difference of Means
NSBa	140.53	129.31	11.22 ++
NSAr	127.13	123.83	3.30
NSGo	105.47	102.78	2.69
SNA	79.63	81.03	1.40
SNB	77.67	77.22	0.45
ANB	2.17	3.86	1.69
NSGn	67.60	66.19	1.41
SNGn	78.37	78.47	0.10
SArGo	144.80	142.19	2.61
SGoGn	110.07	110.64	0.57
ArGoGn	124.03	127.25	3.22
NOAns	11.20	7.58	3.62 ++
AnsTGn	25.10	24.61	0.49
NVGn	34.90	31.89	3.01
SFN	51.30	57.47	6.17 ++
SFA	65.40	68.72	3.32 +
SFB	65.20	66.58	1.38
AFB	0.20	2.14	1.76 +

+ = Significant at 5% level
++ = Significant at 1% level

TABLE XX

MEANS AND DIFFERENCE OF MEANS FOR ALL LINEAR VARIABLES COMPARING THE TRISOMY 21 GROUP AND THE CONTROL GROUP IN THE 9 - 11 YEAR AGE RANGE

Line	Trisomy 21	Control	Difference of Means
SN	57.42	63.39	5.97 ++
SBa	36.42	38.44	2.02
BaN	88.40	92.98	4.58 ++
SAr	23.96	28.74	4.78 ++
ArGo	36.04	39.37	3.33 +
SGo	57.26	62.90	5.64 ++
NM	90.75	97.46	6.71 ++
NW	40.13	44.19	4.06 ++
WM	50.63	53.27	2.64
AnsPns	35.47	41.66	6.19 ++
GoGn	63.84	66.23	2.39
AG	55.57	62.03	6.46 ++
SGn	100.09	106.66	6.57 ++
SF	65.16	69.79	4.63 ++
FX	3.71	2.51	1.20

+ = Significant at 5% level
++ = Significant at 1% level

TABLE XXI

MEANS AND DIFFERENCE OF MEANS FOR ALL RATIO VARIABLES COMPARING THE TRISOMY 21 GROUP AND THE CONTROL GROUP IN THE 9 - 11 YEAR AGE RANGE

Ratio	Trisomy 21	Control	Difference of Means
SN/SBa	1.59	1.66	0.07
SN/NBa	0.65	0.68	0.03 ++
SN/NM	0.64	0.65	0.01
SN/AnsPns	1.63	1.53	0.10 +
SN/GoGn	0.90	0.96	0.06 +
SN/AG	1.04	1.02	0.02
SN/SGn	0.58	0.60	0.02
SBa/NBa	0.41	0.41	0.00
SAr/ArGo	0.67	0.74	0.07 +
ArGo/GoGn	0.57	0.60	0.03
SGo/NM	0.63	0.65	0.02
NW/WM	0.80	0.83	0.03
AnsPns/GoGn	0.56	0.63	0.07 ++
AnsPns/AG	0.64	0.67	0.03
AG/GoGn	0.87	0.94	0.07 ++
SN/SGo	1.01	1.01	0.00
SN/SF	1.13	1.10	0.03 +

+ = Significant at 5% level
++ = Significant at 1% level

TABLE XXII

MEANS AND DIFFERENCE OF MEANS FOR ALL ANGULAR VARIABLES COMPARING THE TRISOMY 21 GROUP AND THE CONTROL GROUP IN THE 12 - 15 YEAR AGE RANGE

Angle	Trisomy 21	Control	Difference of Means
NSBa	137.02	131.30	5.72 ++
NSAr	124.90	125.41	0.51
NSGo	102.44	103.63	1.19
SNA	82.81	80.30	2.51 +
SNB	81.33	77.30	4.03 ++
ANB	1.22	3.00	1.78 +
NSGn	66.25	67.57	1.32
SNGn	82.33	79.35	2.98 +
SArGo	144.62	142.85	1.77
SGoGn	110.10	109.00	1.10
ArGoGn	123.67	125.30	1.63
NOAns	6.65	6.74	0.09
AnsTGn	25.56	24.96	0.60
NVGn	31.71	31.78	0.07
SFN	52.35	59.09	6.74 ++
SFA	67.23	69.04	1.81
SFB	67.45	67.30	0.15
AFB	- 0.31	1.74	2.05 ++

+ = Significant at 5% level
++ = Significant at 1% level

TABLE XXIII

MEANS AND DIFFERENCE OF MEANS FOR ALL LINEAR VARIABLES COMPARING THE TRISOMY 21 GROUP AND THE CONTROL GROUP IN THE 12 - 15 YEAR AGE RANGE

Line	Trisomy 21	Control	Difference of Means
SN	59.31	67.29	7.98 ++
SBa	38.32	43.05	4.73 ++
BaN	90.57	99.38	8.81 ++
SAr	26.12	31.79	5.67 ++
ArGo	43.70	44.20	0.50
SGo	66.40	72.21	5.81 ++
NM	100.54	108.47	7.93 ++
NW	42.27	48.81	6.54 ++
WM	59.36	59.66	0.30
AnsPns	39.13	43.85	4.72 ++
GoGn	69.45	72.09	2.64
AG	57.87	63.15	5.28 ++
SGn	111.07	117.29	7.22 ++
SF	67.11	72.40	5.29 ++
FX	4.50	2.32	2.18 ++

+ = Significant at 5% level
++ = Significant at 1% level

TABLE XXIV

MEANS AND DIFFERENCE OF MEANS FOR ALL RATIO VARIABLES COMPARING THE TRISOMY 21 GROUP AND THE CONTROL GROUP IN THE 12 - 15 YEAR AGE RANGE

Ratio	Trisomy 21	Control	Difference of Means
SN/SBa	1.56	1.57	0.01
SN/NBa	0.66	0.68	0.02 ++
SN/NM	0.59	0.62	0.03 +
SN/AnsPns	1.52	1.54	0.02
SN/GoGn	0.86	0.94	0.08 ++
SN/AG	1.03	1.07	0.04 +
SN/SGn	0.54	0.58	0.04 ++
SBa/NBa	0.42	0.43	0.01
SAr/ArGo	0.60	0.72	0.12 ++
ArGo/GoGn	0.63	0.62	0.01
SGo/NM	0.66	0.67	0.01
NW/WM	0.72	0.82	0.10 ++
AnsPns/GoGn	0.57	0.61	0.04 +
AnsPns/AG	0.68	0.70	0.02
AG/GoGn	0.84	0.88	0.04
SN/SGo	0.90	0.94	0.04
SN/SF	1.13	1.08	0.05 ++

+ = Significant at 5% level
++ = Significant at 1% level

TABLE XXV

MEANS AND DIFFERENCE OF MEANS FOR ALL ANGULAR VARIABLES COMPARING THE TRISOMY 21 GROUP AND THE CONTROL GROUP IN THE 16 - 19 YEAR AGE RANGE

Angle	Trisomy 21	Control	Difference of Means
NSBa	137.15	130.55	6.60 ++
SNAr	127.12	126.00	1.12
NSGo	102.81	103.64	0.83
SNA	82.04	79.86	2.18
SNB	81.54	77.41	4.13 +
ANB	0.50	2.45	1.95
NSGn	66.23	69.45	3.22
SNGn	82.46	79.09	3.35
SArGo	141.46	143.00	1.54
SGoGn	108.92	110.82	1.90
ArGoGn	124.00	127.09	3.09
NOAns	8.96	8.77	0.19
AnsTGn	22.96	25.86	2.90
NVGn	31.19	34.55	3.36
SFN	56.85	58.77	1.92
SFA	67.73	69.18	1.35
SFB	68.38	67.50	0.88
AFB	-0.65	1.68	2.33 ++

+ = Significant at 5% level
++ = Significant at 1% level

TABLE XXVI

MEANS AND DIFFERENCE OF MEANS FOR ALL LINEAR VARIABLES COMPARING THE TRISOMY 21 GROUP AND THE CONTROL GROUP IN THE 16 - 19 YEAR AGE RANGE

Line	Trisomy 21	Control	Difference of Means
SN	60.70	66.64	5.94 ++
SBa	38.43	43.44	5.01 ++
BaN	92.13	100.39	8.26 ++
SAr	27.79	33.45	5.56 ++
ArGo	44.23	47.00	2.77
SGo	68.69	73.37	4.68 ++
NM	103.08	115.91	12.83 ++
NW	44.41	50.94	6.53 ++
WM	58.67	64.97	6.30 ++
AnsPns	40.82	47.51	6.69 ++
GoGn	71.59	74.01	2.42
AG	60.23	64.41	4.18 +
SGn	114.22	124.31	10.09 ++
SF	67.49	72.38	4.89 ++
FX	3.45	2.36	1.09

+ = Significant at 5% level
++ = Significant at 1% level

TABLE XXVII

MEANS AND DIFFERENCE OF MEANS FOR ALL RATIO VARIABLES COMPARING THE TRISOMY 21 GROUP AND THE CONTROL GROUP IN THE 16 - 19 YEAR AGE RANGE

Ratio	Trisomy 21	Control	Difference of Means
SN/SBa	1.59	1.54	0.05
SN/NBa	0.66	0.66	0.00
SN/NM	0.59	0.58	0.01
SN/AnsPns	1.49	1.41	0.08
SN/GoGn	0.85	0.90	0.05
SN/AG	1.01	1.04	0.03
SN/SGn	0.53	0.54	0.01
SBa/NBa	0.42	0.43	0.01
SAr/ArGo	0.64	0.72	0.08 +
ArGo/GoGn	0.63	0.64	0.01
SGo/NM	0.67	0.66	0.01
NW/WM	0.76	0.79	0.03
AnsPns/GoGn	0.58	0.64	0.06 +
AnsPns/AG	0.68	0.74	0.06 +
AG/GoGn	0.85	0.87	0.02
SN/SGo	0.89	0.87	0.02
SN/SF	1.11	1.09	0.02

+ = Significant at 5% level
++ = Significant at 1% level

TABLE XXVIII

MEANS AND DIFFERENCE OF MEANS FOR ALL ANGULAR VARIABLES COMPARING THE TRISOMY 21 GROUP AND THE CONTROL GROUP IN THE ADULT AGE RANGE

Angle	Trisomy 21	Control	Difference of Means
NSBa	140.75	131.67	9.08 ++
NSAr	129.47	127.42	2.05
NSGo	101.93	104.34	2.41 ++
SNA	81.87	80.84	1.03
SNB	81.83	78.39	3.44 ++
ANB	0.04	2.45	2.41 ++
NSGn	65.56	68.30	2.74 +
SNGn	83.12	79.69	3.43 ++
SArGo	138.61	143.27	4.66 +
SGoGn	108.74	108.77	0.03
ArGoGn	123.37	123.73	0.36
NOAns	8.46	8.66	0.20
AnsTGn	21.75	24.02	2.27
NVGn	29.65	32.75	3.10 +
SFN	52.26	58.09	5.83 ++
SFA	66.99	69.19	2.20 +
SFB	68.50	67.89	0.61
AFB	-1.53	1.30	2.83 ++

\+ = Significant at 5% level
++ = Significant at 1% level

TABLE XXIX

MEANS AND DIFFERENCE OF MEANS FOR ALL LINEAR VARIABLES COMPARING THE TRISOMY 21 GROUP AND THE CONTROL GROUP IN THE ADULT AGE RANGE

Line	Trisomy 21	Control	Difference of Means
SN	58.94	67.66	8.72 ++
SBa	37.08	42.38	5.30 ++
BaN	90.41	100.60	10.19 ++
SAr	25.55	32.37	6.82 ++
ArGo	47.01	47.71	0.70
SGo	68.37	76.05	7.68 ++
NM	99.67	114.31	4.64 ++
NW	43.21	51.25	8.04 ++
WM	56.72	63.39	6.67 ++
AnsPns	40.71	47.67	6.96 ++
GoGn	69.54	76.62	7.08 ++
AG	58.32	65.68	7.36 ++
SGn	111.94	123.84	11.90 ++
SF	66.71	73.60	6.89 ++
FX	4.77	2.76	2.01 ++

+ = Significant at 5% level
++ = Significant at 1% level

TABLE XXX

MEANS AND DIFFERENCE OF MEANS FOR ALL RATIO VARIABLES COMPARING THE TRISOMY 21 GROUP AND THE CONTROL GROUP IN THE ADULT AGE RANGE

Ratio	Trisomy 21	Control	Difference of Means
SN/SBa	1.60	1.61	0.01
SN/NBa	0.65	0.67	0.02 ++
SN/NM	0.60	0.59	0.01
SN/AnsPns	1.46	1.43	0.03
SN/GoGn	0.85	0.89	0.04 +
SN/AG	1.01	1.03	0.02
SN/SGn	0.53	0.55	0.02 +
SBa/NBa	0.41	0.42	0.01
SAr/ArGo	0.55	0.68	0.13 ++
ArGo/GoGn	0.68	0.62	0.06 ++
SGo/NM	0.69	0.67	0.02
NW/WM	0.77	0.81	0.04 +
AnsPns/GoGn	0.59	0.62	0.03 +
AnsPns/AG	0.70	0.73	0.03 +
AG/GoGn	0.84	0.86	0.02
SN/SGo	0.87	0.89	0.02
SN/SF	1.13	1.09	0.04 ++

+ = Significant at 5% level
++ = Significant at 1% level

BIBLIOGRAPHY

BIBLIOGRAPHY

Adams, J.W. "Correction of Error in Cephalometric Roentgenograms," Angle Ortho., 10: 3-13, Jan., 1940.

Adams, J.W. "Cephalometric Studies on the Form of the Human Mandible," Angle Ortho., 18: 8, 1948.

Baer, M.J. "Dimensional Changes in the Human Head in the Third Decade of Life," Amer. J. Phys. Anthrop., 14 (4): 557-76, 1946.

Benda, C.E. "Growth Disorder of the Skull in Mongolism," Amer. J. Path., 16: 71, 1940.

Benda, C.E. "Observations on Malformation of the Head in Mongoloid Deficiency," J. Pediat., 19: 800-16, 1941.

Benda, C.E. "Mongolism: Comprehensive Review," Arch. Pediat., 73: 391, 1956.

Benda, C.E. The Child With Mongolism. New York and Boston: Grune and Stratton, 1960.

Bjork, A. "The Face in Profile," Svensk Tandlakare Tidskrift, 40: No. 56, 1947.

Bjork, A. "The Cranial Base Development," Amer. J. Ortho., 41: 198, 1955.

Bjork, A. "Cephalometric X-ray Investigations in Dentistry," Int. Dent. Jour., 4: 718-44, 1954.

Bjork, A. "Facial Growth in Man Studied With the Aid of Metallic Implants," Acta Odont. Scand., 13: 9-34, June, 1955.

Book,J.A., Fraccare, M., and Lindsten, J. "Cytogenetical Observations in Mongolism," Acta Paediatrica, 48: 453-68, Sept.,1959.

Brandt, N.J., et al. "Galactesaemia Loous and Down's Syndrome," Lancet, 2: 700, 1963.

Breg, W.R. "Genetic Aspects of Mental Retardation," Quart. Rev. Pediat., 17: 9-23, Jan.-Mar., 1962.

Broadbent, B.H. "A New X-ray Technique and its Application to Orthodontia," Angle Ortho., 1: 45-66, Apr., 1931.

Broadbent, B.H. "The Face of the Growing Child," Angle Ortho., 7: 209-33, 1937.

Broadway, E.S., Healy, M.J.R., and Poyton, H.G. "Accuracy of Tracings from Cephalometric Lateral Skull Radiographs," Brit.Soc. Study Ortho. Tr., 9-12,

Brodie, A.G . "On the Growth Pattern of the Human Head from the Third Month to Eighth Year of Life," Amer. J. Anat., 68: 209, 1941.

Brodie, A.G. "Facial Pattern, a Theme of Variation," Angle Ortho., 14: 75-87, 1946.

Brodie, A.G. and Ortiz, M.H. "On the Growth of the Head from Birth to the Third Month of Life," Anat. Rec., 103: 311, 1949.

Brodie, A.G., Jr. "The Behaviour of the Cranial Base and its Components as Revealed by Serial Cephalometric Roentgenograms," Angle Ortho., 25: 148-60, 1955.

Carter, C.O., et al. "Chromosome Translocation as a Cause of Familial Mongolism," Lancet 2: 678-80, Sept., 1960.

Cliff, M.W. "Roentgenographic Findings in Mongolism," Amer. J. Rtg., 9: 420-22, 1922.

Coben, S.E. "The Integration of Skeletal and Facial Variants," Amer. J. Ortho., 41: 407-34, 1955.

Davis, R.A. "Dento-facial Phenotype Association with Different Karyotypes in Mongolism." Unpublished Master's thesis, The University of Pittsburg, 1965.

Decoster, L. "The Familial Line Studied by a New Line of Reference," Tr. Europ. Ortho. Soc., 50-56, 1952.

Down, J.L. "Observations on Ethnic Classification of Idiots," London Hosp. Rep. III, 259, 1866.

Ford, C.E., et al. "The Chromosomes in a Patient Showing Both Mongolism and the Klineffelter Syndrome," Lancet, 1: 709-10, Apr., 1959.

Ford, E.H.R. "Growth of the Cranial Base," Amer. J. Ortho., 44: 498-509, 1958.

Fraccare, M., Kaijser, K., and Lindstein, J. "Chromosomal Abnormalities in Father and Mongol Child," Lancet, 1: 724-27, Apr., 1960.

Fraser, J. and Mitchell, A. "Kalmuck Idiocy: Report of a Case with Autopsy," J. Ment. Sc., 22: 161, 1876.

Garrod, A.E. "Congenital Heart Disease and the Mongol Type of Idiocy," Brit.Ment. J., 1: 1200, 1898.

Gibson, D., Pozsony, J., and Zarfas, D. "Dimensions of Mongolism, II. The Interaction of Clinical Indices," Amer. J. Men. Def., 68: 503, 1964.

Gosman, S.D. "Facial Development in Mongolism," Amer. J. Ortho., 37: 322-49, May, 1951.

Goldstein, M.S. "Changes in Dimensions and Form of the Face and Head with Age," Amer. J. Phys.Anthrop., 22: 37-89, 1936.

Gordon, M.B. and Bell, A.L. "Further Roentgenographic Studies of the Sella Turcica in Abnormal Children," J. Pediat., 9: 781-90, 1936.

Griffin, E.M. and Hoffman, N. "The Construction and Application of the Cephalodontometer," Int. J. Ortho. and O. Surg. 22: 339-44, Mar., 1936.

Gustavson, E.H. Down's Syndrome. A Clinical and Cytogenetical Investigation. Uppsala: Alvist and Wiksell, 1964.

Hall, B. "Mongolism in Newborns. A Clinical and Cytogenetic Study," Acta Paediatrica, Suppl.: 154, 1964.

Hallett, G.E.M. "Inherent Errors in Cephalometric Films and Their Reproduction," Dent. Pract., 9: 163-72, 1959.

Hellman, M. "The Face in its Developmental Career," Dent. Cosmos, 77: 1-25, 1935.

Higley, L.B. "Head Positioner for Scientific Radiographic and Photographic Purposes," Int. J. Ortho. and O. Surg., 22: 699-706, July, 1936.

Hofrath, H. "Die Beteutung der Rontgenfernund Abstandsaufnahme fur die Diagnostik der Kieferanomalien," Fortschritte der Orthontik, 1: 232, 1931.

Ingallis, T.H. "Pathogenesis of Mongolism," Amer. J. Dis. Child., 73: 279-92, 1947.

Irwin, G.L. "Roentgen Determination of the Time of Closure of the Sphenoccipital Synchondrosis," Radiology, 75: 450-52, 1960.

Jensen, E. and Palling, M. "The Gonial Angle," Amer. J. Ortho., 40: 120-33, 1954.

Jones, R. "The Mouth of Backward Children of the Mongol Type," J. Med. Soc., 36: 187, 1890.

Keith, A. and Campion, G. "A Contribution to the Mechanism of Growth of the Human Face," Dent.Rec., 42 (2): 61-88, 1922.

Kisling, E. Cranial Morphology in Down's Syndrome. Copenhagen: Munksgaard, 1966.

Koni, J.C. "Comparative Value of X-rays of the Sphenooccipital Synchondrosis and of the Wrist for Skeletal Age Assessment," Angle Ortho., 34: 303-13, 1964.

Krogman, W.M. "The Problem in Timing in Facial Growth, with Special Reference to the Period of the Changing Dentition," Amer. J. Ortho., 37 (4): 258-76, 1951.

Lande, M.J. "Growth Behavior of Human Profile as Revealed by Serial Cephalometric Roentgenology," Angle Ortho., 22 (2): 78-90, 1952.

Lejeune, J., Turpin, R., and Gautier, M. "Mongolism, a Chromosomal Illness," Bull. Acad. Nat. Med. (Paris), 143: 256-65, 1959.

Margolis, H.I. "Standardized X-ray Cephalographics," Amer. J. Ortho. and O. Surg., 26: 725-40, Aug., 1940.

Massler, M. and Schour, L. "Post-natal Growth Pattern of the Facial Skeleton as Measured by Vital Injections of Alizarine Red," J. Dent.Res., 23 (3): Abst., 1944.

Moore, A.W. "A Method of Studying the Cranio-facial Growth Sites in the Macaque Monkey as These Are Exhibited by Vital Staining with Alizarine Red," J. Dent. Res., 25: 157, 1946.

Moss, M. "Correlation of Cranial Base Angulation with Cephalic Malformations and Growth Disharmonies of Dential Interest," N.Y. St. Dent. J., 21: 452-54, Nov., 1955.

Moss, M. "Inhibition and Stimulation of Sutural Fusion in the Rat Calvaria," Anat. Rec., 136: 457, 1960.

McIntire, M.S., Menolascino, F.J., and Wiley, J.H. "Mongolism - Some Clinical Aspects," Amer. J. Ment. Def., 69: 794-800, May, 1965.

Muir, J. "Analysis of 26 Cases of Mongolism," Arch. Pedict., 20: 161-69, 1903.

Nanda, R.S. "The Rate of Growth of Several Facial Components Measured from Serial Cephalograms," Amer. J. Ortho.

Oliver, C.A. "A Clinical Study of the Occular Symptoms Found in Socalled Mongolian Type of Idiocy," Tr. Opht. Soc. U. Kingdom, 6: 140, 1891-1893.

Oster, J. Mongolism. Copenhagen: E. Munksgaard, 1953.

Polani, P.E., et al. "A Mongol Girl with 46 Chromosomes," Lancet, 1: 721-24, Apr., 1960.

Poszony, J., Gibson, D., Zarfas, D.E. "Skeletal Maturation in Mongolism (Down's Syndrome)," J. Pediad., 64 (1): 75-78, Jan., 1964.

Penrose, L.S. "Maternal Age, Order of Birth and Development Abnormalities," J. Dent. Sc., 85: 1141, 1939.

Penrose, L.S. "Mongolism," Brit. Med. Bull., 17: 184-89, 1961.

Penrose, L.S. Biology of Mental Defect. London: Sidqwick and Jackson, 1963.

Raison, J., Lepoivre, M., and Ackermann, R. "Manifestations Buccodentaires du Mongolisme," Actualities Odontos-tomat, 10: 347-59, 1956.

Record, R.G. and Smith, A. "Incidence,Mortality, and Sex Distribution of Mongoloid Defectives," Brit. J. Prev. and Soc. Med., 9 (1): 10-15, Jan., 1955.

Rezk, E.R. "A Comparative Cephalometric Study of Mongoloid and Non-mongoloid Children." Unpublished Master's thesis, The University of Michigan, 1964.

Richards, B.W. "New Work on Down's Syndrome - A Review of the Recent Literature," Develop. Med. Child. Neurol., 6: 175-82, Apr., 1964.

Richard, B.W. "The Diagnosis of Down's Syndrome," Devel. Med. Child. Neurol., 7: 285-88, June, 1965.

Ricketts, R.M. "Facial and Denture Changes During Orthodontic Treatment as Analyzed from the Tempero-mandibular Joint," Amer. J. Ortho. 41 (3): 163-79, 1955.

Riedel, R.A. "The Relation of Maxillary Structures to Cranium in Malocclusion and in Normal Occlusion," Amer. J. Ortho., 22 (3):142-45, 1952.

Roche, A.F., Steward, F.S., and Sunderland, S. "Non-metrical Observations on Cranial Roentgenograms in Mongolism," Amer. J. Rtg., 84: 659-62, 1961.

Salzman, J.A. Practice of Orthodontics. Philadelphia and Montreal: J. B. Lippincott Co., 1966.

Sassouni, V. "Diagnosis and Treatment Planning via Roentgenographic Cephalometry," Amer. J. Ortho., 44: 433-63, 1958.

Sassouni, V. The Face in Five Dimensions. Morgantown: West Virginia University School of Dentistry Publ.,1962.

Sassouni, V., et al. The Face and Teeth in Mongolism. Pittsburg: University of Pittsburg School of Dentistry, Ortho. Dept. Publ., 1964.

Sarnot, B.G. and Engel, M.B. "A Serial Study of Mandibular Growth After Removal of the Condyle in the Mocaca Rhesus Monkey," Plastic and Reconst. Surg., 7: 364-80, 1951.

Schmid, W. "DNA Relocation Patterns of Human Chromosomes," Cytogenetics, 2: 175, 1963.

Schuller, A. Roentgen Diagnosis of Disease of the Head, St. Louis: C. V. Mosby, 1918.

Scott, J.H. "Growth of the Human Face," Proc. Royal Soc. Med. 47: 91-100, 1954.

Scott, J.H. "The Cranial Base," Amer. J. Phys. Anthrop., 16: 319-37, 1958.

Scott, J.H. "The Analysis of Facial Growth," Amer. J. Ortho., 44: 507-12, 1958.

Selman and Sarnat, B.G. "Sutural Bone Growth of the Rabbit Snout," Amer. J. Anat.

Senneville, et al. "Contribution a L'etude de la Morphogenese du Massif Facial," Extr. des Comptes Rendus de L'Association des Anatomistes, 37 ieme reunion: 433-440, Apr., 1950.

Shuttleworth, G.E. "On Idiocy and Imbecility," Brit. Med. J. 183, 1886.

Sicher, M. "Skeletal Disharmonies and Malocclusions," Amer. J. Ortho. 43: 674-84, 1957.

Smith, D.W. "Autosomal Abnormalities," Amer. J. Obst. Gyn., 90: Supp., 1055-77, Dec., 1964.

Smith, T.T. "A Peculiarity in the Shape of the Hand in Idiots of the Mongol Type," Pediatrics, 11: 315, 1896.

Spittzer, R., Rabinovitch, J.Y., and Wybar, K.C. "A Study of the Abnormalities of the Skull, Teeth, and Lenses in Mongolism," Canad. Med. Assoc. J. 84: 567-72, Mar., 1961.

Spittzer, R., Robinson, M.I. "Radiological Changes in Teeth and Skull in Mental Defectives," Brit. J. Rod., 28: 117-27, 1955.

Stedman, D.J. and Eichorn, D.H. "A Comparison of the Growth and Development of Institutionalized and Home-reared Mongoloids During Infancy and Early Childhood," Amer. J. Ment. Def., 69: 391-401, Nov., 1964.

Talbot, F.B. "Studies in Growth; Growth of Untreated Mongolian Idiots," Amer. J. Dis. Child., 28: 152-57, 1924.

Thompson, J. "Note on the Peculiarities of the Tongue in Mongolism," Brit. Med. Jour., 1: 1051, 1907.

Thurow, R.C. "Cephalometric Methods in Research and Private Practice," Angle Ortho., 21 (2): 104-16, Apr., 1951.

Timme, W. "The Mongolian Idiot," Arch. Neuralogy and Psychiatry, 5: 568-71, 1921.

Tricbsch, E. "Developmental and Functional Changes of the Dentition, Jaws, and Facial Structures," Trans. Europ. Ortho. Soc., 353, 1958.

Wardenburg, P. "Das Menschliche Auge und Seine Erbangeh," Mart. Nijhoff, 1932.

Warkany, J. "Etiology of Mongolism," J. Pediatrics, 56: 412-19, Mar., 1960.

Weingart, M.A. "A Simplified Cephalometric Head Positioner," Amer. J. Ortho. 34: 362-66, Apr., 1948.

Weinmann, J.P. and Sicher, H. Bone and Bones. St. Louis: C.V. Mosby, 1947.

Williams, B.H. "Craniofacial Proportionality in a Horizontal and Vertical Plane, a Study in Morma Lateralis," Angle Ortho. 23: 26-33, 1953.

Wylie, W.L. "The Assessment of Antero-posterior Dysplasia," Amer. J. Ortho., 17 (3,4): 97-109, 1947.

GLOSSARY

GLOSSARY

A point (A)

The deepest point on the midline contour at the alveolar process between the anterior nasal spine and the alveolar crest of the maxillary central incisor.

Anterior nasal spine (Ans)

The median, sharp bony process of the maxilla at the lower margin of the anterior nasal opening.

Articulare (Ar)

The point of intersection of the external dorsal contour of the mandibular condyle and the temporal bone. The midpoint is used when the profile radiogram shows double projections of the rami.

B point (B)

The deepest point on the countour of the alveolar projection, between the alveolar crest of the mandibular central incisor and pogonion.

Basion (Ba)

The most forward and lowest point on the anterior margin of the foramen magnum.

Frontale (F)

The point of tangency of a line from A point tangent to the frontal bone.

G point (G)

The perpendicular projection of sella on to the line drawn through A point and parallel to the palatal plane (Ans-Pns).

Gnathion (Gn)

The lowest point of the medium plane in the lower border of the chin, measured at the intersection of the mandibular base line and the line nasion-pogonion.

Gonion (Go)

The lowest most posterior, and most outward point on the angle of the mandibular base line and the line tangent to the posterior border of the ramus.

Menton (M)

The lowest point of the symphysis menti of the mandible.

Nasion (N)

The midpoint of the frontonasal suture.

O point (O)

The intersection of the line SN and the palatal plane (Ans-Pns).

Pogonion (P)

The most prominent anterior point on the chin.

Posterior nasal spine (Pns)

The process formed by the united projecting ends of the posterior borders of the palatal processes of the palatal bones.

Sella (s)

The center of the sella turcica (that is, the pituitary fossa).

T point (T)

The intersection of the palatal plane (Ans-Pns) and the mandibular plane (M-Go).

V point (V)

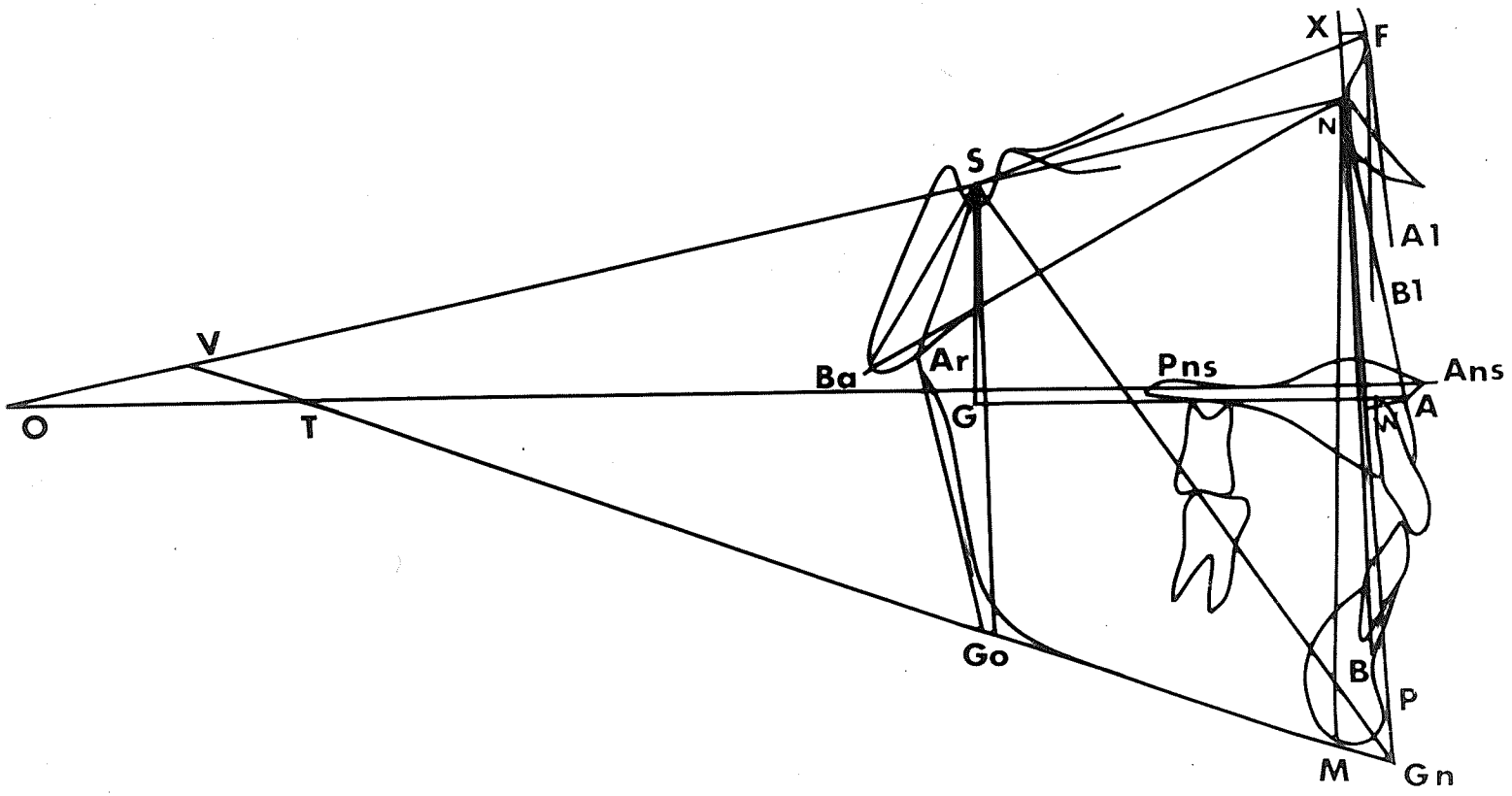
The intersection of the line SN and the mandibular plane (M-Go).

W point (W)

The perpendicular projection of the anterior nasal spine on to the line NPo.

X point (X)

The perpendicular projection of frontale on to the extension of the line NPo.


X
F
N
S
A1
B1
V
Ba
Ar
Pns
Ans
O
T
G
A
N
Go
B
P
M
Gn