CALCIFICATION OF THE MANDIBULAR THIRD MOLAR AND ITS RELATION TO SKELETAL AND CHRONOLOGICAL AGE IN CHILDREN [1]

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Whereas theoretically it may be expected that an intimate relationship exists in the physical maturation of various tissue systems and that this relationship is reflected by the different maturity indicators, the correlation between dental development and growth of the body as a whole is claimed to be low (1, 8).

Yet Talmers (9) has demonstrated that children with late emergence of permanent teeth were usually delayed in both height and weight gain when appraised by referring to the Fels norms, and that children with early eruption of teeth were advanced in their physical growth. The asso-

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ciation between these three variables was demonstrated most clearly for children with late eruption of teeth.

Gleiser and Hunt (2, 4) studied the chronology of calcification of the permanent mandibular first molar in considerable detail and reported that arrests in the ossification of hand and wrist bones often coincide with arrests in tooth formation.

The present study deals with the calcification of the mandibular third molar since it is desirable, especially for the orthodontist, to have this information for evaluating dental development between 9 and 15 years of age, or after the permanent mandibular first molar can be used for this purpose. Such data can complement the estimate of dental maturation based on the clinical emergence of permanent teeth, and Gleiser and Hunt (2) suggest "that the calcification of a tooth may be a more meaningful indication of somatic maturation than is its clinical emergence." The relationships between third molar development and chronological and skeletal age were studied also.

The Present Study

A total of 151 American white children of Greater Boston, who were patients at the Forsyth Dental Infirmary for Children and without obvious signs of nondental disease or of developmental disturbances, were selected for examination according to the year of birth (Fig. 1). When, however, the 81 boys and 70 girls are grouped according to age (Fig. 2), the resulting frequency distributions differ considerably from those based on the year of birth, due to the time lapse between the examination of the first and last subject. In each instance, almost invariably on the same visit, radiographs of the right hand and wrist as well as of the jaw were taken.

The hand radiographs were analyzed according to the technique of S. Idell Pyle by computing the mean skeletal age after comparing each bone of the hand and wrist to the standards of Greulich and Pyle (3). Since in this study only one evaluation of skeletal age was needed, rather than a longitudinal picture of skeletal development, no consideration was given to the differences in maturation of the various hand bones of the individual child, as required by the "Red Graph" method (6).

Differences in evaluating skeletal age were determined by independent examinations of the hand radiographs of 30 children (15 boys and 15 girls). The results, summarized in Table 1, show a high degree of similarity between the readings made by the two observers.

For the evaluation of the calcification of the mandibular third molars, use was made of the standards developed by Gleiser and Hunt for the first molar. Yet, independently of the authors just mentioned, an attempt was made in the initial stage of this study to find suitable developmental stages

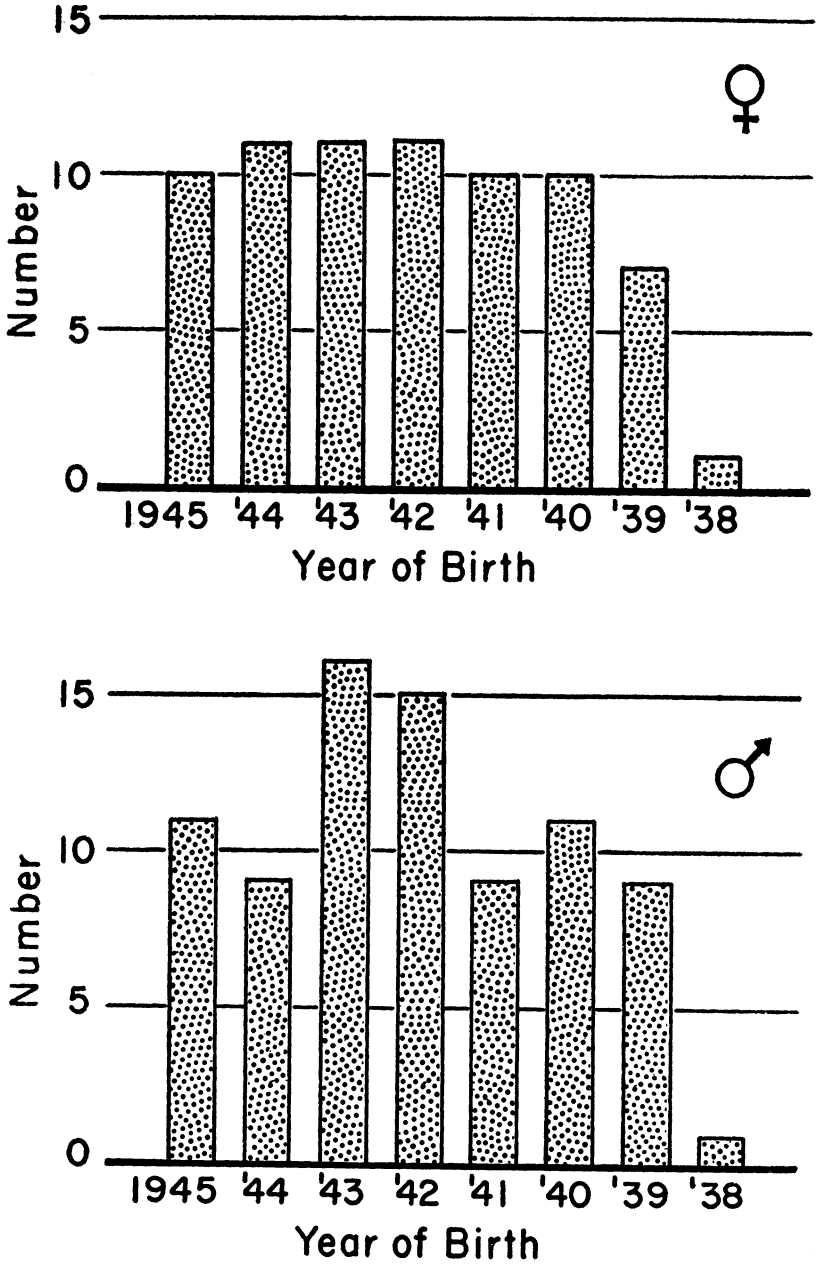

FIGURE 1—The frequency distributions according to the year of birth of the 70 girls and 81 boys studied.

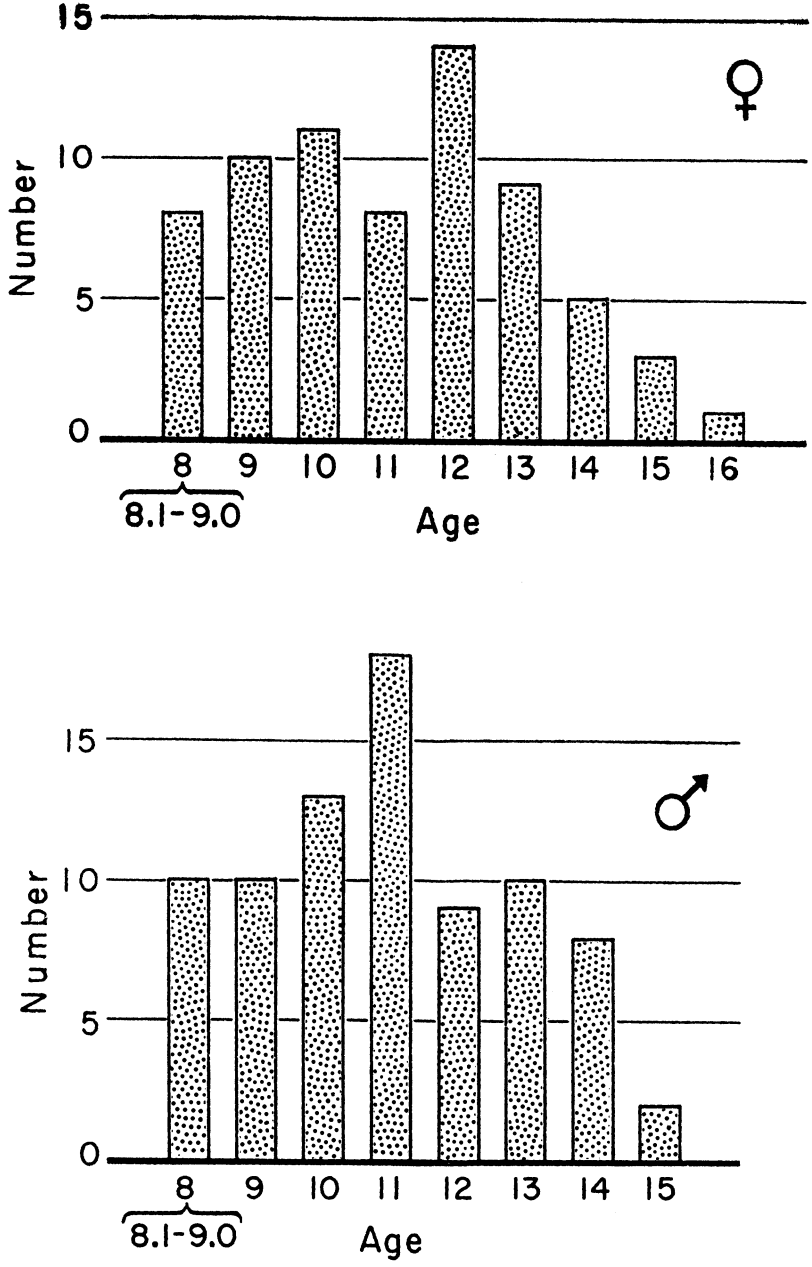

FIGURE 2—The frequency distributions according to the chronological age of the 70 girls and 81 boys studied.

TABLE 1

DIFFERENCES BETWEEN INDEPENDENT EVALUATIONS OF A SERIES OF 30 HAND RADIOGRAPHS BY TWO OBSERVERS

Rating D > Rating W			*Rating D = Rating W*	*Rating D < Rating W*		
9 mo.	6 mo.	3 mo.		3 mo.	6 mo.	9 mo.
0	2	2	22	1	3	0

for gauging the calcification of the third molar. This resulted in almost the same scale as that of Gleiser and Hunt, except that stage 6—2/3 of crown completed—could not be differentiated accurately from its neighboring stages and it was, therefore, omitted. Stage 6 in the present study, signifying completion of the crown, thus corresponds to stage 7 of Gleiser and Hunt and stage 7, the beginning of root formation, to their stage 8. The upper age limit of the sample was not high enough to study the subsequent stages of root formation until the terminal convergence of the root canal. The definitions of each calcification stage as used in this study are given in Table 2.

Unfortunately, it was not possible to obtain satisfactory roentgenologic records for classifying the development of the maxillary third molars, which explains why this investigation was limited to studying the mandibular molars.

Differences in assessing mandibular third molar development were determined by independent evaluations of 50 lateral jaw radiographs. Since

TABLE 2

DEFINITIONS OF EACH STAGE OF THIRD MOLAR CALCIFICATION USED IN THIS STUDY

0	No change in bone density, and no crypt visible.
1	Crypt clearly visible, but no calcification.
2	Calcification of the tips of one to four cusps.
3	Coalescence of two or more centers.
4	Outline of the cusps completed, calcification progressing towards the level of the grooves, but the center of the occlusal crown surface may not yet be calcified.
5	Half of the crown completed, calcification up to the largest mesiodistal diameter of the tooth crown, but the entire enamel formation not yet completed.
6	Crown completed, enamel formation completed to enamel-cementum junction.
7	Beginning of root formation.

stage 5 offered the greatest difficulties for proper classification, a larger number of teeth in this stage than in the other stages of development was selected by the first examiner to test whether his co-observer agreed with the rating given. The disagreement in evaluations of third molar development was never more than one stage, and the range of identical ratings varied between 60 and 100 per cent, as shown in Table 3.

TABLE 3

DIFFERENCES BETWEEN INDEPENDENT EVALUATIONS OF 50 RADIOGRAPHS OF THE MANDIBULAR THIRD MOLAR BY TWO OBSERVERS

	STAGE OF CALCIFICATION								
	0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*Total*
Number of radiographs	5	6	4	5	6	14	5	5	50
Rating D = Rating W	5	4	4	5	4	10	3	4	39
Rating D ≠ Rating W	0	2	0	0	2	4	2	1	11
Per cent of identical ratings ...	100	67	100	100	67	71	60	80	78

The reliability of evaluations of both the wrist and lateral jaw radiographs is considered adequate in view of the following reasons: (1) In general, no tendency for consistent over- or underrating by one observer compared to the other was observed. (2) In testing for the differences when two observers independently studied a series of hand radiographs, the same mean bone age was found in 73 per cent of trials, and, when testing the evaluations of molar calcification, identical ratings were obtained in 78 per cent of the double determinations. The number of identical ratings is thus similar in both instances.

Differences in evaluating third molar development do not exceed one stage or one-sixth of the entire scale of crown formation. The differences in the estimate of bone age are no greater than 6 months which corresponds, according to Gleiser and Hunt, to about one-seventh of the time needed for the formation of the crown of the first molar. If it is assumed, for practical purposes, that the speed of formation of the mandibular third molar crown is approximately the same as that of the first molar, the differences in independent evaluations of molar development and bone age do not exceed one-sixth of the time needed for completion of the third molar crown, or 7 months in the boys and 9.7 months in the girls. However, for bone age only the maximal differences amount to 6 months, while for molar calcification the differences can never be less than one stage. Therefore, the errors made by the two observers in studying third molar development are often greater than those made by them when assessing skeletal age.

Findings

The findings can be grouped under four headings, namely: (1) the relationship between skeletal age and chronological age, (2) degrees of bilateralism in the development of left and right third molars in the mandible, (3) the median chronological and skeletal ages for each calcification stage of these third molars, (4) the mutual relationships between third molar calcification and skeletal and chronological age.

1. The mean difference between skeletal age and chronological age is zero months in the 81 boys and 6 months in 70 girls studied (Table 4). Thus in the average girl the skeletal age is one-half year advanced compared to the chronological age. The range of approximately 48 months for both sexes corresponds closely to the findings of Greulich and Pyle. In a group of "normal" early and late maturing children one may, therefore, expect differences as great as 24 months between the two measures of development.

Table 4

THE MEAN DIFFERENCE AND STANDARD DEVIATION OF SKELETAL AGE AND CHRONOLOGICAL AGE

	N	*Mean*	*S.D.*
Boys	81	0 months	± 12.3 mo.
Girls	70	6 months	± 10.1 mo.

2. Chronological symmetry in the development of the mandibular left and right third molars occurs in 71 per cent of the boys and girls. In the others differences of one, but not more than two, developmental stages are observed in the calcification of antimeres. It is not possible to conclude from the data at hand whether a definite trend exists for more advanced development on one side of the mouth than on the other.

Saito (7) reported earlier calcification and eruption of third molars on the right side of the mouth when compared with those on the left, and he also found that Japanese girls had a more rapid developmental rate than Japanese boys until the age of 13 years. This last conclusion is not corroborated by the findings of the present study.

Unilateral agenesis must be considered also as an asymmetry of development. However, great care was necessary in diagnosing agenesis in this group of young Bostonians inasmuch as the beginning of calcification, as manifested in radiographs (stage 1), was observed as late as 12 years and 5 months in some children.

TABLE 5

AGENESIS OF MANDIBULAR THIRD MOLARS IN CHILDREN "AGED 13.1 YEARS AND OLDER"

	N	*Unilateral*	*Bilateral*	%
Boys	21	1	1	9.5
Girls	17	2	4	35.3

In the small sample of boys 13 years 1 month and older (Table 5), the combined frequency of unilateral and bilateral mandibular third molar agenesis was 9.5 per cent and in the still smaller group of girls it was as high as 35.3 per cent. After an analysis of extensive radiographic material Saito (7) reported "congenitally missing" mandibular third molars in 20 per cent of his Japanese sample, while Nanda (5) found agenesis of one

TABLE 6

MEDIAN CHRONOLOGICAL AND SKELETAL AGES AS WELL AS AGE RANGES OF THE DIFFERENT STAGES OF MANDIBULAR THIRD MOLAR CALCIFICATION

		Median		Range	
M_3	*N*	*CA*	*SA*	*CA*	*SA*
		BOYS	(*N* = 69)		
1	8	9.2	9.3	8.5 –12.0	8.0 –11.0
2	6	10.3	10.6	9.6 –11.5	9.0 –11.6
3	16	11.1	10.6	8.9 –13.0	8.0 –12.0
4	12	11.7	11.9	10.4 –13.7	10.0 –13.0
5	9	12.11	13.3	10.5 –13.9	11.6 –14.0
6	7	14.0	14.0	10.9 –15.2	12.0 –16.2
7	11	14.7	15.0	12.11–16.1	14.0 –17.0
		GIRLS	(*N* = 51)		
1	5	9.3	9.0	8.6 –12.5	7.6 –11.6
2	3	10.3	10.0	9.9 –11.4	8.0 –12.0
3	9	10.5	11.0	9.0 –14.9	9.0 –13.0
4	13	11.5	11.6	8.11–12.11	9.0 –13.0
5	9	13.6	14.0	11.11–14.6	12.0 –14.2
6	3	12.9	13.0	11.10–12.10	10.0 –13.6
7	9	14.11	15.0	12.4 –15.4	13.6 –16.6

NOTE.—Units in years, fractions in months, CA = chronological age, SA = skeletal age, M_3 (1) = stage of calcification.

or more third molars—maxillary or mandibular—in 9 per cent of 216 North American white women.

Unilateral agenesis of the mandibular third molars did not change the statistical findings concerning symmetry of development because it occurred in only three instances.

3. The median age and the age ranges of each of the seven calcification stages studied are given in Table 6. For these statistics an average calcification rating was used in the case of asymmetric development of antimeres, except that when in an individual one mandibular third molar was rated as being in stage 0, the higher rating of its antimere was used as the overall rating. In the majority of subjects (71 per cent of the total sample), however, the calcification of the left and right third molars was symmetrical, as pointed out already.

In both sexes the median chronological and skeletal ages of third molar stages agree closely, the maximum difference being 7 months for stage 3 in both the males and females.

The numbers of mandibular third molars in each calcification stage in each sex and in the two sexes combined are presented in Table 7, together with the percentage frequencies of teeth in each stage.

TABLE 7

THE NUMBER OF BOYS AND GIRLS WITH MANDIBULAR THIRD MOLARS IN DIFFERENT STAGES OF CALCIFICATION AND THE PERCENTAGE FREQUENCIES OF THIRD MOLARS IN EACH STAGE

(Total number of children = 151, total number of teeth = 302; agenesis not considered)

	STAGE OF CALCIFICATION							
	0	*1*	*2*	*3*	*4*	*5*	*6*	*7*
Boys	33	14	6	28	25	17	14	25
Girls	46	5	4	17	24	19	6	19
Boys + Girls	79	19	10	45	49	36	20	44
Per cent of all teeth	26	6	3	15	16	12	7	15

4. An important aspect of this investigation was to determine whether individuals with early or late skeletal age have a correspondingly advanced or delayed developmental pattern of their mandibular third molars. This relationship could be studied in 69 boys and 51 girls only since in some subjects the first sign of calcification of the mandibular third molars was not seen on the radiographs.

Scatter diagrams were prepared for preliminary analysis of the correlation between the different variables, an average calcification rating being used in case of asymmetric development of mandibular left and right third

molars. Frequency distributions of the observations are given on the *X* and *Y* axes of each scattergram.

After studying the scattergrams (Figs. 3 and 4) it was concluded that the regression lines follow a straight trend. However, when the median chronological and skeletal ages for each developmental stage are plotted on the scattergrams, the points are not found to be on a straight line; but their arrangement is such that it seems justified to assume a straight line trend. Therefore, Pearson's product-moment correlation formula was considered satisfactory for further statistical treatment of the material.

For computations of the correlation coefficients fractions of class intervals of molar calcification, resulting from averaging the findings for left and right third molars, were reduced to full stages (e.g., a rating of 3.5 was included in the stage 3 group).

According to the findings (Table 8), a high degree of association exists between third molar calcification and skeletal or chronological

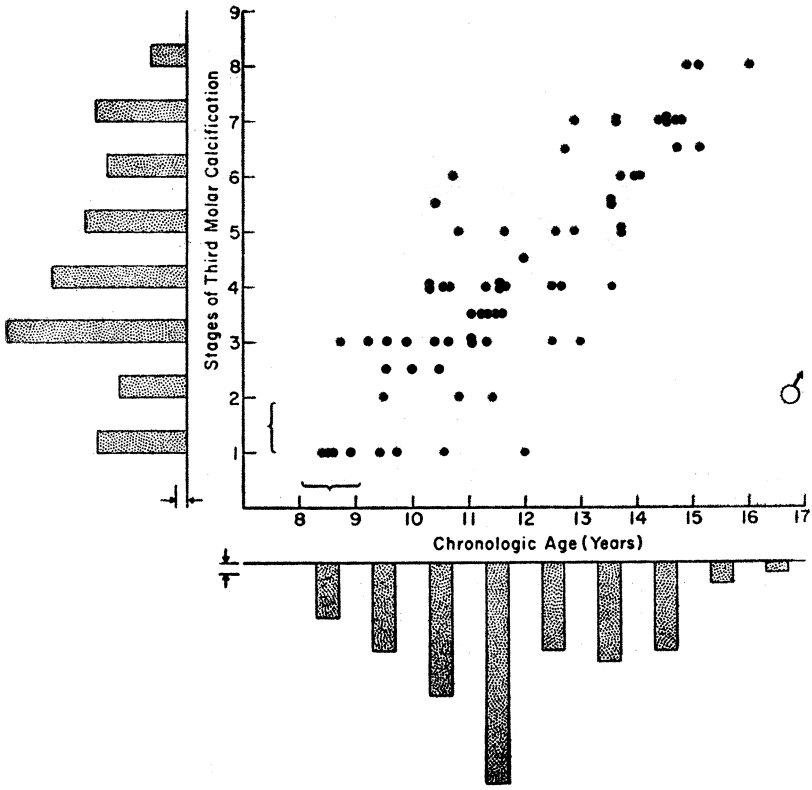

FIGURE 3a—Scattergram to demonstrate the degree of association between stages of third molar calcification and chronological age for 69 boys.

TABLE 8

COEFFICIENTS OF CORRELATION (r) AND THE STANDARD ERRORS ($S.E._r$) OF MANDIBULAR THIRD MOLAR CALCIFICATION (M_3), CHRONOLOGICAL AGE (CA) AND SKELETAL AGE (SA), AND THE MULTIPLE CORRELATION COEFFICIENTS ($R \pm S.E._R$) BETWEEN THESE THREE VARIABLES

	Boys $N = 69$	*Girls* $N = 51$	*Boys and Girls* $N = 120$
	r $S.E._r$	r $S.E._r$	r $S.E._r$
M_3 : CA	.83 ± .037	.73 ± .064	.79 ± .034
M_3 : SA	.86 ± .031	.75 ± .060	.83 ± .028
CA : SA	.89 ± .024	.92 ± .021	.90 ± .016
	R $S.E._R$	R $S.E._R$	R $S.E._R$
SA : CA M_3	.92 ± .019	.93 ± .019	.92 ± .014

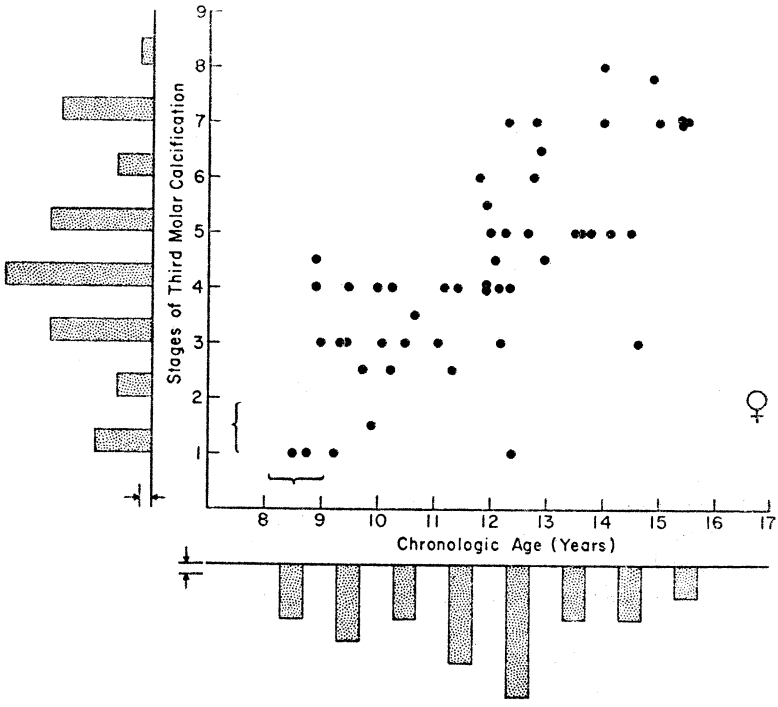

FIGURE 3b—Scattergram to demonstrate the degree of association between stages of third molar calcification and chronological age for 51 girls.

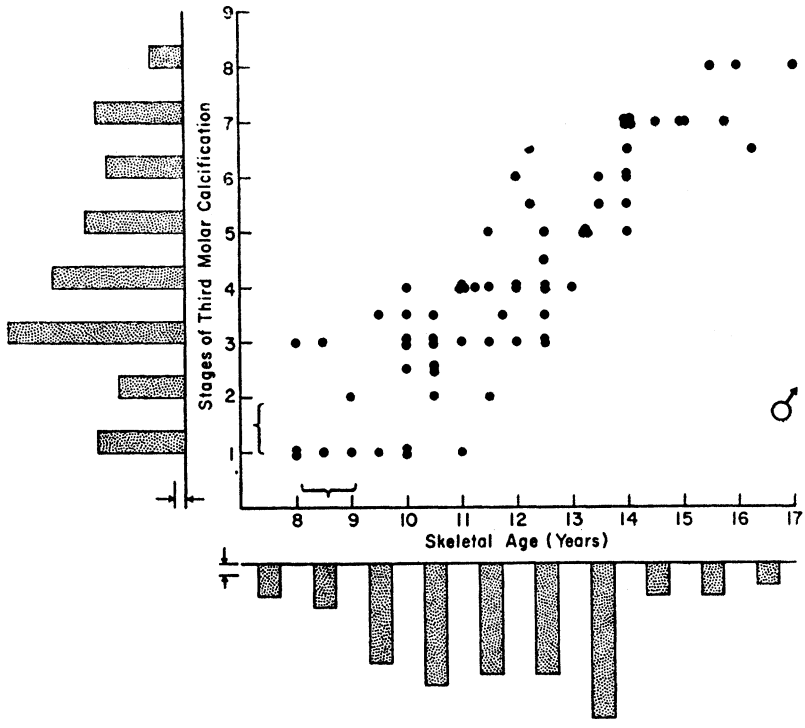

FIGURE 4a—Scattergram to demonstrate the degree of association between stages of third molar calcification and skeletal age for 69 boys.

age as well as between skeletal and chronological age (with values of r ranging between $+.73$ and $+.92$).

The multiple correlation coefficient is likewise high ($R_{SA.CAM_3}$ being $+.92$ or $.93$), but these findings do not differ greatly from those measuring the association between chronological and skeletal age. Therefore, the additional information on third molar calcification enables only a slightly better estimate of skeletal age than that obtained by the use of chronological age alone.

Nevertheless, in view of the comparatively small but significant partial correlation coefficients between third molar calcification and skeletal age with chronological age held constant ($r_{MSA.CA} = +.45$ for boys and girls), it may be possible to estimate skeletal age indirectly when taking into account the development of other permanent teeth in addition to the third molar if adequate calcification data for these other teeth are available, since averaging the variations in the development of individual teeth is likely to give one a more realistic evaluation of the dental age. If the variation in the calcification of different teeth is extensive, it may turn out that a reliable

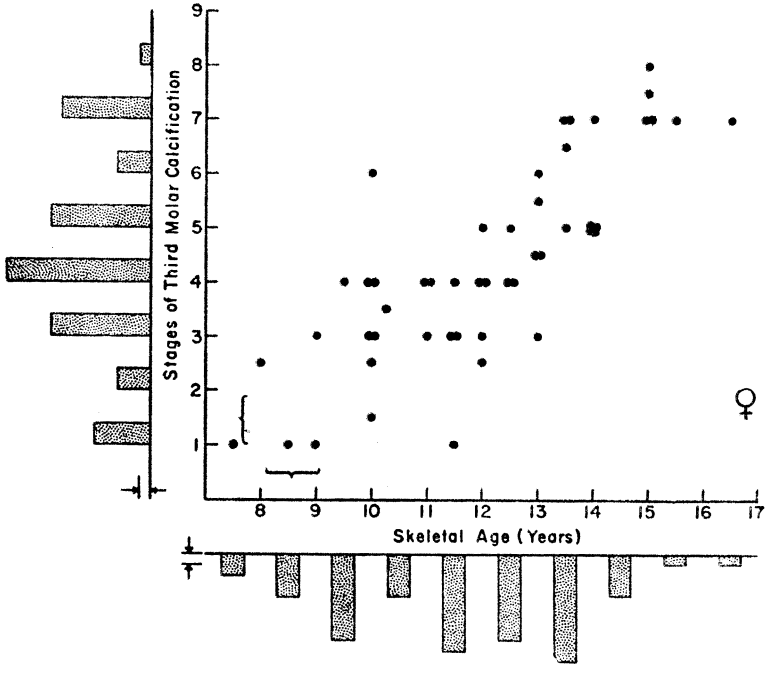

FIGURE 4b—Scattergram to demonstrate the degree of association between stages of third molar calcification and skeletal age for 51 girls.

estimate of skeletal age cannot be made and in such instances it would be of interest to find out from the actual assessment of bone age, by means of the Red Graph, whether the development of the hand and wrist bones also shows a wide distribution around the mean skeletal age. In addition, such efforts would show whether third molar calcification is more variable in comparison to that of other permanent mandibular teeth.

As a pilot study the data presented support the basic theoretical contention that a relationship exists in the physical maturation of various tissue systems, and the chronology of dental development may prove to be useful as an indicator of physiologic age. Exactly how valuable it is for this purpose remains to be established, preferably by a study of longitudinal data on a sufficiently large group of individuals.

SUMMARY

1. Radiographs of the right hand and each half of the jaws of 151 North American white individuals aged 8 to 16 years were studied for assessment of skeletal age and for the development of the mandibular third molars.

For estimating skeletal age, the standards of Greulich and Pyle were utilized and for molar calcification, the (slightly modified) standards of Gleiser and Hunt were used.

2. The results confirm the earlier studies concerning the wide range of skeletal ages compared with the chronologic ages in "normal" children. The differences when two observers evaluate the same wrist radiographs independently are much smaller than the "normal" variation of skeletal age in "healthy" children at a given chronological age. The differences in independent ratings of third molar development are somewhat higher but still adequate for the purpose of this study. Gleiser and Hunt's scale for rating the calcification of mandibular molar crowns appears satisfactory for clinical studies, except that their stage 6, which could not be differentiated clearly from its neighboring stages, had to be omitted.

3. The calcification of the mandibular third molar is symmetrical in 71 per cent of the children studied. In the others, no tendency is seen for consistently advanced development of either the left or right teeth.

4. There is a high positive correlation, with an approximately straight line trend, between the degree of calcification of the mandibular third molar and the skeletal or chronological ages. The findings support the theoretical contention that a relationship exists between the maturation of various tissue systems.

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