

A CEPHALOMETRIC COMPARISON
OF CHILDREN WITH DOWN'S SYNDROME
AND THEIR NORMAL SIBLINGS

by

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INTRODUCTION

Working in London in 1866, J. Langdon Down¹ first described the clinical entity known as mongolism. Since that time, the disorder has been given several names, mongolian idiocy, congenital acromicria, kalmuck idiocy, and mongolism; more recently it has been referred to as Down's syndrome. Down's description of the syndrome is as applicable today as it was over a hundred years ago:

".... a representative of the great mongolian race: when placed side by side it is difficult to believe that specimens compared are not children of the same parentage. The hair is not black as in the real mongol, but a brownish colour, straight and scanty. The face is flat and broad and destitute of prominence. The cheeks are roundish and extended laterally. The eyes are obliquely placed and the internal canthi more than normally distant from one another. The palpebral fissure is very narrow. The forehead is wrinkled transversely from the constant assistance which the levatores palpebrarum derive from the occipito-frontalis muscle in the opening of the

eyes. The lips are large and thick and much roughened. The nose is small. The skin has a slight dirty yellowish tinge and is deficient in elasticity, giving the appearance of being too big for the body."

A considerable amount of information has been added to the clinical picture of the syndrome since Down's original work. However, the description remains essentially valid as an initial impression of a child with mongolism: "... when placed side by side it is difficult to believe that all specimens compared are not children of the same parentage..." It was this feature of the syndrome which must have impressed Down considerably, since it appears as the first clinical sign in his description. And it is this particular feature which impresses investigators who work with these children. Herein lies the most intriguing aspect of mongolism. Why do mongoloid children bear such a striking resemblance to one another? Their faces almost seem to be cast from the same mold. The genetic backgrounds controlling a major portion of bone morphology and bone growth are obviously quite diverse. Yet there is a remarkable photographic similarity among mongoloid children.

With this most puzzling question in mind the present study was designed.

In 1959, LeJeune^{2,3} found that children with the clinical signs of Down's syndrome had, upon careful analysis of their chromosomes, an extra autosomal chromosome, approximating the number 21 chromosome. This gave great new and hithertofore undreamed of insight into the etiology of the disease. To this time, many theories had been postulated. Maternal age, paternal age, birth injury, prenatal trauma, and a host of others had been mentioned as the prime etiologic factor. And there is much evidence to support each of these theories, but none of these agents is as consistent a finding as is trisomy* of the 21st chromosome. This being the most common finding in all mongoloid children, it can be assumed with some conviction that the chromosomal aberration has a multi-faceted effect on the growing child. It may be further postulated that this chromosomal derangement has some minimal effect on the morphology and physiology of the growing bones. Therefore, it is the attempt

*A trisomy is the presence in an otherwise diploid complement of an extra member of a particular chromosome pair.

of this study to minimize genetic effects of the other chromosomes of affected individuals as much as possible. This was done by using siblings for control comparisons.

The object of this study was to attempt to evaluate that pattern of craniofacial growth in the mongoloid child that can be attributed to the chromosomal aberration. In order to do this the effects of the remainder of the genome must be minimized. For this reason, children with Down's syndrome were selected for study on the criteria of having a sibling of comparable age and of the same sex, whenever possible. Cephalometric radiographs were then taken on both children. The radiographs were then traced on acetate paper and measurements made. These data were then analyzed in the light of normative data compiled on skeletally normal children of ascending age groups, between the ages of two and one-half and eleven years. In essence, it is the aim of this project to attempt to evaluate what factors determine a mongoloid child's craniofacial characteristics.

REVIEW OF LITERATURE

Normal Craniofacial Growth

A study of Down's syndrome and its manifestations in the growing skull of the child is not easy to perform since considerable knowledge of the normal growth parameters is mandatory before it is possible to denote any pathologic changes that might be present in the mongoloid face and cranium. For this reason a review of the pertinent features of craniofacial growth is presented.

The data that Broadbent has collected over the last quarter of a century on normal growth, has provided valuable information in the assessment of dentofacial changes and growth during orthodontic treatment. It was Broadbent,⁴ in 1931, who gave cephalometry its greatest impetus as both a practical and a research tool. Later in 1937, Broadbent⁵ proposed his theory on the composite pattern of growth; that the bony facial pattern was established with the completion and eruption of the deciduous dentition. Rosenberg,⁶ in 1934, using the Bolton Fund data, studied the nasomaxillary area of children. He showed that the floor of the nose grew downward and forward in an orderly manner when the tracings were superimposed on sella-nasion and registered on sella.

In 1956, Scott⁷ presented the idea that growth of the human face may be divided into three phases:

1. Prenatal to the third year of life.

During this time, and especially during late foetal life, growth is active at the facial and cranial sutures. The individual cranial and facial bones are rapidly enlarging in conformity with the growing brain, eyeballs, tongue and the basinasal cartilage or chondrocranium. The general sutural pattern, however, remains remarkably constant from foetal to adult life.

This is not because the suture sites are themselves predetermined, but because there is an overall pattern of skull growth related to the growth and form of the chondrocranium and various organs within the growing skull. Furthermore, the suture pattern is remarkably constant not only among the primates, but in all mammals.

The chief regulating element appears to be the chondrocranium which takes on the form peculiar to each species late during foetal life. The various sutures can be classified

into a number of suture systems related to the direction of growth of the skull in three planes. These include (a) the coronal suture system separating the frontal, sphenoid and ethmoid bones (comprising the anterior cranial segment) from the parietal and temporal bones (comprising the middle cranial segment), (b) the lamboidal suture system separating the parietal and temporal bones from the occipital (comprising the posterior cranial segment), (c) the sagittal suture system (including the metopic suture between the frontal bones, the mid-palatal suture and the mandibular symphysis), (d) the retromaxillary suture system separating the maxillary suture bones from the zygomatic, frontal, lacrimal, ethmoid, vomer, and palatine bones, (e) the cranio-facial bones from the frontal, mesethmoid, sphenoid and temporal bones of the cranium. These suture systems are so arranged as to permit growth of the skull in three dimensions around the brain and eyeballs, and to enable the facial skeleton to grow downward and forward from the cranial base.

2. Between three years and seven years suture growth continues at certain sites but is less active. Deposition of bone occurs on the outer surface of the facial skeleton associated with bone absorption on the inner surfaces related to the nasal cavities and air sinuses, and the oral cavity begins to play a more important part in facial growth. These processes, (in addition to) regulating the form and spatial relationships of the bones, regulate thickness so that certain regions may be strengthened to resist the forces of mastication.
3. After the seventh year, following eruption of the first permanent molars and the beginning of the replacement of the deciduous by the permanent teeth, sutural growth ceases in the facial skeleton. The facial skeleton then becomes consolidated, and although certain sutures may persist throughout life, they are no longer active sites of growth, a conclusion which is verified by the absence of signs of

osteogenesis upon histologic examination. Growth of the face continued by surface bone deposition, especially in the alveolar region of the jaws. Two sites of cartilage growth, however, persist until the end of the growth period. These are in the condyles of the mandible, which regulate the growth of the lower jaw in relation to the upper facial skeleton, and at the cranial base between the occipital and sphenoid bones. This latter synchondrosis indirectly regulates the growth of the cranial cavity at the coronal and lamboidal suture systems, enabling the cranial bones to thicken by internal as well as external deposition of bone, and also provides space for the growing muscles of mastication between the vertebral column and the back of the facial skeleton. Since the upper facial skeleton is attached to the anterior cranial segment, it will be thrust forward from the vertebral column by growth at the synchondrosis in the cranial base. The lower jaw, however, articulates with

the middle cranial segment which lies behind the coronal suture system and thereby grows in large part independently of the upper face. A delicately balanced growth-regulating mechanism must be present, if the upper and lower jaws are to remain in proper relationship to one another during growth.

Growth at the mandibular condyles thrusts the lower jaw downward and forward, and this downward direction of growth, which is characteristic of primates and especially of man, tends to separate the upper and lower jaws from each other. The space produced between the jaws is actually filled in mostly by the alveolar bone, which in normal growth continues to maintain the functional teeth in normal occlusion.

Prior to Scott, Goldstein,⁸ in 1936, established that of the three dimensions of the face the facial length had the fastest rate of growth; depth was next, and width slowest. In depth, the lower portion of the face progressed more rapidly than the upper. It was noted that spurts of growth occurred between three to five and 13 to 15 years of age and these

were most pronounced in the vertical dimension, less in the transverse aspect, and least in depth.

Hellman⁹ in 1935, showed that a continuous increase in the size of the face occurred, but this was not uniform. In the course of metamorphosis, the face gradually moved forward, and in so doing, changed position relative to the cranium.

Brodie^{10,11,12} presented several classic reports on the growth pattern of the human head. Using various methods of observation, such as cephalometry, vital staining and anthropometrics, he reported that the facial pattern remained constant from the third month of life to the eighth year. However, he did recognize the fact that there are individual variations. He stated that the cranial base posteriorly is shorter than the anterior portion but the growth rate is equal, and this relationship continues through the child's eighth year. Brodie reported no change in the angular relationship between anterior nasal spine, nasal floor, and cranial base. Anterior nasal spine grows downward and forward, while posterior nasal spine grows straight down after one year. Brodie theorized that the maxilla grew downward and forward in a linear manner. The mandible

at chin point grows forward rapidly until three-and-one-half or four years, the regression lines representing the growth of the body are parallel and there is no change in the gonial angle. There is mainly linear growth after the first year-and-one-half of life, and the angular measurements remain constant. This study showed the trends of craniofacial growth but did not present the individual measurements of component parts.

In a subsequent study in 1953, Brodie¹³ observed that the face developed by adhering to original proportions laid down by the end of the first three months of postnatal life. He did feel that there are high and low extremes of each growth pattern, but that the highs and lows of each individual bone seem to cancel each other out. Brodie also made the point that the individual cannot be compared to a statistical yardstick derived from a group.

Ricketts¹⁴ in 1957 reported that facial form was determined by chin position and that chin position in turn was determined by cranial base, condylar position, and condylar growth. This meant that the main factors in changing chin position are located in the temporomandibular joint complex.

He further stated that there is a great deal of variation in the manner in which the mandible grows. In 1964, Ricketts¹⁵ proposed his "keystone triad," which is composed of the lower incisor, alveolar process and the attached musculature. These three factors, he felt, were instrumental in the construction of the chin.

In 1951, Krogman¹⁶ stated that there were "Avenues of Growth". These were height, breadth and depth of the face. At birth he found that height was 40 to 45 percent, breadth 55 to 60 percent, and depth 30 to 35 percent of their respective final adult values.

Björk¹⁷ in 1947, studied 240 Swedish males who were 12 to 20 years of age. He used a cross-sectional sample, and observed that the degree of prognathism in both jaws increased during the growth period. He also found that the lower jaw grew more than the upper and in doing so, the facial profile became straight. The gonial angle remained constant while the ramus increased twice as much in length as the body of the mandible. In 1955¹⁸ he reported that 12-year-old Swedish males had a cranial base measurement of 68.8 millimeters from nasion to sella with a standard deviation of 2.8 millimeters. In 1955, Ricketts¹⁹ confirmed

Björk's findings in the area of the cranial base. Later the same year, Björk²⁰ using metallic implants, found that the "direction of growth in individual cases is variable and unpredictable."

Williams²¹ in 1953 showed that while the lower face was variable, the upper face remained fairly constant along the X axis or vertical coordinate. He also stated that while B point moved less than gnathion, A point remained stable in the vertical and horizontal planes.

In 1955, Coben²² reported on his investigation of growth in males and females between eight and 16 years of age. He found that mid-facial depth increased slightly in comparison to lower facial depth, and in both sexes, facial height increased more than facial depth.

Nanda²³ in 1955, reporting a study on the rate of growth concluded that while the cranium had a neural* type of growth curve, facial dimensions were typical of general skeletal growth. The form

*Neural growth here refers to the fact that the cranium increases in size from increased intracranial pressure from the growing brain.

of the face changed since all dimensions did not grow at the same rate.

These last several reports seem to suggest that the midfacial areas are more stable than the lower face, and in this situation, the profile tends to become more orthognathic during growth.

Brodie Jr.²⁴ in a 1955 serial study of the cranial base between three and 20 years of age, noted that there was a relatively constant contribution by each part of the cranial base to the craniofacial growth through the period studied, and that this constancy was maintained throughout the entire age range studied.

In 1955, Moss²⁵ reported on cranial base angle at different age levels. He showed that the clivocriform angle remained constant. Later in 1956, studying individuals with cleft palate,²⁶ he found that the cranial flexure angle was small than in normal individuals.

The literature reviewed to this point represents a selected group of studies describing the pertinent features of craniofacial growth and is not intended to be exhaustive. There is, however, very little information available pertaining to the craniofacial

development of the mongoloid child. Most of the studies have not been cephalometric evaluations, but rather have relied on direct skull measurements obtained either on living institutionalized subjects or on autopsy material. Unfortunately, the majority of findings have been based upon "clinical impression" and do not represent objective data which may lend itself to refined statistical analyses.

Craniofacial Growth in Mongolism

Mongolism was first classified as a separate disease entity in 1866 by J. Langdon Down.¹

Working in the London Hospital, he was concerned with the cause of the mental state of the affected individuals. He felt this cause to be hereditary or the result of a postnatal accident and also that the condition was always congenital and that tuberculosis in the parent had a great deal to do with the child's condition. An interesting observation, illuminating the thoughts of this early medical researcher, can be found at the end of his paper. Down philosophizes that, "if the races are separate and distinct, why does disease break down the barrier? The differences in the races are not specific but variable. The examples of the result of degeneracy among mankind appear to me to furnish some argument in favor of the unity of the human species." Down's exact description of mongolism can be found in an earlier section of this paper.

In 1876, Fraser and Mitchell²⁷ gave a scientific paper in Edinburgh on a disease they termed "Kalmuck Idiocy". In 1890, Jones²⁸ reported characteristics of the mouth in children of the mongolian

type. Oliver²⁹ in 1891, reported on a vast number of ocular symptoms found in the so-called mongoloid type of idiocy. Smith³⁰ in 1896 followed with a report on the hands of mongoloid children.

Clift³¹ in 1922, felt that little knowledge had been added to Down's original observations except that over a period of 56 years, some alleged changes in the anterior clinoid process were noted. This, he felt, might be due to an altered pituitary gland. He reviewed 50 cases at the Michigan Home and Training School at Lapeer, and five private cases. He found the affected individual in general to have a small cranium and to be classified as microcephalic and dolichocephalic. The cranial bones were found to be uniformly thin. Suture lines were separated and irregular rarified areas occurred along the edges. The nose and the maxilla were poorly developed. Sella turcica was not different in mongoloids or normals. He found that bone in the walls of the sella was normal and changes that others had reported could be produced by changing the central radiographic angulation. Clift concluded that there was no single roentgenographic

feature of mongolism except the nose and the underdeveloped maxilla being smaller than normal, and a generalized retardation of skeletal development.

In 1924, Talbot³² measured the circumference of the head over the occiput and frontal bones of an unspecified number of mongoloids aged four months to ten years. He reported that the contour of the head was abnormal in nearly all instances. Characteristic flattening of the posterior skull with consequent shortening of the anterior-posterior diameter was a typical finding and this may be responsible for the slightly diminished circumference.

Grieg³³ studied the skull of the "mongolian imbecile" by making measurements on dry female "mongolistic" skulls 16, 14, and five years of age. He reported the skulls to be brachycephalic, (having a cephalic index of 81-85.4, a wider than normal head measurement), hypsocephalic (having a head with a larger than normal vertical dimension), orthognathic, (having a larger than normal lower jaw), platyrine, (having a broad nose), and megasme (having an orbital index over 89). There was no account of facial flattening. In 1927, the same author reported that

there was a lack of sinus development in mongoloids and he quoted LeDouble as saying that when the metopic suture persists, the frontal sinuses lack development. The nasal aperture was found to be asymmetric, normal in width but short in height. The maxilla was flattened somewhat and he felt that a portion of the maxilla comes forward thereby shutting off growth of the premaxilla (the alveolar portion of the premaxilla remains defective). He found no high palatal vault and the mandible was rather square, its anterior margins made the upper lip protrude.

Ingalls³⁴ in 1947, reported that the skull was indeed brachycephalic, technically microcephalic and short antero-posteriorly. Dwarfism of the basilar portion of the skull, nasal bones and maxilla was a consistent finding. The association of cranial and numerous skeletal anomalies suggested to him that developing masses of precartilage and membranous centers of ossification throughout the skeleton were affected in chance combinations.

Gosman³⁵ in 1951, using anthropometry, photographs, models and clinical observations, reported that head length, depth of the face and total facial

height were smaller in the mongoloid child than in the normal. He also found that the mongoloid facial change after 16 to 18 years was mainly due to a progressive mandibular prognathism. This prognathism seemed to be attributable to a large tongue in a small oral cavity. Gosman's recommendation was to do tongue surgery at 11 or 12 years of age to decrease tongue mass.

In 1955, Levinson et al.³⁶ reported the following findings on 50 mongoloid patients: in 82 percent there was a flat occiput, 16 percent showed delayed closure of the anterior fontanelle, 88 percent had slanted palpebral fissures, 50 percent had epicanthal folds, 74 percent had a demonstrably high arched palate, 88 percent showed hyperextensible joints, 84 percent had flabby hands, and 48 percent had the horizontal palmar line. The electroencephalograph findings were varied and revealed nothing significant since this data had the same variability between the mongoloids as was observed in the normal populations.

Triebshel³⁷ in 1958 studied mongoloid children and found that there was a reduced anterior cranial base in addition to brachycephaly. He also noted an

underdeveloped mid-face, and advanced the theory that the tongue, when interposed between the teeth, causes a lengthening of the alveolar arches due to functional muscle pull. This also causes the maxilla to slide forward. Triebshé also noted a large "freeway" or interocclusal space.

Spitzer and Quilliam³⁸ reported the congenital anomalies observed in a comparative craniofacial growth study matching 20 mongoloids with 20 microcephalics. Occipito-mental, occipito-frontal and lateral projection radiographs were used. Mongoloids failed to develop frontal sinuses. Fifteen of the mongoloids had an open metopic suture. Both the mongoloids and the microcephalics had large craniums and small jaws. The mongoloids showed impaired growth of the maxilla, seemingly caused by a lack of growth downward and forward of the alveolar crest from the inferior orbital margin. They felt that shape of the mongoloid skull is pathognomonic and that the hypoplastic jaws and alveoli have a bearing on the impaired development of the face.

Roche and Sunderland³⁹ in 1960, observing the crania of mongoloids at postmortem examinations, demonstrated that these crania were thinner than

normal. Some of the skulls approached the normal in thickness but were never greater. They found that, although the anterior fontanelle was late in closing, there was no evidence of a critical value for thickness below which the anterior fontanelle did not close. In three subsequent studies, Roche et al.^{40,41,42} reported that the sutures are wider in mongoloids with the growth potential the same as normals but is spread over a wider time period. Metopism* is an almost constant feature of mongolism, with the frontal sinuses late (if ever) developing, and the supercilliary arches remaining poorly developed. The foregoing observations were made by these authors using a Bolton-Broadbent cephalometer.

Using non-cephalometric techniques, which are direct skull and soft-tissue measurements, they observed that the maximum head breadth was within one standard of deviation of normal during the first year. From this point sex differences were noted. The males showed a sub-normal growth

*Metopism - The persistence of the frontal suture.

rate in head breadth up to the fifth year, then a faster than normal increase between the ages of five and nine years, and essentially no growth after this. On the other hand, female mongoloids showed a steady, uniform increase up to the age of nine years. During the first few months postnatally, the rate of increase in head length was normal but was slower than normal from one to five years, after which the rate of increase was within the normal range.

In 1955, Spitzer and Robinson⁴³ examined the hands, skulls, wrists, jaws and teeth of mongoloids and feeble-minded children. They found a high incidence of malformed teeth, an absence of frontal sinuses, underdeveloped maxillae and mandibles and obtuse gonial angles in the mongoloid children. Spitzer et al,⁴⁴ in a later study, noted that the cribiform plate was very low and that a high arched palate with a short nasal septum made the nasal space short. They felt, in general, that there was a hypoplasia of the middle third of the face in mongoloid children.

Strean et al.⁴⁵ listed what he considered to be the newer criteria for the diagnosis of mongol-

lism in 1961. They reported the commonest findings to be: mental retardation, heart defects, progeria, pointed head, brachycephalic skull, and macacus hands. In their list of oral findings, they noted: fissured lips, multiple labial frena, scrotal tongue, gingivitis (a finding corroborated by Johnson and Young⁴⁶) mobile teeth, hypertrophied filiform and fungiform papillae of the tongue, mouthbreathing and submucous clefts. They stated that these characteristics along with the systemic findings can make an early diagnosis possible, although the great majority of clinicians find little difficulty in making the correct diagnosis. Strean et al. stated that cleft palate was a more frequent finding in mongoloid children than in the normal population, (42 affected out of 178 mongoloids examined). Since the palate closes somewhere between the eighth and tenth week of intrauterine life, Strean felt it might be possible that the physical stigmata of mongolism is caused at this point. However the genetic findings of LeJeune do not bear this out. Furthermore, his criteria for submucous cleft was not mentioned. The causative agent was noted as "uterine stress or damage," measles, etc.

Cohen and Winer⁴⁷ reported a low number of class II malocclusions due to the forward position of the mandible, and a high number of class III malocclusions due to an underdeveloped maxilla with an anterior cross bite. The flattened nose was due to the underdevelopment of the nasal bones.

Rarick et al.⁴⁸ studied the bones of the hands and wrists of mongoloid children over a period of four years. They demonstrated that the mongoloid child has a mean skeletal age of approximately three years less than a normal child at seven to nine years of chronological age. However, at 12 to 14 years of age, the mongoloid children were only a little over a year retarded in mean skeletal age. They reported that only one child in six reached the mean skeletal age of normal children, and the retardation in skeletal maturity in mongoloid children is more pronounced than was previously thought.

Benda,⁴⁹ who has probably performed the most detailed clinical studies including most of the parameters of Down's syndrome, has divided his skeletal growth data into two categories: (1) direct anatomic measurement, and (2) radiographic observation. Due to the paucity of radiographic skeletal information,

Benda confined most of his observations to those made by direct measurement. In general, he found the major growth discrepancy of the skull to be lack of growth in length. The mongoloid skull maintains its fetal proportions even though there is an increase in size over the growth period. The face remains small in comparison to the cranium. The nasal complex and maxilla are underdeveloped and the mandible is fetal in shape. He also noted a shortness of upper facial height.

Gorlin,⁵⁰ reporting the oral manifestations in 1963, supported Benda and previous investigators in their findings.

Sassouni et al.⁵¹ using a composite cephalometric analysis, studied the faces and teeth of mongoloid children. The 91 mongoloid children used in the study were matched for sex and age with normal children. They found that cranial base was shorter in the mongoloids when measured from sella to nasion but not when measured from sella to the internal surface of the frontal bone, suggesting underdevelopment of the frontal nasal suture. The midface was underdeveloped both vertically and horizontally. The length of the mandible and gonial angle were found

to be normal. The anterior facial height was reported as smaller than normal.

Pozonyi et al.⁵² examined 100 mongoloid children ranging in age from two weeks to 15 years. Using wrist plates and the standards of Gruilich and Pyle, this group of investigators found that the skeletal maturation in mongoloid children was a function of age and sex. They reported that skeletal maturation was delayed up to the eighth year of life and then it increased past the theoretical norms. There was a suggestion that the male mongoloid was more retarded than the female but this was not statistically significant. They also found that skeletal maturation as a function of the degree of amentia (prematurity and nutrition) had no clear cut significance.

In summation, the majority of workers have found several mutually agreed upon characteristics of the mongoloid craniofacial complex. The mongoloid skull appears to be brachycephalic. The middle third of the face has a concave shape when the mongoloid is seen in profile. A smaller than normal maxilla, anteroposteriorly, may account for the concave appearance of the mongoloid face in profile. The

cranial sutures, especially the anterior fontanelle, are late to close. As for the rest of the reported craniofacial aberrations, such as prognathism, high arched palatal vault, etc., there are few if any confirming or denying studies in existence. Those reports that do exist, listing the features of Down's syndrome, have not been done using a standardized cephalometric technique. The observations have in most instances been based upon clinical impressions. Therefore, it is the purpose of this study to add quantitative information to the scanty literature pertaining to the growth and development of the mongoloid face and skull.

STATEMENT OF THE PROBLEM

This study attempted to characterize the craniofacial skeletal patterns in mongoloid children and their siblings. The results were compared to similar data obtained from an essentially normal population in which the standards and norms for the different age groups were calculated.

EXPERIMENTAL PROCEDURE

Twenty, matched sibling pairs of children (Figure 1) were selected for study, one sibling a normal child, the other a mongoloid. The pairs of children used in the study were chosen on the basis of the following criteria:

1. The mongoloid child was not or had not been institutionalized.
2. The diagnosis of Down's syndrome was confirmed.
3. The mongoloid child did not have a history of cardiac disease.
4. The mongoloid child was below the age of puberty and had a healthy, normal sibling.

Fourteen pairs of siblings were found through the Medical Genetics Department of the Indiana University School of Medicine. The mongoloid child had been previously diagnosed at the Medical Center as having Down's syndrome, and a family history had been taken. The remaining six pairs of children were obtained from the Marion County Society for Retarded Children, which maintains a day school for children in Indianapolis. These children were also selected by the aforementioned criteria.

The child afflicted with Down's syndrome is usually diagnosed as having this disorder at birth.^{49,53} There are many stigmata that are associated with this disease, each one in and of itself not pathognomonic of mongolism since many of them are found in other disease entities. However, when several of the following clinical signs and laboratory findings are present, the diagnosis of Down's syndrome can be made with a high degree of accuracy.

The most readily apparent signs of Down's syndrome are those found in and around the orbit. Lowe⁵⁴ found the palpebral apertures to be oblique and short, often with an asymmetry existing between the two sides of the face. Speckling of the iris, commonly called Brushfield spots,⁵⁵ are present in the eyes of these children. These spots are due to the stroma of the iris, which is thin, and tends to bunch up presenting the appearance of small, golden or white splashes in the iris. Epicanthal folds, which are not a diagnostic sign because they disappear with age, are found in about 50 percent of young, mongoloid children. The orbit holes are usually smaller than normal and are more oval.⁴⁹

Strabismus is a frequent finding, however, this too is self-correcting with age in about two-thirds of the cases.

Anomalies in the formation of the external ear are frequent in children with Down's syndrome.⁴⁹ This is a common finding in children with mental retardation, so that this finding alone cannot be used to make the diagnosis. The ear in these children is smaller and is often very primitive in shape.

The hand lines and dermatoglyphic patterns are of special note in these children. The "Macacus line" or transverse palmar (Simian) crease or the four finger line, is often seen in these children. In mongoloid children, the four finger line traverses the palm from ulnar to radial edge of the palm without a break and is often the deepest crease on the hand. This line is not always seen due to the roughened, cracked and dry palmar surface.⁴⁹

A high axial triradius is characteristically found in mongoloid children. A triradius as defined by Penrose is the "meeting place of the lines or spokes of the hand which make angles of 120 degrees with each other". The axial triradius is very close

to the wrist in normal children, (Figure 7) but is found about in the center of the palm in mongoloids. The angle that is made by connecting the triradius at the base of the little finger and the triradius at the base of the first finger is therefore more obtuse in mongoloid children.^{56,57,58}

If the diagnosis is still in doubt, the chromosomal pattern of children with Down's syndrome can be karyotyped to determine the number and configuration of the chromosomes. Since LeJeune's original work in 1959,² many other investigators have confirmed the fact that mongoloids have an additional small acrocentric chromosome that most clearly resembles the number 21-22 chromosomes.^{59,60} The fact that there are proposed to be three number 21 chromosomes has given rise to the synonym for mongolism, trisomy 21. There are reports in the literature of mongoloid children with the standard number of chromosomes (46). However, all of these mongoloids have been found to have either an abnormal chromosome or at least one chromosome that could be interpreted as a translocation.^{61,62*}

*Translocation is the joining of a part of one broken chromosome with a part of another.

Dental anomalies are often associated with Down's syndrome. They are of special interest in this case since the teeth are intimately related to the bony facial skeleton. The teeth in mongoloid children are delayed in eruption, are abnormal in shape and are often mal-aligned.^{49,50,63,64} The teeth are caries free in most cases,⁶⁴ but advanced periodontal disease is a common finding.^{46,64}

Thus, the criteria for the diagnosis of Down's syndrome are many and varied. Leukemia,^{65,66} congenital heart defects,⁴⁹ an altered serum calcium blood level,^{67,68} altered excretion of metabolic products,⁶⁷ along with many more defective anatomical features are all reported in the mongoloid child. The examiner can select a list of the major and minor features of the disorder as diagnostic criteria and can subsequently make the diagnosis of mongolism with high probability. The children at the Marion County school were diagnosed as mongoloids in such a manner since their medical records were somewhat incomplete. The main diagnostic features used were short, oblique, palpebral fissures, Brushfield spots, the accepted dermatoglyphic features of mongolism, and the aural findings. It was not possible to

karyotype these children.

A sample of 75 normal children, initially selected as having normal occlusion (Angle Class I), who were to act as a control population, was obtained from the records of the Orthodontic Departments of Indiana University. This data, previously compiled, stated the cephalometric norms (with standard deviations) of children from the age of five years-three months to 27 years of age. A group of 26 three year olds who were judged to be dentally and medically normal were selected from the Pedodontic Clinic of the Indiana University School of Dentistry and their cephalometric norms evaluated in the same manner as the age five to adult sample just described. These data provided average measurements of cranio-facial size from the age of 30 months to adulthood.

Materials

Cephalometric radiographs were taken on all mongoloids and their siblings. These children were placed in a Broadbent-Bolton cephalometer, series 5AKS60 and Kodak Blue Brand medical x-ray film was exposed in cassettes using intensifying screens. An acetate tracing (Figure 6) was then made of each developed radiograph and the following landmarks

recorded:

1. Nasion (N) - the most anterior point of the naso-frontal suture.
2. Basion (Ba) - the most inferior point on the anterior margin of foramen magnum. It was found to lie above the tip of the odontoid process of the second cervical vertebra.
3. Sella (S) - an arbitrary center point in the sella turcica which was determined by inspection.
4. Anterior Nasal Spine (ANS)- the most anterior point of the nasal floor as seen in norma lateralis.
5. Point A (A) - the deepest midline point on the premaxilla below ANS.
6. Articulare (Ar) - the intersection point of the external cranial base and the posterior border of the mandibular ramus.
7. Gonion (Go) - the point of intersection of the lines formed by constructing mandibular plane and ramal plane.
8. Pogonion (Pg) - the most anterior point on the chin button.

9. Gnathion (Gn) - the midpoint between the most inferior and most anterior points on the chin. (The deepest point of the chin).
10. Posterior Nasal Spine (PNS) - the most posterior limit of the nasal floor.

Using these landmarks the following measurements were made on the acetate tracing with a millimeter rule, a #4H drawing pencil, and a protractor. The measurements have been grouped according to that portion of the craniofacial complex which they most accurately represent:

Cranial Base

1. N-S-Ar cranial flexure angle
2. Ba-N cranial base length

Maxilla

1. PNS-ANS maxillary length
2. Point A-N maxillary position

Mandible

1. Ar-Go ramal length
2. Go-Pg body length
3. Ar-Go-Gn gonial angle

Other

1. N-ANS upper facial height
(measured perpendicular to Frankfort horizontal plane).

The preceding measurements, unless otherwise specified were made on a line dropped 7° below the line S-N instead of Frankfort Horizontal.*

*The Orthodontic Department of Indiana University by clinical trial has found the Frankfort Horizontal Plane to be parallel to a line 7° below S-N. The latter is used because it is easier to construct.

DATA

It was decided that the data obtained from the cephalometric radiographic tracings could be analyzed in three separate ways. First, the groups of children were broken into subgroups according to age, and the means of the individual measurements were calculated from the raw data. (Table I). Using the means (within age groups) of the measurements, graphs were constructed to give some idea as to the variation and direction of differences between the normal, sibling and mongoloid children. (Figures 3, 4, 5).

Secondly, the data obtained from the normal children were used to calculate a regression coefficient on age for each measurement used. These coefficients were then used to "correct" the sibling of the mongoloid child to the same age as the mongoloid. The means of the measurements of the "corrected" siblings and the mongoloid children were compared using "t" tests. The differences for each of the variables were not statistically significant (Table II). Possible reasons for this will be discussed in a later section.

The third method of data analysis used was a multivariate, step-wise regression⁶⁹ of the various

cephalometric measurements. This system was chosen because of its ability to handle multiple variables in a comparison of two population groups where the variables are highly correlated. Using this method, three statistical comparisons were made: normals versus siblings, normals versus mongoloids, and mongoloids versus siblings. The step-wise regression is used to indicate differences in specific measurements between the two groups being compared taking into account correlations between all of the included variables. In this case the dependent variable was group membership, (normal, mongoloid, or sibling), which meant that the numerical value of the partial regression coefficient* was not of interest in this study. However, the sign of the coefficient indicates which of the two compared groups had a larger value when all the other independent variables were held constant (Table III).

*The partial regression coefficient is the actual amount of change in the dependent variable per unit change in the independent variable.

The variables entered into the step-wise regression analysis were the numerical values obtained from the radiographic tracings. Age and age squared were entered as control variables. Age squared was used to correct for the fact that growth is not a linear regression but in general increases linearly and then levels off before puberty.

The statistical significance of the values obtained was calculated using "t" tests. Also calculated, was the increase in R squared. This value, shown as a percent figure (Table IV), indicates what percent of the variation between normals and siblings, normals and mongoloids and mongoloids and siblings, is due to each of the independent variables.

Simultaneously, correlation matrices showing the correlations between each pair of measurements were obtained for each of the three comparisons. These are summarized in Tables V, VI, VII. All of the aforementioned calculations were done on the 7040 IBM computer at the Indiana University Medical Center so that computation time was held to a minimum and statistical values obtained simultaneously with a

high degree of accuracy.

The following results were obtained (Table III):

1. Cranial flexure angle (N-S-Ar) was not found to be significantly different between the normal children and the siblings. The angle was significantly smaller in the mongoloids than in the normal group ($P < .05$) and was more acute than in the sibling group, but not significantly. The length of cranial base (N-Ba) was essentially the same in the normal and sibling groups. It proved to be significantly larger in the mongoloids than in the normals ($P < .01$), but the mongoloid children did not have a significantly longer cranial base than the siblings. This is, of course, with all the other variables taken into account.

Thus for the measurement, N-S-Ar, the siblings $>$ normals (N.S), mongoloids $<$ normals ($P < .05$), and siblings $>$ mongoloids (N.S). For N-Ba, the siblings $<$ normals (N.S) the mongoloids $>$ normals ($P < .01$) and the mongoloids $>$ siblings (N.S).

2. Even though the mandible was observed to

have a significantly longer ramus (Ar-Go) in the sibling group than in the normal group ($P < .01$), the mongoloids were recorded as having shorter rami than either the normals ($P < .01$) or the siblings ($P < .01$). The body of the mandible (Go-Pg) was found to be smaller in the mongoloids than in the normals ($P < .01$) but not significantly different than the siblings. Gonial angle (Ar-Go-Gn) was more obtuse in the sibling group than in the normal ($P < .01$) and the mongoloids were less obtuse than the siblings ($P < .05$). The mongoloids also had a less obtuse gonial angle than the sibling children ($P < .01$).

Thus for Ar-Go, the siblings $>$ normals ($P < .01$), the mongoloids $<$ normals ($P < .01$), and the mongoloids $<$ siblings ($P < .01$). For Go-Pg, the siblings $>$ normals (N.S.), the mongoloids $<$ normals ($P < .01$) and the mongoloids $<$ siblings (N.S.). For Ar-Go-Gn, the siblings $>$ normals ($P < .01$), the mongoloids $<$ normals ($P < .05$) and the mongoloids $<$ siblings ($P < .01$).

3. The maxilla in the mongoloids was shown to be the shorter in length (PNS-ANS) than the normal ($P < .01$). The sibling group showed no statistical difference from the normal group while the mongoloids had a maxillary length less than the siblings and this difference approached statistical significance. The sibling children did prove to have a more retruded maxilla than the normal children (A-N), ($P < .01$). The mongoloids were found to have a less retruded maxilla than the normals ($P < .05$). Thus for PNS-ANS the sibling $<$ normals (N.S.), the mongoloids $<$ normals ($P < .01$) and the mongoloids $<$ siblings (N.S.). For A-N, the siblings $>$ normals ($P < .01$), the mongoloids $>$ normals ($P < .05$) and the mongoloids $>$ siblings (N.S.).
4. Upper facial height (N-ANS) was found to have the less vertical dimension in the mongoloid children than in the normal ($P < .05$). There was no difference between the normal children and the sibling children, however the mongoloids were smaller than the sibling

group to a degree closely approaching significance ($0.1 < P > .05$). Thus for N-ANS, the siblings $<$ normals (N.S.), mongoloids $<$ normals ($P < .05$) and the mongoloids $<$ siblings (N.S.).

The intermeasurement correlations (Tables V, VI, VII) are of interest. The length of the cranial base is highly correlated with maxillary length and length of the body of the mandible in all three comparisons. Cranial base also seems to be highly correlated to upper facial height in all three comparisons. Since the growth of the face and cranium is dependent upon the growth of the various bones of the skull, the correlation between the measurements are expected to be high. This observation indicates the dangers of measuring a single variable in a multivariate system and attempting to draw conclusions about that one variable. The correlations between the other measurements are included for their interest value, and, since they are only relative values, no concrete conclusions can be drawn from them.

The total amount of the variance accounted for by these measurements can be calculated by adding the

individual R square values (Table IV). In the normal-sibling group, the eight measurements accounted for a total of 24.79 percent of the variance. In the normal-mongoloid comparison, these measurements were responsible for 53.52 percent of the variance, while in the mongoloid-sibling comparison, they accounted for 63.1 percent of the variance. This indicates the percentage of the variance between the groups which is accounted for by each of the independent variables or measurements. In the normal-sibling comparison, for example, the gonial angle accounted for 10.7 percent of the total variance, with ramus length and maxillary position accounting for approximately four percent each. In the normal-mongoloid group, 19.1 percent of the intragroup variance is due to the difference in maxillary length (PNS-ANS). Ramus length accounts for 11 percent and mandibular body length accounts for 7.6 percent. Ramus length accounts for 24 percent of the variance in the mongoloid-sibling comparison. Upper facial height at 14.7 percent and cranial flexure angle at 8.3 percent account for a large portion of the difference in variance in the normal-mongoloid group.

TABLES AND FIGURES

TABLE I Means of the Measurements of the Three Groups

Group	N-S-Ar	N-Ba	Ar-Go	Go-Pg	A-N	N-ANS	Ar-Go-Gn	PNS-ANS
Normal								
3 yrs	117.9 ^o	79.4	34.6	57.2	-1.3	38.5	132.2 ^o	43.1
5 yrs	123.0 ^o	84.9	36.0	62.4	-2.1	42.3	129.2 ^o	47.1
8 yrs	123.0 ^o	88.0	38.3	68.7	-2.8	46.5	127.0 ^o	49.7
10 yrs	122.9 ^o	91.3	40.8	73.0	-2.9	49.2	125.4 ^o	52.2
12 yrs	122.8 ^o	92.2	44.2	73.7	-0.7	48.7	125.9 ^o	55.6
Siblings								
4 yrs	122.8 ^o	80.1	36.7	57.5	-2.4	38.6	131.5 ^o	43.6
7 yrs	122.8 ^o	88.6	40.6	64.9	-4.8	43.5	131.0 ^o	48.1
10 yrs	127.3 ^o	92.8	40.7	74.2	-5.0	49.9	130.1 ^o	50.9
12 yrs	145.2 ^o	91.7	43.4	70.7	-4.4	48.6	132.3 ^o	48.1
Mongols								
3 yrs	118.5 ^o	78.7	31.1	56.6	-0.4	33.8	128.4 ^o	39.4
5 yrs	121.1 ^o	81.3	32.4	58.4	-1.0	36.0	130.1 ^o	41.8
7 yrs	119.8 ^o	85.1	34.2	62.3	-2.8	38.2	125.7 ^o	42.3
9 yrs	113.8 ^o	88.6	38.8	66.9	-2.4	43.9	127.0 ^o	44.1

All figures are in millimeters unless otherwise specified

TABLE II - Comparison between "Age Corrected" Siblings and Mongoloids

Measurement	Mean of Age of Corrected Siblings	Mean of Mongoloids	t Value
	96.4 months	75.2 months	
N-S-Ar			0.028
N-Ba			0.091
Ar-Go			0.304
Go-Pg			0.283
A-N			0.021
N-ANS			0.057
Ar-Go-Gn			0.057
PNS-ANS			0.241

All t values are non-significant at the 5% level of confidence ($t=1.96$).

TABLE III - Partial Regression Coefficient Signs and "t" Values for the Three Comparisons

Measurement	Siblings-Normals		Mongoloids-Normals		Siblings-Mongoloids	
	Sign*	t value	Sign**	t value	Sign***	t value
N-S-Ar	+	0.53	-	2.03	-	1.79
N-Ba	-	1.01	+	4.36	+	1.21
Ar-Go	+	3.43	-	2.90	-	2.56
Go-Pg	+	1.11	-	3.42	-	1.20
A-N	-	2.72	+	2.24	+	0.79
N-ANS	-	0.98	-	1.99	-	1.88
Ar-Go-Gn	+	3.20	-	2.27	-	2.56
PNS-ANS	-	1.17	-	5.82	-	1.82

*+ means Siblings Normals

** + means Mongoloids Normals

*** + means Mongoloids Siblings

Sign.....sign of the partial regression coefficient

t value.....1.96 is significant at the five percent level of confidence ($p < .05$). 2.50 is significant at the one percent level of confidence ($p < .01$).

TABLE IV - Increase in R^2 Values for the Three Comparisons

Measurement	A	B	C
	Siblings-Normals Increase in R^2	Mongoloids-Normals Increase in R^2	Mongoloids-Siblings Increase in R^2
N-S-Ar	3.4%	3.6%	8.3%
N-Ba	0.02%	0.32%	2.3%
Ar-Go	4.6%	11.9%	24.0%
Go-Pg	0.45%	7.6%	1.3%
A-N	4.2%	1.4%	2.7%
N-ANS	0.32%	4.8%	14.7%
Ar-Go-Gn	10.7%	4.8%	6.9%
PNS-ANS	1.1%	19.1%	2.9%
Total	24.79%	53.52%	63.10%

TABLE V - Correlation Matrix for Normals and Siblings

	N-S-Ar	N-Ba	Ar-Go	Go-Pg	A-N	N-ANS	Ar-Go-Gn	PNS-ANS
N-S-Ar	1.0	0.33	0.13	0.10	-0.49	0.01	-0.04	0.17
N-Ba		1.0	0.54	0.67	-0.38	0.49	-0.13	0.73
Ar-Go			1.0	0.62	-0.01	0.34	-0.34	0.62
Go-Pg				1.0	-0.08	0.52	-0.45	0.79
A-N					1.0	-0.10	-0.07	-0.17
N-ANS						1.0	-0.10	0.49
Ar-Go-Gn							1.0	-0.38
PNS-ANS								1.0

Correlation is significant at ± 0.030 .

TABLE VI - Correlation Matrix for Normals and Mongoloids

	N-S-Ar	N-Ba	Ar-Go	Go-Pg	A-N	N-ANS	Ar-Go-Gn	PNS-ANS
N-S-Ar	1.0	0.27	-0.04	0.13	-0.38	0.03	-0.014	0.14
N-Ba		1.0	0.51	0.72	-0.41	0.50	-0.17	0.70
Ar-Go			1.0	0.59	0.16	0.37	-0.36	0.66
Go-Pg				1.0	-0.09	0.53	-0.46	0.75
A-N					1.0	-0.12	0.03	-0.11
N-ANS						1.0	-0.08	0.51
Ar-Go-Gn							1.0	-0.27
PNS-ANS								1.0

Correlation is significant at ± 0.030 .

TABLE VII - Correlation Matrix for Mongoloids and Siblings

	N-S-Ar	N-Ba	Ar-Go	Go-Pg	A-N	N-ANS	Ar-Go-Gn	PNS-ANS
N-S-Ar	1.0	0.29	0.08	0.19	-0.51	0.28	-0.12	0.14
N-Ba		1.0	0.57	0.63	-0.27	0.76	0.07	0.67
Ar-Go			1.0	0.62	-0.12	0.73	-0.12	0.67
Go-Pg				1.0	-0.10	0.78	-0.27	0.67
A-N					1.0	-0.38	0.05	-0.22
N-ANS						1.0	0.03	0.75
Ar-Go-Gn							1.0	0.03
PNS-ANS								1.0

Correlation is significant at ± 0.030 .

Figure 1. A child with Down's syndrome,
age eight years

Figure 2. A sibling of the child in Figure 1,
age six years.



Figure 3. A graphic representation of the maxillary measurements in Table I.

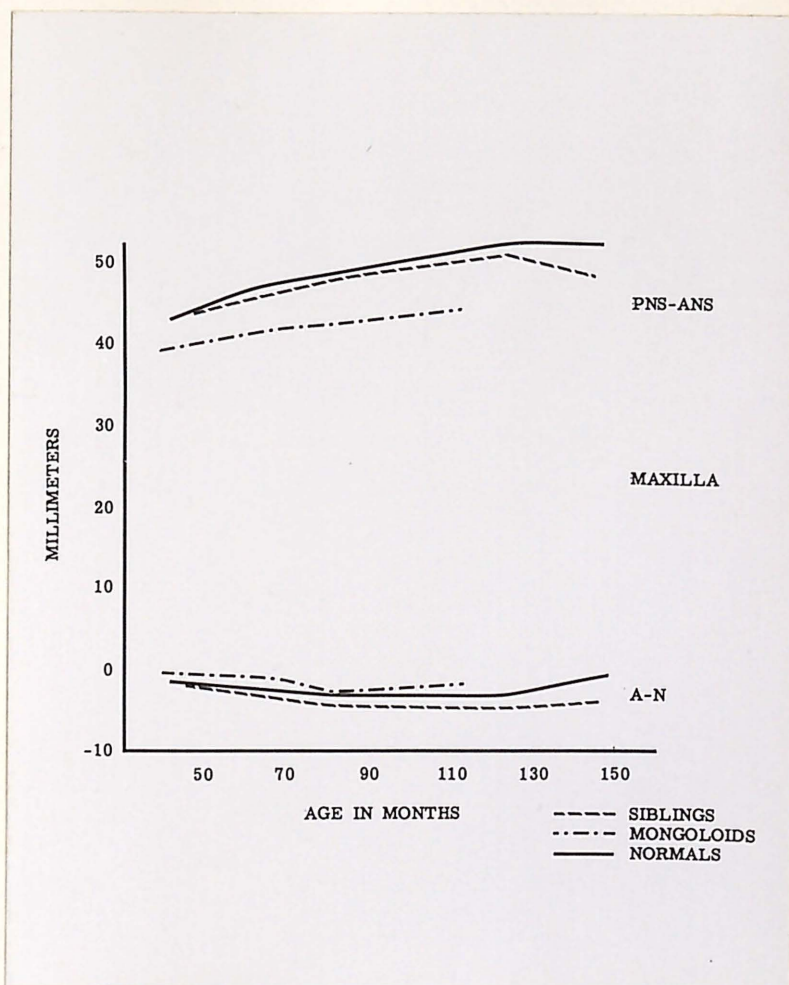


Figure 4. A graphic representation of the
mandibular measurements in Table I.

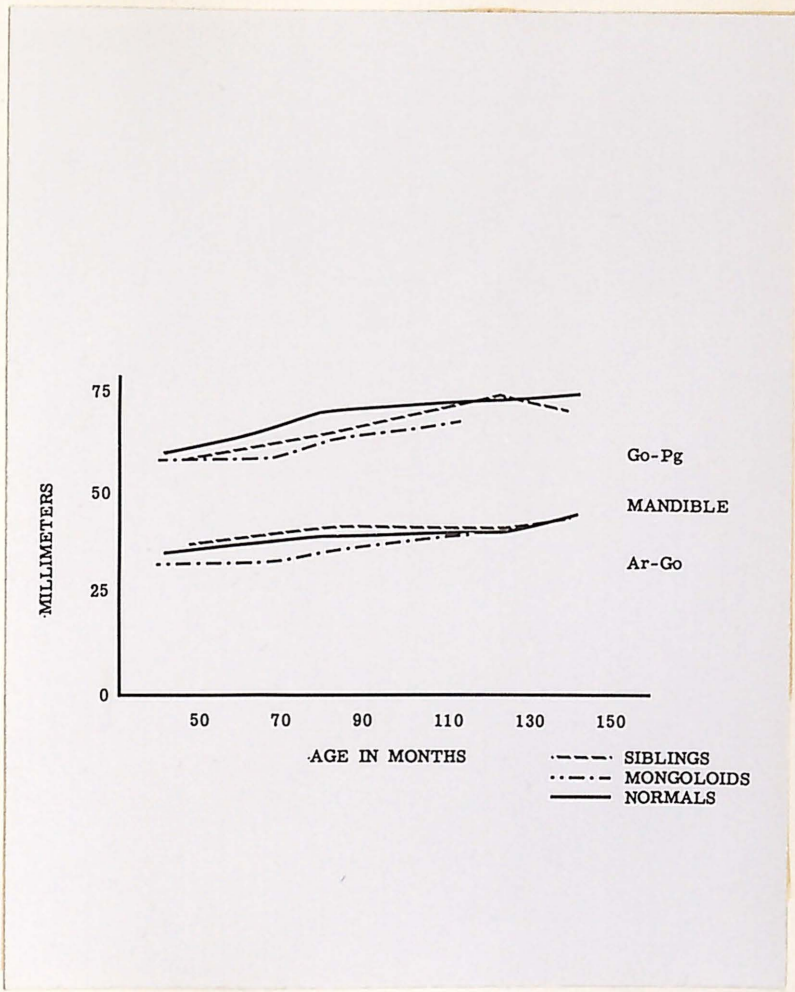


Figure 5. A graphic representation of the measurements of cranial base length and upper facial height in Table I.

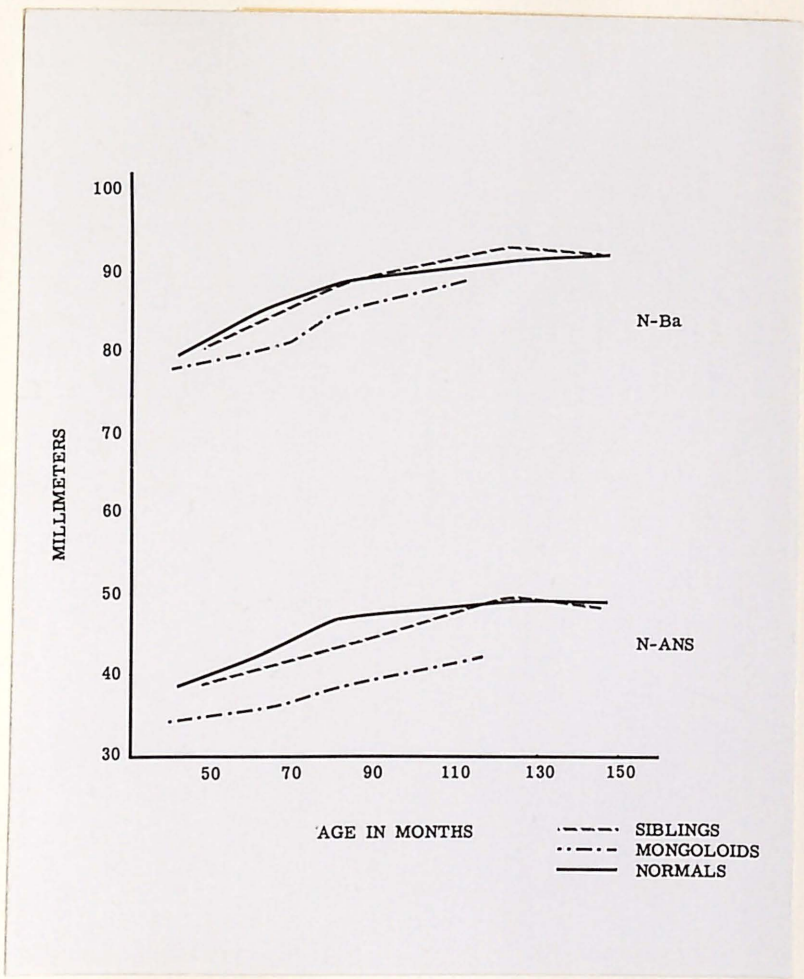


Figure 6. A diagrammatic representation of a typical cephalometric radiographic tracing.

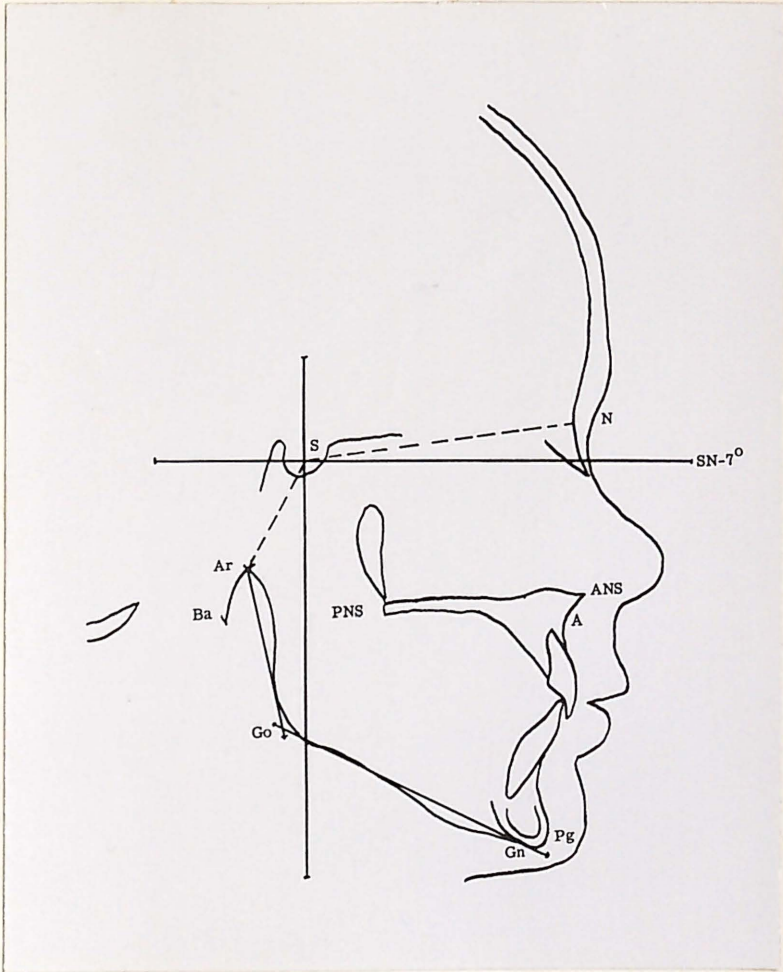


Figure 7. A diagrammatic representation of the hand of the normal and mongoloid child, showing the triradii of both hands. a, d, and t are found on the normal hand. a, d, and t' are found on the hand of the mongoloid child.



DISCUSSION

In this study an attempt has been made to characterize the mongoloid face and cranium. The data were gathered in a reproducible manner using a standard cephalometric technique and were then analyzed by several refined statistical methods.

The means of the measurements were calculated for the various age ranges. This was done to provide a simple visual picture of the direction in and differences of growth in the three groups of children. The means indicated that there was little if any difference between the measurements of the normal and the sibling children. The mongoloids were smaller in all the linear measurements and had more acute angular measurements than either the normal or sibling children. This conclusion was made by evaluating each measurement individually.

Using a regression equation, the measurements of the siblings were corrected, on the basis of a sample of normal individuals, to match the age of the mongoloid. The means of these measurements were subjected to "t" tests to see if the differences between groups for the different measurements were statistically significant. As was seen in

Table II, the differences between mongoloid children and their "age corrected" siblings were not significant, possibly for two reasons. First, the sample of children included in this study was small and individual variations were so great as to preclude finding significant differences. Secondly; the normal sample selected for making age corrections was in fact a select group of children with normal occlusion and skeletal patterns. They do not represent children chosen at random and thereby an average cross-section of the population. The result was, in fact, that the siblings were corrected on the basis of only normal skeletal development and did not include the deviant skeletal pattern which would be expected by choosing children at random. The siblings were chosen for comparative purposes because they were close genetic relatives of a mongoloid and were healthy children below the age of puberty. It should be noted that this sort of a growth study using matched siblings might be designed in a different manner which would eliminate the problem of age correction. When a mongoloid child is old enough (three years or older) he should be radiographed in a cephalostat. All

subsequent children in the same family should also be radiographed when they are old enough and serial cephalograms should be made at approximately one year intervals. Cephalometric radiographs of the mongoloid child could then be taken at the exact age of the sibling who was previously studied at that age. This would allow for both exact age comparisons and individual longitudinal growth data. Thus, the need for mathematical correction is eliminated and the growth values of the sibling child at any specific age would be readily available.

The third method used to analyze the data obtained from the cephalometric radiographs was the step-wise regression analysis, the methodology of which was described in an earlier section of this study. This system proved to be the best evaluation and the most realistic in the light of the sample size. This multivariate analysis allows for a system of computation of variance in the face of independent variables which are highly correlated.

Significant differences were found in the normal-sibling group. This was to be expected. The normal children were selected on the basis of having essentially normal craniofacial skeletons, and, if

not an ideal occlusion, they did have class I occlusions. The siblings obviously were a more random representation of the population since they were not selected on any skeletal basis. Therefore differences did appear. It seems logical to reason that the differences between the normal children and siblings can be attributed to the fact that each group was selected using different criteria.

Furthermore, the cephalostat used to radiograph the normal children was different from the one used for the mongoloid and sibling children. This cephalostat, a Higley, maintained a constant mid-sagittal plane to film distance thereby creating an enlargement factor in the normal children. The Bolton-Broadbent machine which was used on the mongoloids and siblings keeps the film plane as close as possible to the mid-sagittal plane. This fact may also account for the significant differences between the normals and siblings and for large significant differences between the mongoloid children and the normals.

The multivariate analysis showed the mongoloid child to have retarded upper facial growth as com-

pared to the normal child. The maxilla was smaller both in length and depth (horizontally and vertically) in the mongoloid child than in the normal child. It was also more anteriorly positioned. Because the maxilla is small in the mongoloid child, anterior positioning of the maxilla may represent attempt at compensation. The ramus and body of the mandible was also smaller in the mongoloid child. Unexpectedly the sign of the partial regression coefficient indicated that cranial base, (N-Ba) was significantly larger in the mongoloid than in the normal child; while the raw means as shown in Table I do not support this. This discrepancy may be related to the fact that when two measurements are small for a group and a regression analysis is done, occasionally one measurement stays small and the other becomes large. This is an indication that the variable that did not change sign, is measuring the major component of variation. This fact then indicates that the major component of variation in the mongoloid group is the measurement of PNS-ANS and N-Ba is only contributing a small portion of the variation.

The apparent differences noted between the

mongoloid children and their siblings were essentially the same as those noted in the mongoloid-normal comparison but in most cases to a lesser magnitude. In fact, the variances in the measurements between the mongoloids and their siblings were not significant for cranial base length; body of the mandible, maxillary position or cranial flexure angle, but did approach significance for maxillary length and upper facial height. However, even though the variance was below the five percent significance level, mongoloid children were smaller in six of the eight measurements as indicated by the sign of the partial regression coefficient. A larger sample might have made the "t" values significant, as all of them with the exception of the maxillary position approach statistical significance.

SUMMARY AND CONCLUSIONS

This study was designed to show the pattern of craniofacial growth in children with Down's syndrome and the differences between them and their normal siblings. Twenty mongoloid children between the ages of three and 10 years were selected on the basis of having a sibling between the ages of three and 12 years and having no history of congenital heart disease. The mongoloid children were non-institutionalized and were obtained through the Medical Genetics Department of the Indiana University School of Medicine and from the Marion County Society for Retarded Children and the diagnosis of mongolism in these children was confirmed by clinical examination. A sample of 75 children with essentially normal occlusion was obtained from the Orthodontic and Pedodontic Departments of the Indiana University School of Dentistry, and used as a control group.

Cephalometric radiographs were taken of the children and acetate tracings were made. Measurements were recorded for cranial flexure angle (N-S-Ar), cranial base length (N-Ba), maxillary length (PNS-ANS), maxillary position (N-A), mandibular ramus length (Ar-Go), mandibular body length (Go-Pg), gonial

angle (Ar-Go-Gn), and upper facial height (N-ANS).

The data were analyzed by three separate methods. First, the measurements of the normal, mongoloid and sibling children were arranged in groups of three, five, seven, 10 and 12 years of age. Means of the grouped measurements were tabulated. These means were used to construct graphs in order to visualize the magnitude and direction of the various measurements in the three groups of children.

Secondly, the data obtained from the normal children were used to calculate a regression coefficient on age for each measurement. The measurements taken from the sibling children were then "corrected" to the same age as their mongoloid siblings using these coefficients. The means of the measurements were compared using "t" tests. The results of these tests showed the differences in the measurements between the two groups were not statistically significant.

Thirdly, the data were analyzed using a multivariate, step-wise regression of the various cephalometric measurements. Three statistical comparisons were made: sibling versus normals, mongoloids versus normals

and mongoloids versus siblings. This analysis is of great value as it is capable of handling many variables simultaneously in cases where the variables are highly correlated. The step-wise regression was used here to show differences between each of the three comparisons while taking into account the correlations between the included variables. The variables were the various measurements and age and age squared. The computations were done in a 7040 IBM computer so that the individual correlation values, regression coefficients, "t" values and R^2 values could be calculated quickly and easily for each of the three comparisons.

Thus, using the multivariate step-wise regression analysis, the following results were obtained:

1. N-S-Ar (cranial flexure angle) was found not to be significantly different between siblings and normals. This angle was significantly less obtuse in the mongoloids than in the normal children, while the siblings also had a less obtuse flexure angle than the mongoloids. This latter difference closely approached significance at the five percent

level of confidence.

2. N-Ba (cranial base length) was found to be significantly larger in the mongoloids than in the normal children. It was also larger in the mongoloids than in the siblings but not significantly. There was no significant difference between the normals and the siblings even though the siblings did have a longer cranial base.

PNS-ANS(maxillary length) was found to be significantly shorter in the mongoloid children than in the normals. The mongoloids were smaller than the siblings in this measurement but only to a degree approaching significance. The sibling children were smaller than the normals but not significantly.

Because of the high correlation between length of the cranial base (N-Ba) and length of the maxilla (PNS-ANS), the regression analysis indicates the amount of growth of cranial base above and beyond that of the maxilla. Since, in fact, the growth of cranial base and maxilla are retarded, the amount of growth of cranial base beyond that of the maxilla appears to be negative. Therefore, it is reasonable to assume that the

cranial base in mongoloids is shorter than that of the normal or sibling children.

3. Ar-Go (mandibular ramus length) was found to be significantly longer in the siblings than in the normals. The mongoloid children proved to have a shorter ramus than either the normals or the siblings.

4. Go-Pg (mandibular body length) was found to be significantly smaller in the mongoloids than in the normal children, but not significantly smaller than the siblings. There was no significant difference between the normals and the siblings, even though the siblings were larger.

5. Ar-Go-Gn (gonial angle) was found to be significantly more obtuse in the siblings than in the normals. The mongoloids were shown to have a significantly more acute gonial angle than either the normal children or their siblings.

6. The maxillary position (N-A) of the mongoloid children was found to be positioned anteriorly, when related to cranial base as compared to the normals. The siblings were significantly more retruded than the normal children. There were no significant differences in this dimension between the mongoloids and the siblings.

7. N-ANS (upper facial height) was found to be significantly smaller in the mongoloid children than in the normals. The mongoloids were also smaller in this dimension than the siblings to a degree closely approaching significance at the five percent level. The siblings were smaller than the normals but not significantly.

8. The midface of the child with Down's syndrome was found to be small in the vertical and horizontal dimensions and was anteriorly positioned under the cranial base. The mandible also was small with an acute gonial angle. The fact that cranial flexure is less obtuse in mongoloids, places the mandible in a forward position, may account for the prognathic appearance of some of these children. It is not due to a large mandible.

9. The sibling and normal children showed a similar growth pattern when compared to the mongoloid children. However, the differences between siblings and mongoloids were not so great as the differences between the normal children and those with Down's syndrome.

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ABSTRACT

A Cephalometric Comparison of Children
with Down's Syndrome and their Normal Siblings

by Macy J. Landau

The mongoloid face and craniofacial skeleton has been characterized by many investigators using clinical impressions and soft tissue measurements on living and autopsy material. Few studies have included data derived from cephalometric radiographs. The present study was designed to describe the mongoloid face and cranial base and to analyze the data.

Twenty mongoloid children ranging in age from three years to 12 years, and their siblings were selected for study. A control group of children were selected on the basis of their essentially normal occlusion and facial skeleton.

The data obtained from the cephalometric radiographs were analyzed in three ways. Each of the three groups of children, normal, mongoloid and their siblings were divided into four age groups, approximately three, five, seven and 11 years of age and means for the individual measurements were calculated. The sibling measurements were "corrected" to the age of the mongoloid child using the growth progression data from the normal children. The mean measurements of the "corrected" siblings and mongoloids were then compared using "t" tests for statistical significance. All children were then divided into three comparison pairs, normal-sibling, normal-mongoloid, and mongoloid-sibling, and the cephalometric measurements subjected to a multivariate, step-wise regression analysis.

The growth of the maxillae and mandible were retarded in the mongoloid children. The maxilla and mandible were positioned anteriorly under the cranial base.