Comparative Value Of X-rays Of The Spheno-occipital Synchondrosis And Of The Wrist For Skeletal Age Assessment

JOSEPH C. KONIE, D.D.S., M.S.
Chicago, Illinois

INTRODUCTION

The words growth, development and maturation have a common meaning to many people and, owing to their overlapping and interdependence, it is impossible to separate them by exact definition. It therefore seems advisable that each investigator set for himself certain boundaries within which he will categorize phenomena if only for the sake of communication. As an example, growth may be considered as increase in the size of an organism and of its parts; development, as changes in form and relationships; maturity, as alterations in tissues which result in states which differ from those of earlier stages. All three of these areas have been linked by studies which related them to each other and to the universally employed measuring scale, chronological age.

Until the advent of the x-ray, studies in the field of maturation lagged behind those of growth and development as these have been delineated above. There had been marked advances in knowledge of many maturational processes by historical and chemical methods but these had been largely of cross-sectional nature. It had been well-nigh impossible to study maturational processes in the individual throughout the growth period, i.e., longitudinally. The x-ray offered this opportunity.

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Among the earliest efforts to develop standard scales for appraisal of levels of development were those directed at the hand and wrist. Since then, most of the bone junctions of the body have been similarly attacked. However, the hand and wrist remain the favorites with researcher and clinician alike.

Aside from certain cross-sectional studies on the endocranial and ectocranial sutures, the skeleton of the head has been almost completely neglected. The findings that had been made were derived from dried skeletal material on which histories were unknown. Even with the advent of cephalometric roentgenography there were problems to be overcome in the head region that were not present in other parts of the body. In bony junctions of the hand, wrist, knee, foot and ankle it is possible to secure a clear x-ray image of the individual part while in the head this is almost impossible owing to the bilateral images thrown on the screen. Even the single midline junctions of the cranial base are too often obscured by denser overlying structures. Nevertheless, this technique, which demanded accurate positioning of the head, raised doubts of the correctness of certain prevailing concepts that had resulted from other types of investigation.

Cephalometric laminagraphy, employing a similar, precise head positioning technique, made possible the gathering of accurate data on these sites from x-ray films. The present study was an effort to determine whether there was correlation between the closure of the spheno-occipital synchondrosis and the maturation of the hand and wrist. Such correlation was shown to exist.

Review of Literature

Ranke, 1896, is thought to be the first to employ roentgenograms for the illustration of the ossification processes in human carpals. He studied child development as related to the appearance of ossification sites at birth and through childhood.

Pryor, 1925, wrote a series of treatises on carpal development dating as early as 1905. These covered a span of more than twenty-five years of observations. He tabulated the time of appearance of bones of the hand, time of union of the epiphyses, and sex differences in skeletal development. He noted that females show earlier maturation than males, the difference becoming apparent as early as the embryonic stage of development. These differences were measured in hours during the prenatal stage, in days postnatally, and in years as puberty was approached. He felt that the hand was a good indicator of skeletal development, since it reflected the rate of skeletal maturation of the body.

Rotch, 1908 and 1910, studied the appearance of carpal bones and the appearance of the distal epiphyses of the radius and ulna for the purpose of developing a thirteen stage scale covering the period from birth to the fourteenth year of life. He assigned approximate ages for the various stages of his scale.

Severson, 1922, used a similar method of study on one hundred children, ten years of age. He concluded that morphological changes in the skeleton of the hand gave a better indication of the development of the child than did chronological age. He felt that wrist radiograms were more accurate than dentition or pubescence in determining physiologic age.

Todd, 1930, developed an inspectional system in which a judgment was rendered on the radial and ulnar epiphyses, metacarpal and phalangeal epiphyses, and carpal bones for skeletal development. His method differed from those presented up to this time in that he studied other centers of ossification (shoulder, knee, foot) in conjunction with the hand.

Hellman, 1928, reported a study of ossification of the epiphyses in which he used both inspection and measurement. The study was based on sixty females between ten years three months, and twelve years and three months. He used the total length of the digits and the width and length of the phalanges as a supplement to inspection. He found that the greatest increment to bones of the hand preceded the greatest increase in height of the body by one year. He found that the greatest activity in the course of development took place at twelve years and five months, or at the time of eruption of the second permanent molar.

Baldwin, 1928, was the first to measure carpal bones for the determination of degree of development. He determined the total ossified area in the carpals by means of the planimeter and measured bone shadows directly from the radiograms. He felt that the development of the carpals, when considered quantitatively, was of value in determining the degree of development. He reported high correlation between ossification, height and weight. However, he made no correction in his early measurements for hand size.

Flory, 1936, developed a qualitative scale of carpal development based on one hundred radiograms for each age group for each sex from eight to seventeen years of age. He chose the median roentgenogram for the standard of that age group and was able to evaluate roentgenograms to the nearest six months. He showed a very high reliability even when checked by non-experienced raters. Flory showed that pubertal onset can be fairly well predicted by the appearance of the adductor and flexor sesamoid bones of the thumb.

Todd, 1937, selected Cleveland children who had excellent health backgrounds as determined by physicians. The data were gathered over a ten year period. The study included six areas of examination (hand, foot, elbow, knee, shoulder and pelvis). These areas yielded approximately the same level of maturity at the specific time the x-rays were taken. He arranged the roentgenograms in a sequence of maturity for a specific age group and sex, and chose from the central group a standard that was the median on which the fewest reservations had to be made. The hand standards covered the ages of three months to sixteen years in girls and three months to nineteen years in boys.

Simmons and Greulich, 1943, compared menarcheal age, height, weight and skeletal age of girls seven to seventeen years in a serial study of two hundred females of the Brush Foundation regular series. The skeletal age was obtained from the wrist, pelvis, knee, shoulder, elbow and foot. The study showed that skeletal age was better correlated to menarcheal age than were standing height, weight, or annual increments in standing height.

Nanda, 1955, studied ten males and five females in a serial study from four to twenty years of age for the purpose of relating face growth to general body growth. He concluded that the curve of facial length has the general basic growth characteristics common to many parts of the human body.

Dreizen, 1957, studied 227 males and 223 females from one month to sixteen years, eleven months of age in order to compare skeletal ages derived from x-rays of the right and left hands. He found that only five of 450 children showed a dissimilarity of more than six months between the skeletal age derived from the two hands. In only thirteen per cent of the cases the right hand was slightly more advanced.

Lamons and Gray, 1958, studied the relationship between tooth eruption age, skeletal age, and chronological age of sixty-one Atlanta children — twenty-five white males and thirty-six white females from four to fourteen years of age. They concluded that hand and tooth development may vary independently.

Minkoff, 1959, used a mixed sample of thirty-two individuals ranging from four to twelve years of age for the study of skeletal growth with reference to the mandible, metacarpals and standing height. He found a statistically significant correlation between condylar growth and height, and metacarpal and condylar growth.

Rose, 1960, from a cross-sectional study of the relationships of facial areas with several body dimensions concluded that chronological age and carpal ranking were not as reliable guides as were stature and body weight.

Of the many studies of the human skull, only two concerned themselves with the ossification of the spheno-occipital synchondrosis as determined by the radiographic section of this junction. Irwin, 1960, through the use of midsagittal tomographs of forty-seven individuals between five and twenty-five years studied the closure of the spheno-occipital synchondrosis. He found that this junction began to close from the tenth to the thirteenth year of age with obliteration occurring by the eighteenth year. Complete fusion was present in one patient fourteen years of age. Irwin showed that a superior narrowing of this junction occurs as early as six years of age, and that the narrowing precedes superior fusion.

Powell, 1962, studied the spheno-occipital synchondrosis of 205 males ranging in age from eight to twenty-one years and of 193 females from six to eighteen years through the use of the midsagittal laminagraph. He demonstrated a significant sex difference for the onset of closure and obliteration of this junction, the females showing a precocity as compared with the male. However, he also showed that, generally, closure of the spheno-occipital synchondrosis occurs much earlier than stated by other researchers. Powell felt that no further growth occurred in this area after thirteen years nine months of age in the female, and fifteen years two months of age in the male.

Materials and Methods

Three hundred fourteen patients at the College of Dentistry, University of Illinois were studied. Of these, 162 were females ranging in age from seven years six months to twenty-two years. The males ranged in age from seven years nine months to twenty-four years. Hand and wrist x-rays, and midsagittal head laminagrams were taken of all individuals.

Two hypopituitary males, one hypopituitary and one hyperpituitary female from the endocrine clinic, University of Illinois Research and Educational Hospitals were added to the sample to study extreme variation.

The method employed for taking the midsagittal cephalometric laminagram was the same as that used by Powell and the same Keleket-Kieffer laminagraph was used. Exposures were made at a 36 inch focal film distance with a seven inch sweep. The exposure was 120 milliampere seconds. Kilovoltage was determined for each individual and varied between 55 and 75 kilovolts. The thickness of the lamina in focus was 2.2 millimeters.

In order to stabilize the head and to obtain the correct level of "cut" to assure a true midsagittal laminagram a head holder devised by Ricketts, 1950, was employed. The construction of this device is such that the ear posts are interchangeable and adjustable. This allows for the fixing of the midsagittal plane of the head at a predetermined level above and parallel to the table top. A nasal rest is employed to limit movement about the ear post axis.

A corrected midsagittal dimension was obtained from a frontal cephalometric radiogram to determine the level of focus of the lamina and the laminagraph was adjusted accordingly.

The anode was positioned one-half inch anterior to the ear posts so that the spheno-occipital junction would be in the center of the zone of movement at the predetermined plane. The gauge controlling the focal plane was set and the subject was told to occlude his teeth.

The radiograms of the hand and wrist were assessed according to the standards of Greulich and Pyle whose *Radiographic Atlas of Skeletal Development of the Hand and Wrist* is an enlargement and refinement of the *"Atlas of Skeletal Maturation of the Hand"* by Todd. The technique employed was the inspectional method for skeletal assessment.

The film to be assessed was compared with the standard of the same sex and nearest chronologic age in the Atlas. After this, it was compared with adjacent standards or until a standard which superficially resembled it was found. In studying the hand x-ray superficially, certain features denoted periods in development: the presence or absence of carpal or epiphyseal ossification centers during infancy and early childhood; the degree of diaphyseal-epiphyseal fusion during puberty and late adolescence; and changes in shapes of bones and other skeletal features during the intermediate period.

In order to obtain a more accurate assessment a detailed comparison of the individual bones and epiphyses was done. If an individual bone in the film was at the same stage of development as the corresponding bone in the standard selected for detailed comparison, it was given the skeletal age of that standard. If less or more advanced than its counterpart in that standard, it then was compared with adjacent standards and assigned the next standard's age if the comparison was favorable. If the bone was intermediate between the standard selected for detailed comparison and the adjacent standard, it was given an intermediate age between the two standards.

The subjects were divided into two groups according to sex and each group was arranged in order of chronological age. In a second column were placed the corresponding skeletal appraisals of age, as determined from the wrists. In a third column the state of the spheno-occipital synchondrosis was tabulated as 0, open; 25, one-quarter closed; 50, one-half closed; 75, three-quarters closed, and 100, completely obliterated. These data appear in Tables I and II.

Although casual inspection was enough to convince statistical consultants that there was close correlation between the chronological and skeletal age levels, it was decided to test them still further. A regression line was drawn on the basis of the total sample (Charts 1 and 2).

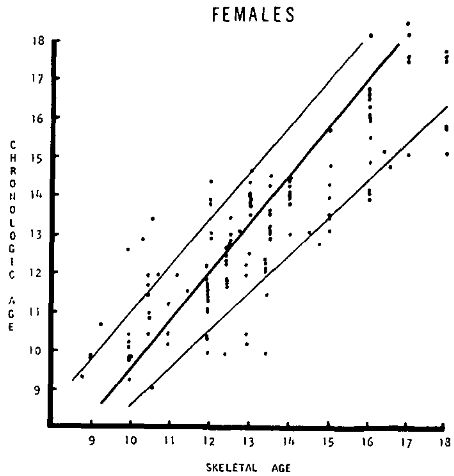

Chart 1 Linear regression line for data from Table I. Narrower lines indicate confidence limits.

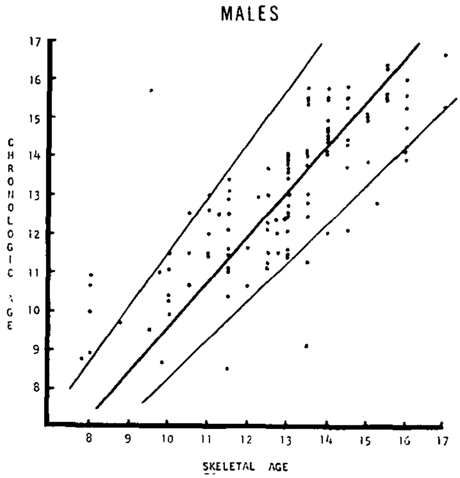

Chart 2 Linear regression line for data from Table II. Narrower lines indicate confidence limits.

Findings

The means of the chronologic and skeletal ages were found to compare favorably and similarly to the Greulich and Pyle standards.

Before ossification the spheno-occipital synchondrosis appeared as a radiotranslucent band lying between the sphenoid body and the basilar part of the occipital bone. It was often very irregular in outline.

When beginning fusion was evident, it was observed to be most often initiated on the superior aspect of the junction. No radiolucency was seen at the site

Table I

COMPARISON OF AGES TO CLOSURE OF THE SPHENOOCCIPITAL SYNCHONDROSES

FEMALES

Chronologic Age Yrs-Mos	Skeletal Age Yrs-Mos	% SO Closed	Chronologic Age Yrs-Mos	Skeletal Age Yrs-Mos	% SO Closed	Chronologic Age Yrs-Mos	Skeletal Age Yrs-Mos	% SO Closed	Chronologic Age Yrs-Mos	Skeletal Age Yrs-Mos	% SO Closed
7-6	7-6	0	11-6	10-6	25	12-11	12	50	14-1	14	100
8	8-3	0	11-7	12	25	12-11	12	50	14-2	16	100
8-4	7-10	0	11-7	11-6	50	13	12-6	50	14-2	16	100
9-1	10-6	25	11-8	12-6	100	13	13-6	100	14-3	14	100
9-3	10	0	11-8	12	100	13	13-6	100	14-3	15	100
9-4	8-8	0	11-8	12-6	25	13	14	100	14-3	13-6	50
9-8	10	0	11-8	12	25	13	14	100	14-4	13	25
9-9	10	0	11-8	12	25	13-1	13-6	100	14-4	12	25
9-10	9	0	11-9	12-6	75	13-1	12	25	14-5	14	100
9-10	10	0	11-9	10-6	50	13-1	14-6	100	14-6	14	100
9-11	9	0	11-9	12	100	13-2	15	100	14-6	13	75
10	12-5	25	11-10	12-6	50	13-2	12-9	75	14-7	13	50
10	12	50	11-11	12	100	13-2	13-6	100	14-9	16-6	100
10	13-6	100	12	11-3	25	13-3	13-6	100	14-9	15	100
10-2	10	0	12	13	100	13-3	13-6	100	14-9	15	100
10-3	11	0	12	13	75	13-3	13-6	100	14-10	16	100
10-3	13	75	12	10-6	25	13-4	13	50	15-1	17	100
10-4	10	25	12	10-9	25	13-5	12-6	100	15-2	18	100
10-4	12	25	12-1	13-6	100	13-5	10-6	0	15-2	16-4	100
10-5	12	75	12-2	13-6	100	13-5	15	100	15-5	16	100
10-6	10-9	75	12-3	12	25	13-6	15	100	15-8	15	100
10-6	10-6	50	12-3	12-6	50	13-6	13	100	15-9	18	100
10-6	11	75	12-3	13	100	13-6	15	100	15-10	18	100
10-6	10	0	12-3	12-6	50	13-6	13-6	100	15-10	18	100
10-6	13	100	12-3	12-6	50	13-7	13-6	100	15-11	16	100
10-6	10-6	25	12-4	13-6	100	13-7	13-6	100	15-11	16	100
10-8	9-3	0	12-4	12-6	25	13-8	13	75	16	16	100
10-10	10-6	25	12-5	12-6	75	13-9	14	100	16-1	16	100
11-1	12	50	12-5	12-6	75	13-9	13	50	16-1	16-6	100
11-1	10-6	0	12-5	12-6	75	13-9	12	25	16-3	16	100
11-2	12	75	12-6	12-6	25	13-10	16	100	16-6	16	100
11-3	11-6	25	12-6	12-6	50	13-10	12	75	16-6	16-6	100
11-3	11	25	12-7	12-6	50	13-10	13	50	16-7	16	100
11-4	12	75	12-7	10	0	13-10	12	100	17-6	17	100
11-4	12	25	12-7	12-6	25	13-11	15	100	17-6	18	100
11-4	12	25	12-7	12-6	25	13-11	14	100	17-7	18	100
11-5	12	75	12-8	12-6	25	14	13	50	17-9	18	100
11-6	13-6	100	12-9	14-9	100	14	14	100	18-3	17	100
11-6	12	25	12-10	13-6	100	14-1	13	100	18-4	16	100
11-6	13-6	100	12-10	10-3	0	14-1	16	100	18-6	17	100

Table II

COMPARISON OF AGES TO CLOSURE OF THE SPHENOOCCIPITAL SYNCHONDROSES

MALES

Chronologic Age Yrs-Mos	Skeletal Age Yrs-Mos	% SO Closed
7-9	6	0
8-6	11-6	0
8-7	9-8	0
8-8	7-8	0
8-11	8	0
9-2	13-6	50
9-6	9-6	0
9-7	3-6	0
9-8	8-9	0
9-11	10	0
10	8	0
10-3	10	0
10-3	10	0
10-4	11-6	0
10-5	10	0
10-7	10-6	0
10-7	12	0
10-8	8	0
10-11	8	0
11	9-9	0
11	11-6	0
11-2	11-6	0
11-2	11-6	0
11-2	12-6	25
11-2	10	0
11-3	12-6	25
11-3	13-6	50
11-4	13	25
11-4	11-6	0
11-5	11	0
11-5	11-6	0
11-5	13	25
11-5	10	0
11-5	12-6	25
11-6	11-6	0
11-6	11	0
11-6	10-6	0
11-6	11-6	0
11-6	12-9	25
11-7	13	25
11-8	12	25
11-8	11-6	0
12	11	0
12	11	0
12	12-9	75
12	14	100
12-2	12-6	25
12-2	12-6	25
12-2	14-6	50
12-2	12-6	25
12-2	13	50
12-2	11-6	0
12-3	12-6	25
12-4	12-8	25
12-4	11	0
12-5	13-6	50
12-5	13	25
12-6	11-3	0
12-6	10-6	0
12-6	11-6	0
12-7	11	0
12-7	13	25
12-7	12-6	75
12-8	13	25
12-9	13-6	75
12-9	13-6	100
12-9	15-3	100
12-10	11-6	0
12-11	12-3	0
12-11	12-6	25
13	12-9	25
13	13-6	25
13	11	0
13	13-6	25
13	13	75
13	13	25
13-2	13	25
13-2	13	25
13-2	13	75
13-2	11-6	0
13-5	13	25
13-5	13	0
13-5	11-6	0
13-5	13	75
13-7	13	50
13-7	13	50
13-8	13	100
13-8	14-6	25
13-8	12-6	100
13-8	13	50
13-9	13-6	50
13-9	13	75
13-10	15	50
13-10	13-9	100
13-10	16	100
13-10	16	50
13-10	13	75
13-11	13	50
13-11	13	50
13-11	13	75
13-11	13	50
14	13-6	100
14	14	50
14	14	50
14	13	75
14-1	13	75
14-1	13-6	50
14-2	14	50
14-2	13-6	25
14-2	16	100
14-3	14-6	100
14-3	16	100
14-3	14	75
14-5	14-6	75
14-5	14	50
14-5	14	100
14-6	14	50
14-7	14	75
14-8	14	100
14-9	16	100
14-10	14	50
14-10	15	100
15	15	100
15-2	15	75
15-3	17	100
15-3	14-6	50
15-3	16	100
15-4	13-6	75
15-5	13-6	50
15-5	14	50
15-5	15-6	100
15-6	14-6	100
15-6	13-6	50
15-6	14	75
15-6	15-6	100
15-7	16	100
15-7	9-6	0
15-7	15-6	100
15-9	14	100
15-9	14	50
15-9	13-6	25
15-9	14-6	100
16	16	100
16-3	15-6	50
16-4	15-6	100
16-8	17	100
17-2	18	100
17-9	19	100
17-10	19	100
19-8	19	100
20-9	19+	100
24	19+	100

of this junction when it was completely ossified. Eventually, the radio-opaque site where fusion of the two bones occurred disappeared, and the sphenoidal sinus was seen to penetrate into the basio-occiput completely obliterating this junction.

Female

Ossification was first observed in females at the chronologic age of nine years one month; however, this individual had a skeletal age of ten years six months. In only one case did ossification begin before the skeletal age of ten years six months and it occurred at ten years. Also, only one case showed a complete patency at the skeletal age of eleven. Ossification began in the majority of cases at a skeletal age of ten years six months.

The appearance of the hand and wrist at this age shows all of the bones to be present except the sesamoids. These bones are destined to appear within the following six month interval as determined from the Greulich and Pyle standard. The bones present at this age are at a low level of development as compared with the adult state.

Complete closure was seen in all cases but one by the skeletal age of thirteen and one-half years. However, even in this case a closure of fifty per cent was observed. All cases more mature than the age of thirteen years six months showed complete ossification of the spheno-occipital synchondroses.

At the bone age of thirteen and one-half years, the hand and wrist show that all the bones are present. The epiphyseal fusion in the first metacarpal is beginning, as is the fusion in the proximal phalanges of the third, fourth and fifth fingers. The epiphyses of all the distal phalanges were fused with their shafts.

Males

The earliest chronologic age at which fusion occurred in the male was nine years two months. However, this chronologic age corresponded to a skeletal age of thirteen and one-half years. In only one case was ossification present before the skeletal age of twelve and one-half, and this case had a skeletal age of twelve. Also, only one case showed a patency at the skeletal age of thirteen. In the majority of cases initial fusion occurred at the skeletal age of twelve and one-half to thirteen years. The appearance of the hand and wrist in the male at the bone age of twelve and one-half is similar to that of the female described for the skeletal age of ten and one-half years.

At the skeletal age of sixteen years in the male there was complete closure of the spheno-occipital junction in all cases but one. In this instance a closure of twenty-five per cent was seen. All cases more mature than age sixteen showed complete ossification of the spheno-occipital synchondroses.

The hand and wrist of the male at this age are similar to the hand and wrist of the female at age thirteen and one-half years. The epiphyseal-diaphyseal union is well advanced in all the proximal phalanges and in the middle phalanges of some of the fingers, while the remaining fingers showed beginning fusion in the middle phalanges. All of the distal phalanges were fused.

Children with endocrine dysfunction

The spheno-occipital synchondroses of the two hypopituitary male subjects were open. The first subject had a chronologic age of seven and one-half years but a skeletal age of only three years and seven months. The second had a chronologic age of fifteen years and one month, but a skeletal age of seven years five months.

A female hypopituitary subject who was of a chronologic age of fourteen years four months had a skeletal age of six years six months. This subject had a patent spheno-occipital synchondrosis. The other female who was a hyperpituitary had a chronologic age of eleven years three months, but a bone age of thirteen. The synchondrosis was fifty per cent closed.

Discussion

One of the largest samples of children for the study of skeletal development from serial x-rays was that of the Brush Foundation. These were used for the standards set forth in the Greulich and Pyle Atlas. The means of the present study fell within the range of variation of these standards, and showed that the present study was based on Chicago area individuals of comparable genetic and environmental backgrounds. Also, the close concordance between the means of the skeletal and chronologic ages compared favorably with the studies of Flory and Todd.

As was shown by past research, most authors now agree on a definite sex difference in the rate of skeletal maturation. That the females are ahead in skeletal maturation as related to the spheno-occipital synchondrosis was pointed out in this study. The males are slower than females, not only in the time of initial fusion of this junction, but also in complete obliteration of this site. This slower rate of maturation in males was more evident at the time of obliteration. Whereas the male was only two years behind the female in beginning ossification of this junction, he was two and one-half years behind the female when the synchondrosis was considered obliterated. This can be reconciled by the generally slower physiologic development of the male and the concept that the female's development is compressed into a shorter span of time.

Irwin's study showed that the junction began to close from the tenth to the thirteenth year of age, and that it was obliterated by the eighteenth year. His sample was small and he did not divide it according to sex. The present investigation showed that closure and obliteration may occur earlier than that stated by Irwin.

When interpreted in the light of chronologic age this study supports that of Powell. He felt that no further growth was present at the spheno-occipital synchondrosis after thirteen years nine months of age in the female and fifteen years two months of age in the male. The present study showed that the chronologic ages and the spheno-occipital junction closure of both samples corresponded very closely. The latest chronologic date at which the spheno-occipital synchondrosis was open in the female was thirteen years five months and in the male fifteen years seven months. It should be noted that at these ages the skeletal ages were respectively ten years six months and nine years six months. A definite sex difference in maturation of the spheno-occipital junction was shown to exist and it was in agreement with Powell's findings.

Maturity indicators elsewhere in the body aside from the skull may be useful in predicting whether the growth and development of the head has been completed or if further growth may be expected.

Early studies of extreme variation were based on maturation of the wrist, shoulder, pelvis, foot, and ankle. Kost, 1931, compared individuals who had endocrine disorders with normal individuals and found that the lack or abundance of the growth hormone from the hypophysis would result in retarded or advanced union of the epiphyses.

The slower rate of maturation in individuals with endocrine dysfunction as pointed out in this study was additional evidence in support of the work done by Engel, 1941. From a study of hypothyroidism in children, he presented evidence to show the interrelation between the craniofacial, carpal, and dental developmental patterns. He felt that diminished chondral activity at the spheno-occipital junction helped to explain the shortening of the cranial base. Another observation was that the spheno-occipital synchondrosis in hypothyroid children was irregular and wider than normal. This disturbance in growth and development was evident elsewhere in the body as a delay in appearance of centers of ossification or the retardation of epiphyseal maturation.

Crigler, Cohen, and Wittenborg, 1962, presented cases of retarded and accelerated growth due to endocrine dysfunction. Through the use of cephalometric roentgenograms and x-ray films of the hand and wrist, they pointed out a delay in bone age and also a delay in dentofacial growth in a hypopituitary patient, and an advanced bone age and dentofacial growth in one who was hyperpituitary.

A similar observation was reported in the findings of the present study as to the above-mentioned research. Not only was there an advancement or retardation of maturation as determined by the hand and wrist x-rays, but also there was a similar occurrence in maturity of the spheno-occipital synchondroses. Additional investigation in this area is necessary in order to correlate the subtleties of the maturation process in the skull and elsewhere in the body.

The question still remains as to whether classification by degrees of closure has any real significance. Although many believe that the possibility of dimensional growth is gone when bridging of the synchondrosis occurs, there is no positive evidence that this is so. Observations of continuing growth activity of bones after apparent closure of their epiphyses demand that other methods of investigations, e.g., implants, vital staining, and isotopes, be employed for a definitive answer to this problem.

Summary and Conclusions

1. Hand and wrist x-rays, together with midsagittal head laminagrams were obtained on 152 males ranging in age from seven years nine months to twenty-four years, and 162 females from seven years six months to twenty-two years, in order to determine whether there was correlation between the closure of the spheno-occipital synchondrosis and the maturation of the wrist and hand.

2. The samples were tested and found to agree closely to the standards of Greulich and Pyle.

3. To study variation four patients with endocrine dysfunction were also radiographed.

4. The spheno-occipital junction showed a consistency in initial fusion at the skeletal age of ten and one-half in the female (± six months) and twelve and one-half in the male (± six months).

5. Complete obliteration of the junction in the males required a slightly greater length of time after initial ossification than it did in the female.

6. Acceleration or retardation of skeletal development as determined from radiograms of the hand and wrist with respect to chronologic age showed similar alterations in maturation of the cranial base at the spheno-occipital synchondrosis. This was the case whether dealing with the general sample or with patients of known endocrine disturbance.

7. It is not likely that the spheno-occipital junction would be used for determining skeletal maturation; however, it is probable that the wrist x-rays can become an effective tool in ortho-

dontic case treatment planning and prognosis.

5867 W. 95th St.

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