Skeletal Development of Cleft Palate Children as Determined by Hand-Wrist Roentgenographs: A Preliminary Study

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Studies by Mainland (*4–6*), Pryor (*7*), and Todd (*8*) have shown the value of the hand-wrist roentgenograph as a diagnostic and developmental study aid in determining skeletal growth. According to Greulich and Pyle (*3*), the hand-wrist roentgenograph is the most useful single procedure available at present for determining the developmental status of the child. They point out that, by such procedure, accelerated or delayed sexual maturity may be detected or imbalances in skeletal maturation as a result of an endocrine dysfunction can be demonstrated.

Additional review of the literature failed to disclose information on skeletal development directly related to the cleft palate child. This prompted consideration of a study designed to determine the skeletal, dental, and chronological ages of cleft palate children and to compare them with accepted standards for children without clefts (*3*). It was felt that this preliminary study of individuals with cleft palates might indicate whether these subjects display skeletal development within the normal range expected for children without clefts, or whether the group of cleft palate children tend to exhibit an altered pattern of general skeletal growth. The purpose of the study, then, was to determine whether, for children with clefts, a significant deviation from normal skeletal development as evidenced by hand-wrist roentgenographs could be demonstrated.

Method

Forty-eight subjects, each presenting some form of palatal cleft with or without an associated cleft lip, were selected at random from a group of white cleft palate children. To assist in determining chronological, dental, and skeletal ages for each child, certain diagnostic data and study aids were obtained. These included sex, height, weight, type of cleft, oral examination, complete intraoral roentgenographs, and hand-wrist roentgenographs.

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AGE DETERMINATIONS. Chronological age was determined by recording the date of birth and reducing the age in years to months.

Dental age was determined by oral observations of teeth present or missing, estimated stages of eruption of unerupted or partially erupted teeth, and stages of root development as evidenced on the intraoral roentgenographs. A universally accepted method of determining dental age is not available. However, ages of tooth eruption and root completion as compiled by Logan and Kronfeld, later modified by McCall and Schour (*1*), were used in this study. These dental age determinations were recorded for comparison and chronological and skeletal ages.

Skeletal age was determined by interpreting a hand-wrist roentgenograph, since it affords an objective measure of the progress a child has made toward physical maturity. Roentgenographs of the left hand and wrist were used and were compared to the standards established by Greulich and Pyle (*3*), which appear to be generally accepted as reliable standards.

Three factors influenced the selection of the left hand for roentgenographic evaluation. a) Reports of Dreizen and associates (*2*) stated that there was no significant difference between the right and left hands. b) There are far fewer left-handed people and therefore a lower incidence of injury or disfigurement to the left hand as compared to the right hand. c) The International Agreement for the Unification of Anthropological Measurements to be Made on Living Subjects adopted at the Monaco and Geneva Conferences of Physical Anthropologists in 1906 and 1912 specifies that the left side of the body should be used in all anthropological measurements.

The bones in the hand and wrist ossify in a regular sequence and in most normal children there is usually an adequate balance to allow the assignment of a single skeletal age to the hand-wrist complex which is a composite of each individual element (*3*). The skeletal age determination for each child was compared with his chronological and dental ages and with those of normal children of the same age and sex.

ROENTGENOGRAPHIC PROCEDURE. A General Electric dental x-ray machine was used to obtain the hand-wrist roentgenographs utilizing a specially constructed apparatus (Figure 1). The attached apparatus made it possible to standardize a 30-inch film-target distance and to direct the central roentgen rays perpendicular to the film plate. In order to provide roentgenographs which compared favorably with the standards, a series of films were exposed using various combinations of voltage, amperage, and time. Several types and speeds of film and cassettes were examined.

The following exposure factors were established after evaluating the sample roentgenographs for density, clarity, and contrast:

1. Voltage: 50 K.V.P.
2. Amperage: 10 milliamperes
3. Time: large children 4/15 of a second
   small children 2/10 of a second

4. Film: Kodak Blue Brand Medical X-ray film, medium speed, size 8 x 10
5. Cassette: Picker slow screen
6. Developing: in accordance with manufacturer's recommendations
7. Protection: adequate filtration in x-ray machine and lead upon drape for subjects

In order to assure the investigators that satisfactory radiation protection was provided, the amount of radiation to which the subjects were to be exposed was predetermined. The radiation received by each subject during one hand-wrist roentgenographic exposure was measured by the Department of Biophysics and Biometry of the Medical College of Virginia. Radiation to the hand was measured with a Model 70 Victorum "R" meter and a 250 roentgen nylon, low energy chamber. The dose rate measured at a target-film distance of 3.25 inches was 5–9 r/sec. Interpolation to a target-film distance of 30 inches gives a dose rate to the hand of .018 r for the 4/15 second exposure and .013 r for the 2/10 second exposure. Determinations in the genital area under the protective apron

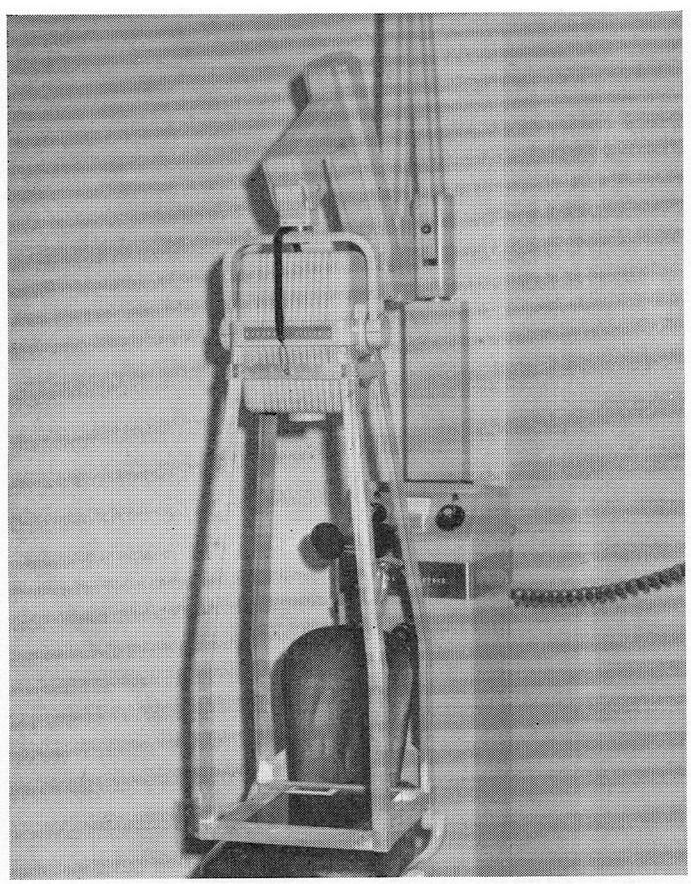

FIGURE 1. Special apparatus to standardize hand-wrist roentgenographs.

were made using a Model 2612 Nuclear Chicago thin window G. M. survey meter. The radiation dose rate under this apron was 10 mr/hr. Interpolation gives a radiation dose of .0008 mr for the 4/15 second exposure and a radiation dose of .0006 mr for the 2/10 second exposure. Two millimeters of aluminum were used in the tube head to control and absorb soft radiation.

Roentgenographic Interpretation. Each roentgenograph was evaluated on the basis of comparison of 29 centers of ossification with the same centers depicted in the standards, and included the following:

1. Distal end of the radius
2. Distal epiphysis of the ulna
3. Capitate carpal bone
4. Hamate carpal bone
5. Triquetral carpal bone
6. Pisiform carpal bone
7. Lunate carpal bone
8. Scaphoid carpal bone
9. Trapezium carpal bone
10. Trapezoid carpal bone and base of the second metacarpal
11. to 15. Epiphyses of the first, second, third, fourth, and fifth metacarpals
16. to 20. Epiphyses of the proximal phalanges of the thumb and four fingers
21. to 24. Epiphyses of the middle phalanges of the four fingers
25. to 29. Epiphyses of the distal phalanges of the thumb and four fingers

Each ossification center was compared with the standards for that particular center and an estimated numerical value recorded. For each subject the numerical values of the 29 centers were totaled and a mean derived. This mean value was converted to a skeletal age by comparing it with the numerical value system given by Greulich and Pyle (*3*). A numerical value for which no exact standard age was represented was converted to the nearest age by prorating it between the skeletal ages of the two adjacent standards.

The calculated skeletal (hand-wrist) age of each subject was compared with the subject's chronological age. The difference, if any, between these two ages was noted. In those instances where the difference was greater than the allowable standard deviation, the amount above or below was recorded. Stuart's standards of deviation as presented by Greulich and Pyle (*3*) were used in the determinations made on all subjects. Those standards of deviation were obtained from a group of Boston children, many of whom were from a low socio-economic level similar to that of the subjects selected for this study.

Results

Tables 1 (males) and 2 (females) summarize findings in reference to chronological age in months, skeletal age in months, Stuart's standard deviation for each represented age, and indicate whether or not the subject was above (+), below (−), or within (W) normal limits of the

TABLE 1. Summary of findings for males in relation to accepted standards for skeletal age, dental age, height and weight (W, within; −, below; +, above accepted standard limits), and type of cleft (B, complete bilateral; L, complete unilateral left; R, complete unilateral right; S, soft palate only; HS, hard and soft palate without cleft of lip).

Subject	*Age in months*		*Standard deviation*	*Relation to accepted Standards*				*Type of cleft*
	Chronological	*Skeletal*		*Skeletal age*	*Dental age*	*Height*	*Weight*	
1	58	45	7.0	−	W	W	W	B
2	73	104	9.3	+	+	+	−	S
3	88	58	10.4	−	−	W	W	B
4	89	55	10.3	−	W	W	−	L
5	92	60	10.6	−	−	+	W	B
6	94	57	10.3	−	W	+	+	R
7	99	54	10.8	−	W	−	W	B
8	103	78	10.9	−	W	−	−	B
9	116	104	11.3	−	W	W	W	L
10	132	142	10.5	W	W	W	−	L
11	133	108	10.5	−	W	−	W	L
12	136	133	10.5	W	W	W	+	HS
13	139	109	10.4	−	W	−	−	B
14	139	120	10.4	−	−	−	−	R
15	142	108	10.4	−	W	−	−	B
16	150	164	11.4	+	W	+	W	L
17	151	132	10.7	−	W	−	−	R
18	153	135	11.1	−	W	W	W	B
19	154	159	10.4	W	W	+	+	R
20	156	110	11.1	−	W	−	−	B
21	159	153	11.1	W	W	−	−	HS
22	160	127	11.1	−	−	−	−	L
23	162	186	11.1	+	W	+	W	B
24	210	190	15.4	−	W	+	W	B
25	214	195	15.4	−	W	W	−	L
26	219	189	15.4	−	W	W	W	L

standard deviations for skeletal age, dental age, height, and weight. These tables also indicate the type of cleft exhibited by each subject.

Of the 26 males studied, 19 were found to be below the standard deviation limits in skeletal age, three were above the standard deviation limits, and four were within normal limits (Figure 2). Of that group, 11 male subjects had complete bilateral clefts, 12 had complete unilateral clefts, and three had less extensive cleft defects (Table 1).

Of the 22 females studied, eight were found to be below the standard deviation limits in skeletal age, 14 were within normal limits, and none were above the standard deviation limits (Figure 3). Of that group, one female subject presented with a complete bilateral cleft, 14 with complete unilateral clefts, and seven with less extensive cleft defects.

TABLE 2. Summary of findings for females in relation to accepted standards for skeletal age, dental age, height and weight (W, within; −, below; +, above accepted standard limits), and type of cleft (B, complete bilateral; L, complete unilateral left; R, complete unilateral right; H, hard palate only; S, soft palate only; HS, hard and soft palate without cleft of lip; Lip, cleft lip only).

Subject	*Age in months*		*Standard deviation*	*Relation to accepted standards*				*Type of cleft*
	Chronological	*Skeletal*		*Skeletal age*	*Dental age*	*Height*	*Weight*	
1	69	53	8.9	−	W	W	W	Lip
2	84	84	8.6	W	W	+	+	R
3	86	89	8.3	W	W	W	W	HS
4	88	89	8.4	W	W	W	W	R
5	116	86	10.3	−	−	−	−	S
6	125	110	10.8	−	W	−	−	L
7	127	118	10.8	W	W	−	+	L
8	144	132	14.0	W	W	−	W	B
9	148	142	14.1	W	W	W	W	R
10	148	143	14.1	W	W	W	W	HS
11	157	153	14.6	W	W	−	−	L
12	159	156	14.6	W	W	W	−	L
13	164	151	13.0	W	W	W	−	R
14	169	180	12.6	W	W	−	−	S
15	176	178	12.6	W	W	−	−	H
16	180	174	11.2	W	W	W	+	L
17	190	166	11.2	−	W	−	W	S
18	194	188	11.2	W	W	−	W	L
19	194	180	11.2	−	W	W	W	L
20	196	172	11.2	−	W	+	+	R
21	217	204	11.2	−	W	−	−	L
22	227	180	11.2	−	W	W	+	L

Dental age determinations were within normal limits for all subjects except five males and one female.

Discussion

In the study group of 48 cleft palate subjects, 27 presented skeletal age determinations below the standard deviation limits. This appears to be a significant proportion except that the smallness of the study group renders all results somewhat inconclusive. However, interesting findings or trends, especially within the group of male subjects, merit reporting.

Nineteen of 26 male subjects presented skeletal age determinations below the standard deviation limits. Ten of the 11 males with complete bilateral clefts are represented in this group of 19, nine of the 12 males with complete unilateral clefts are represented, but none of the three males with less extensive clefts is represented. From this, we note that 83% of the male subjects with more extensive types of palatal clefts displayed calculated skeletal ages lower than standard deviation limits permit.

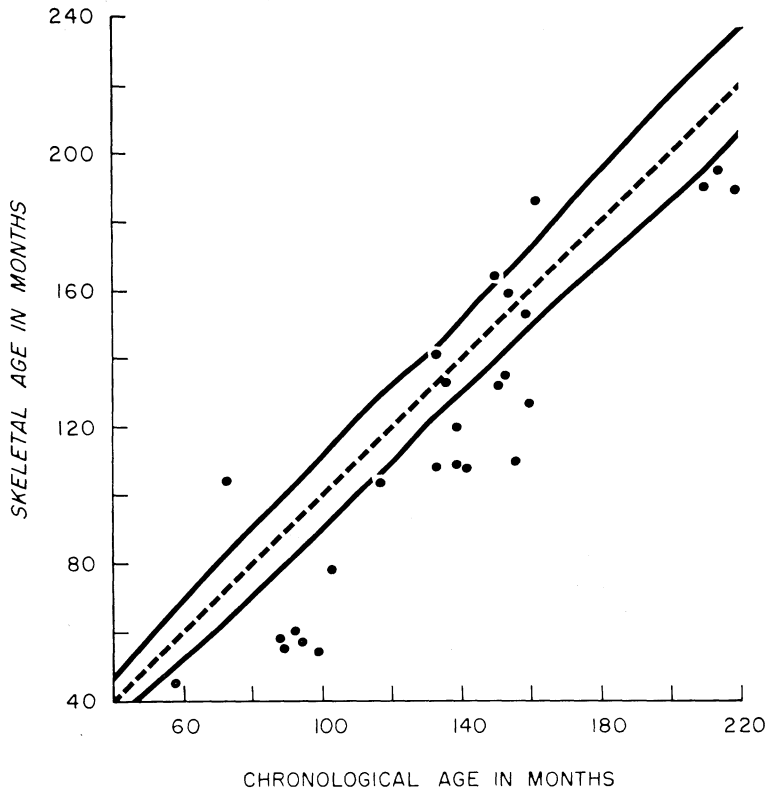

FIGURE 2. Skeletal age distribution of cleft palate males in reference to Stuart's standards of deviation.

Eight of the 22 female subjects presented skeletal age determinations below the standard deviation limits. Five of the 14 females with complete unilateral clefts are represented in this group of eight, three of the seven females with less extensive clefts are represented, but the one female with a complete bilateral cleft is not represented. From this we note that 33% of the female subjects with more extensive types of palatal clefts displayed calculated skeletal ages lower than standard deviation limits allow, an interesting contrast to the male subject group.

As noted earlier, each subject's skeletal age was calculated by totaling the values of the 29 ossification centers and deriving the mean. For every subject, each of the ossification centers was compared with the calculated skeletal age and, with certain exceptions, each center fell within acceptable limits. The exceptions include, for the female group, the radius and the epiphyses of the distal phalanges of the second, third, and fourth fingers, each of which tended to be below the standard deviation limits of the calculated skeletal age. For the male group, the exception was the radius, which deviated significantly below the standard deviation limits

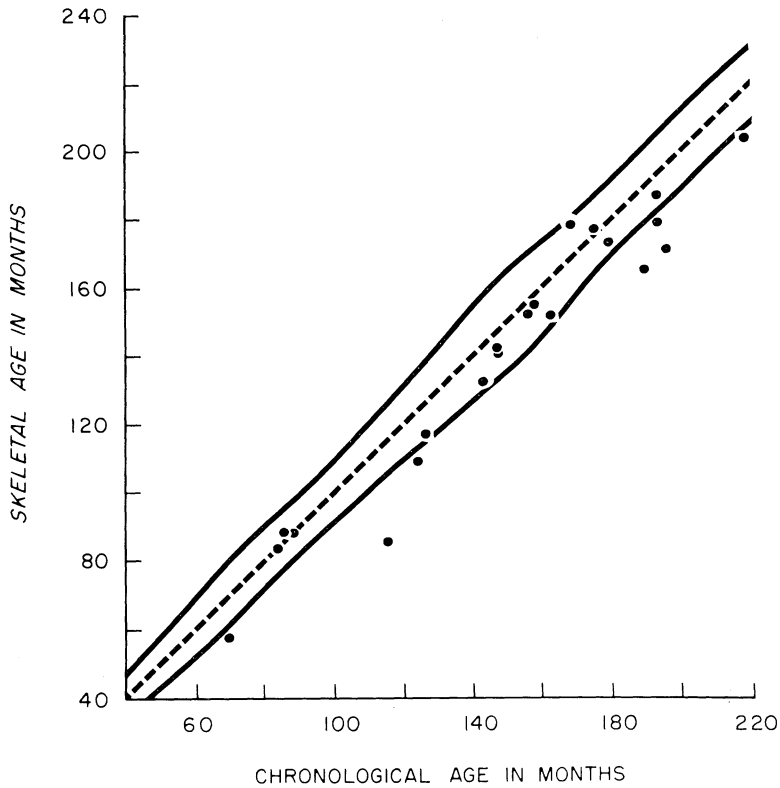

FIGURE 3. Skeletal age distribution of cleft palate females in reference to Stuart's standards of deviation.

of the calculated skeletal age. Factors contributing to these exceptions were not determined, but as previously stated (*3*) the maturity level of the radius is difficult to assess at the higher age levels. Since all 29 ossification centers were used in making the skeletal age determinations, the exceptions exhibited by the radius and the epiphyses of the distal phalanges of the second, third, and fourth fingers did not appear to influence skeletal age calculations significantly.

Dental age determinations were below the standard deviation limits in five instances. These included four male subjects and one female subject each of whom exhibited a calculated skeletal age below standard deviation limits. A dental age determination above the standard deviation limits was exhibited in only one instance and this was a male subject who displayed a calculated skeletal age also above the standard deviation limits. There appears to be no significant relationship between the calculated skeletal ages, the recorded heights and weights, and the estimated dental ages.

Unfortunately, determining the exact socioeconomic level for each subject was not possible, since this factor may influence development and growth generally. However, most of the subjects were from similar, relatively low socio-economic backgrounds.

Summary

Hand-wrist roentgenographs were used to determine the skeletal ages of 48 children presenting with palatal clefts. The chronological ages, calculated skeletal ages, and calculated dental ages for these 26 male subjects and 22 female subjects were compared to determine whether or not deviations from acceptable normal limits were displayed. Although the limited size of the study group made results somewhat inconclusive, an interesting trend was noted. A disproportionate number of cleft palate subjects, especially males, exhibited skeletal ages which were lower than the established normal standards, suggesting that a more extensive, longitudinal study merits consideration.

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References

1. Boyle, P. E., *Kronfeld's Histopathology of the Teeth and Their Surrounding Structures.* Philadelphia: Lea and Febiger, 44, 1956.
2. Dreizen, S., Snodgrasse, R. M., Webb-Peploe, H., Parker, G. S., and Spies, T. D., Bilateral symmetry of skeletal maturation in the human hand and wrist. *J. dis. Child., 93,* 122–127, 1957.
3. Greulich, W. W., and Pyle, S. D., *Radiographic Atlas of Skeletal Development of the Hand and Wrist.* Stanford: Stanford University Press, 1959.
4. Mainland, E., Evaluation of the skeletal age method of estimating children's development: I Systematic errors in the assessment of roentgenograms. *Pediatrics, 12,* 114–124, 1953.
5. Mainland, E., Evaluation of the skeletal age method of estimating children's development: II Variable errors in the assessment of roentgenograms. *Pediatrics, 13,* 165–173, 1964.
6. Mainland, E., Evaluation of the skeletal age method of estimating children's development: III Comparison of measurements and inspection in the assessment of roentgenograms. *Pediatrics, 20,* 979–992, 1957.
7. Pryor, J. W., The hereditary nature of variation in the ossification of bones. *Anat. Record, 1,* 84–88, 1907.
8. Todd, T. W., *Atlas of Skeletal Maturation (Hand),* St. Louis: C. V. Mosby Co., 1937.