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New systems for dental maturity based on seven and four teeth

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Summary. An updated system for estimating dental maturity is presented. It extends the original system (Demirjian *et al.*, 1973) based on radiographs of 7 teeth by including two extra stages, and by enlarging the standardizing sample to include 2407 boys and 2349 girls. Percentile standards from ages 2·5 to 17·0 years are presented separately for boys and girls.

Scoring systems and percentile standards are presented for two different sets of 4 teeth and a comparison of all three systems is made. It is suggested that these systems may measure somewhat different aspects of dental maturity.

1. Introduction

In an earlier paper (Demirjian, Goldstein and Tanner, 1973) a new method for assessing dental maturity was described. It was based on ratings of radiographs of the seven left side teeth of the mandible, which were shown to be representative of all the teeth of the mandible. Eight stages of calcification for each tooth were identified and described and each one was allocated a score. The sum of these scores for an individual provides an estimate of dental maturity on a scale measuring from 0 to 100. Scores and percentile standards were given separately for boys and girls for the age range 3–16 years. The mathematical technique used to calculate the scores for the stages is the same as has been used for the measurement of skeletal maturity (Tanner, Whitehouse, Marshall, Healy and Goldstein, 1975), and a detailed description is given by Healy and Goldstein (1976).

This earlier system had two main shortcomings. First, ratings of all seven teeth needed to be made. In many older children however, one or more teeth are missing, nor is it always possible to use the corresponding tooth from the right side of the mandible. Also, for practical reasons, it is often simpler to take a radiograph of fewer than seven teeth, so that there is some purpose in studying systems based on fewer teeth. Naturally some information and precision is lost in the process and such systems may be measuring slightly different components of dental maturity.

The second limitation of the earlier system was the absence of sufficient numbers of very young and very old children in the standardizing sample. This meant that the early stages of some teeth could not be included since they were insufficiently

represented in the sample, and that percentile standards could not be provided for the extreme age groups.

The purpose of the present paper is to present new seven-tooth systems which extend the age range and the number of stages, and also to present two new four-tooth systems.

2. Materials and methods

A full description of the tooth rating system is given by Demirjian *et al.* (1973). Briefly, this consists in identifying eight stages of calcification for each tooth, ranging from the calcification of the tip of a cusp to the closure of the apex. The stages are labelled 0 for no calcification and A to H for the 8 calcification stages. Panoramic radiographs were obtained from a standardizing sample of 1446 boys and 1482 girls aged 2–20 years of French-Canadian origin.

Age	Boys	Girls	Total
0·0– 2·5	27	23	50
2·5– 3·5	115	72	187
3·5– 4·5	171	146	317
4·5– 5·5	198	157	355
5·5– 6·5	223	194	417
6·5– 7·5	147	135	282
7·5– 8·5	111	120	231
8·5– 9·5	148	167	315
9·5–10·5	223	208	431
10·5–11·5	114	130	244
11·5–12·5	193	170	363
12·5–13·5	234	239	473
13·5–14·5	183	215	398
14·5–15·5	123	157	280
15·5–16·5	134	166	300
16·5–17·5	57	48	105
17·5–20·0	6	2	8
Total	2407	2349	4756

Table 1. Number of children at each age.

The sample has now been increased to 2407 boys and 2349 girls (Table 1). This has allowed us to include two stages which were excluded in the earlier system, namely stage A of the first premolar (PM_1) and stage C of the first incisor (I_1). It has also allowed us to include 3rd and 97th percentile estimates for the maturity standards.

Where panoramic radiographs cannot be used, two periapical radiographs of the molars and premolars may be taken. We have therefore considered these four teeth as a separate system (M_2, M_1, PM_2, PM_1) for which scores and standards will be presented. The development of the lower central incisor being chronologically almost the same as for the first molar, in older age groups where this latter is often missing the central incisor has been assessed instead of the molar. This is the reason why we also present separate scores and standards for this group of four teeth (M_2, PM_2, PM_1, I_1). In this case an additional periapical film of the incisor area is required. In all three systems we have used equal "biological" weights for each tooth (see Demirjian *et al.*, 1973).

3. Results

The maturity scores for the three systems are given in tables 2–4.

Boys

	Stages								
Tooth	0	A	B	C	D	E	F	G	H
M_2	0·0	1·7	3·1	5·4	8·6	11·4	12·4	12·8	13·6
M_1				0·0	5·3	7·5	10·3	13·9	16·8
PM_2	0·0	1·5	2·7	5·2	8·0	10·8	12·0	12·5	13·2
PM_1		0·0	4·0	6·3	9·4	13·2	14·9	15·5	16·1
C				0·0	4·0	7·8	10·1	11·4	12·0
I_2				0·0	2·8	5·4	7·7	10·5	13·2
I_1				0·0	4·3	6·3	8·2	11·2	15·1

Girls

	Stages								
Tooth	0	A	B	C	D	E	F	G	H
M_2	0·0	1·8	3·1	5·4	9·0	11·7	12·8	13·2	13·8
M_1				0·0	3·5	5·6	8·4	12·5	15·4
PM_2	0·0	1·7	2·9	5·4	8·6	11·1	12·3	12·8	13·3
PM_1		0·0	3·1	5·2	8·8	12·6	14·3	14·9	15·5
C				0·0	3·7	7·3	10·0	11·8	12·5
I_2				0·0	2·8	5·3	8·1	11·2	13·8
I_1				0·0	4·4	6·3	8·5	12·0	15·8

Table 2. Self weighted scores for dental stages. 7 teeth (mandibular left side).

Boys

	Stages								
Tooth	0	A	B	C	D	E	F	G	H
M_2	0·0	3·2	6·2	9·9	14·4	18·4	20·7	21·9	23·3
M_1				0·0	8·0	12·6	16·9	21·8	27·4
PM_2	0·0	3·1	5·6	9·5	13·7	17·4	20·1	21·4	22·5
PM_1		0·0	5·9	10·7	15·7	20·7	23·8	25·4	26·8

Girls

	Stages								
Tooth	0	A	B	C	D	E	F	G	H
M_2	0·0	3·6	6·1	9·9	15·3	19·2	21·7	23·0	24·2
M_1				0·0	5·4	9·8	14·3	20·1	25·9
PM_2	0·0	3·7	5·8	9·8	14·7	18·1	20·8	22·3	23·3
PM_1		0·0	4·6	9·2	15·1	20·2	23·3	25·1	26·6

Table 3. Self weighted scores for dental stages. 4 teeth M_2, M_1, PM_2, PM_1 (mandibular left side).

Boys	Stages								
Tooth	0	A	B	C	D	E	F	G	H
M_2	0·0	3·3	6·1	9·9	15·0	19·7	21·3	22·1	23·5
PM_2	0·0	3·2	5·6	9·6	14·2	18·8	20·9	21·7	22·8
PM_1		0·0	7·1	11·6	16·9	22·8	25·8	26·8	27·9
I_1				0·0	7·4	11·5	14·6	18·9	25·7
Girls	Stages								
Tooth	0	A	B	C	D	E	F	G	H
M_2	0·0	3·4	6·3	10·2	15·7	20·0	21·5	22·3	23·5
PM_2	0·0	3·7	6·2	10·3	15·1	19·1	21·0	21·7	22·8
PM_1		0·0	5·9	10·2	16·2	21·9	24·6	25·6	26·8
I_1				0·0	8·1	12·2	15·6	20·7	27·0

Table 4. Self weighted scores for dental stages. 4 teeth M_2, PM_2, PM_1, I_1 (mandibular left side).

The percentile curves in figures 1–6 enable an assessment of the percentile position for the maturity score of an individual. If required, a conversion of a maturity score to a "dental age" may be obtained by finding the age at which the 50th percentile value equals the maturity score.

Comparing the systems

Although we have no absolute standard by which to judge the validity of a dental maturity system, we can require it to have two general properties. First, the change in maturity scores with age should be "smooth" in order to reflect the continuous nature of biological development. Secondly, the individual variability in maturity scores at each age should be large enough to reflect the natural variability in the population.

	Systems					
	7 teeth— M_2, M_1, PM_2, PM_1		7 teeth— M_2, PM_2, PM_1, I_1		M_2, PM_2, PM_1, I_1 $-M_2$, M_1, PM_2, PM_1	
Age	Boys	Girls	Boys	Girls	Boys	Girls
2·5– 3·5	0·8	0·7	1·9	1·5	1·1	0·9
3·5– 4·5	2·3	1·9	3·2	3·3	0·9	1·4
4·5– 5·5	3·6	2·3	4·8	4·1	1·1	1·7
5·5– 6·5	3·2	1·7	4·4	3·7	1·3	2·1
6·5– 7·5	1·2	−1·2	3·1	1·6	2·0	2·7
7·5– 8·5	−2·0	−3·8	1·5	0·2	3·4	4·0
8·5– 9·5	−5·0	−6·0	0·4	−0·6	5·4	5·3
9·5–10·5	−5·7	−5·9	−0·4	−1·2	5·3	4·7
10·5–11·5	−4·6	−4·5	−0·7	−1·3	3·8	3·2
11·5–12·5	−3·0	−2·6	−0·8	−1·3	2·1	1·2
12·5–13·5	−2·0	−1·6	−0·8	−1·1	1·1	0·4
13·5–14·5	−1·3	−0·9	−0·8	−0·7	0·4	0·1
14·5–15·5	−0·8	−0·5	−0·7	−0·4	0·1	0·0
15·5–16·5	−0·3	−0·2	−0·4	−0·2	0·0	0·0
16·5–17·5	−0·1	0·0	−0·3	0·0	0·0	0·0

Table 5. Mean difference between systems at each age. Smoothed values.

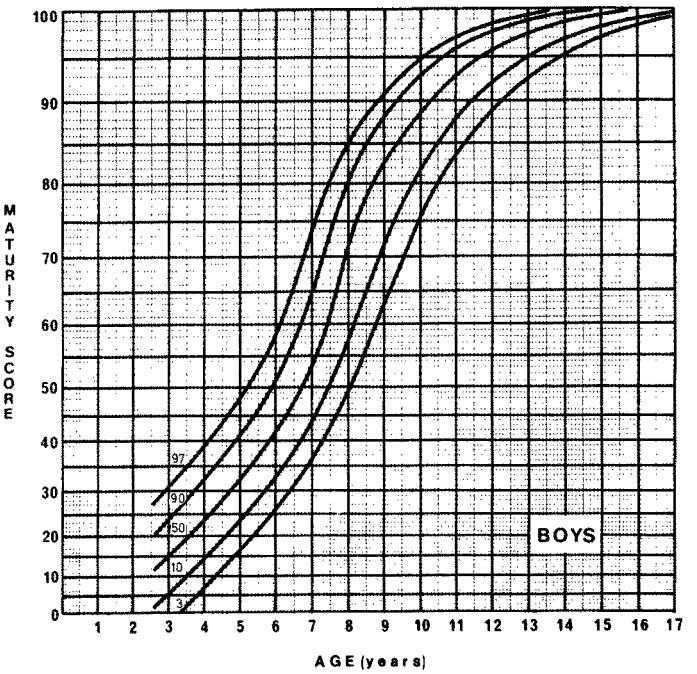

Figure 1. Dental maturity percentiles (7 teeth).

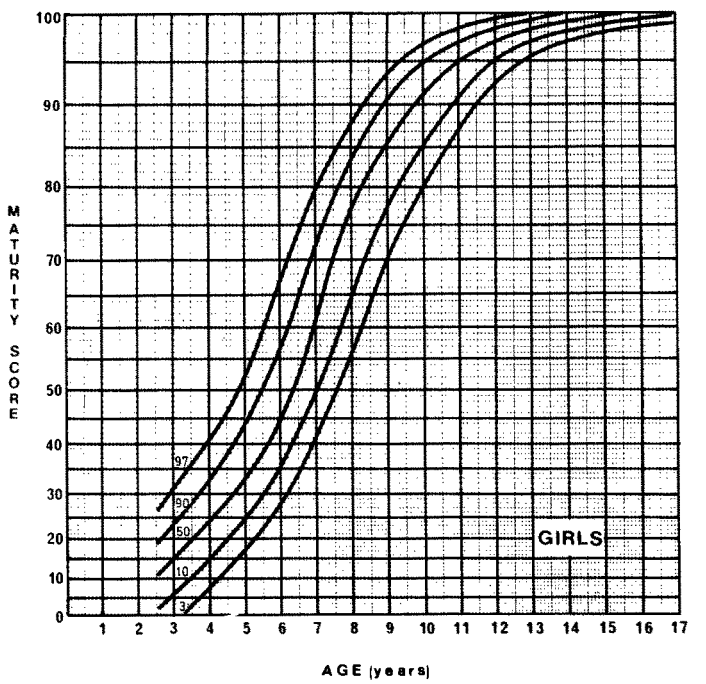

Figure 2. Dental maturity percentiles (7 teeth).

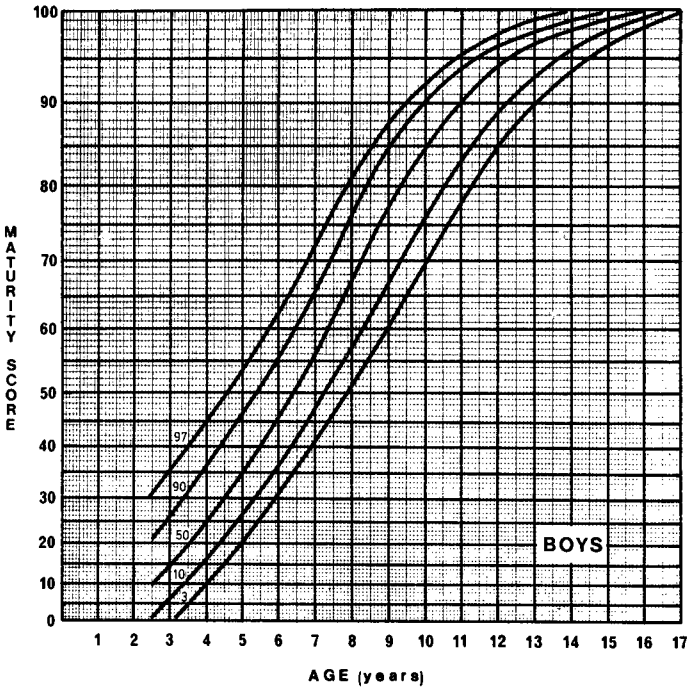

Figure 3. Dental maturity percentiles (4 teeth I) M_2, M_1, PM_2, PM_1.

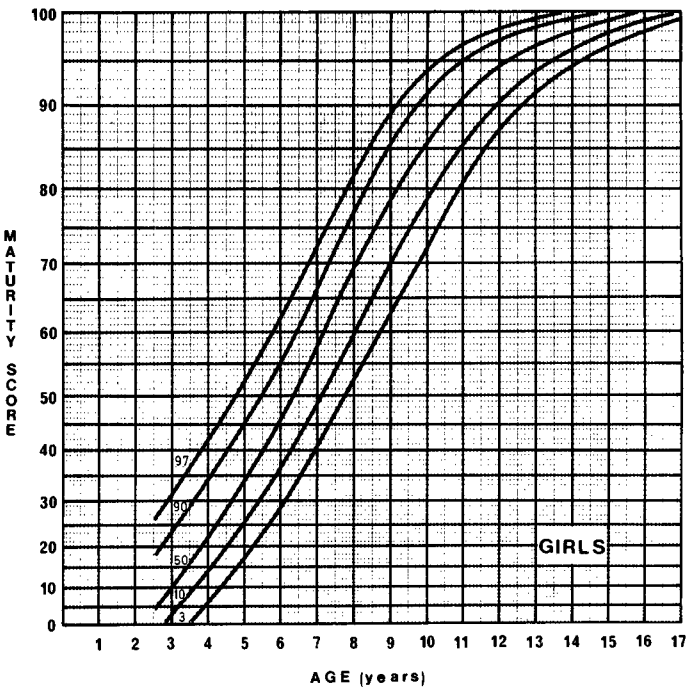

Figure 4. Dental maturity percentiles (4 teeth I) M_2, M_1, PM_2, PM_1.

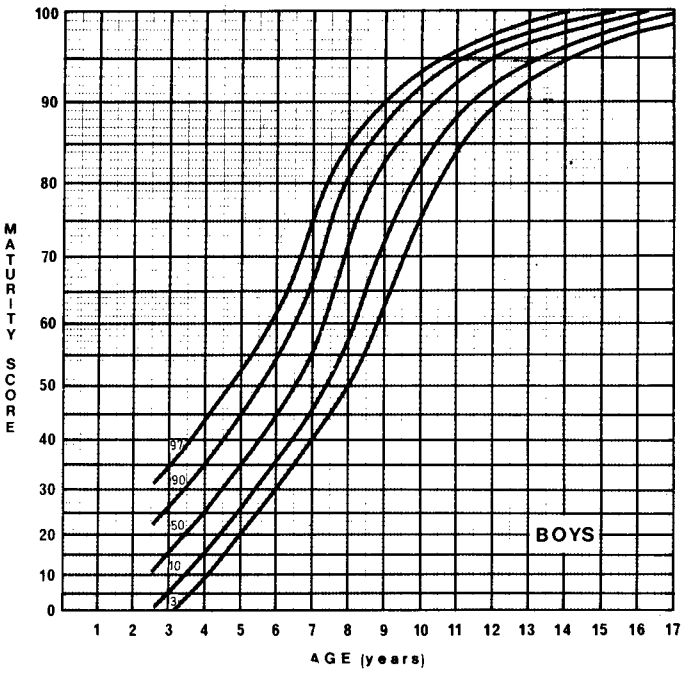

Figure 5. Dental maturity percentiles (4 teeth II) M_2, PM_2, PM_1, I_1.

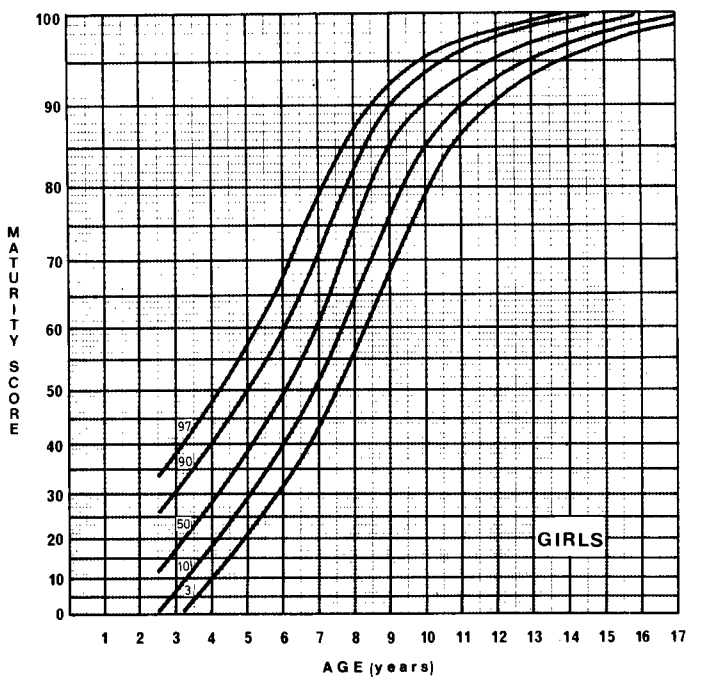

Figure 6. Dental maturity percentiles (4 teeth II) M_2, PM_2, PM_1, I_1.

When comparing two systems, perfect agreement will be indicated by a constant difference between an individual's score at each age. We may therefore use the variability of the within-individual difference as a measure of lack of agreement between systems. The average difference between the systems can be used to convert a maturity score on one system into a maturity score on the other. (Table 5 gives the mean differences at each age.)

Thus, to convert a maturity score based on M_2, M_1, PM_2, PM_1 to one based on 7 teeth for a boy aged 6·0 years we add 3·2 score points.

As a first step, the new 7-tooth system has been compared to the previous one. Table 6 shows, at each age, the average difference, the standard deviation of the difference, the separate standard deviations for each system and the average rate of change of maturity with age. The standard deviation of the difference between the

	Old–New; Mean difference*		S.D. of difference*		Average of separate S.D.'s of two systems		Average rate of change with age (Score pts per year)	
Age	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
2·5– 3·5	4·3	4·2	1·6	1·6	6·0	6·7	9	9
3·5– 4·5	4·0	4·0	1·1	1·2	6·6	8·0	8	8
4·5– 5·5	3·6	3·5	0·9	1·0	7·6	9·0	8	9
5·5– 6·5	2·8	2·6	1·1	1·2	8·6	9·8	11	15
6·5– 7·5	1·6	0·9	1·4	1·7	9·0	9·9	16	20
7·5– 8·5	−1·0	−1·7	1·5	1·3	8·4	7·8	15	10
8·5– 9·5	−1·7	−1·4	1·0	1·0	6·9	6·1	7	8
9·5–10·5	−0·9	−0·5	0·8	0·8	5·1	4·8	5	5
10·5–11·5	0·0	0·4	0·7	0·6	3·4	3·6	4	3
11·5–12·5	0·8	1·0	0·5	0·5	2·5	2·6	2	2
12·5–13·5	1·0	1·1	0·4	0·4	1·8	1·7	2	1
13·5–14·5	1·0	0·8	0·4	0·4	1·3	1·2	1	1
14·5–15·5	0·8	0·5	0·3	0·4	0·9	0·8	1	1
15·5–16·5	0·4	0·2	0·3	0·3	0·5	0·5	—	—
16·5–17·5	0·0	0·0	0·2	0·2	0·3	0·3	—	—

* Smoothed values.

Table 6. Comparisons of individual scores of new and old 7-tooth systems.

two systems up to the age of 13 is not more than about three months of the average change in maturity per year. After this age the relative value of the standard deviation increases, a reflection of the increasing indeterminancy associated with assigning a chronological age to almost fully mature individuals. A similar pattern for both sexes exists for the standard deviations of the separate systems which are between three and six times the standard deviations of the difference. There is a decrease in the standard deviations of the difference to about age 6 followed by an increase to age 8 and thereafter a steady decrease. This is paralleled by the average rate of change of maturity with age where the peak "velocity" occurs at about age 7.

The similarity of patterns and the relatively small values of the standard deviations of the differences between the systems implies that only a small change is likely to occur in moving from one to the other.

Table 7 compares the new 7-tooth system and each 4-tooth system. A somewhat different pattern is apparent. The standard deviations of the differences do not parallel the standard deviations and the rates of change for the separate systems (the 4-tooth systems are similar to the 7-tooth system). For the comparison of the 7-tooth and 4-tooth systems the decrease is slow to about age 9, and more rapid thereafter. The standard deviations are equivalent to up to 10 months average change in maturity per year as far as age 13. The comparison between the 4-tooth systems show a rapid decrease in the standard deviation up to age 6 followed by a slower decrease to about age 11. It appears therefore that the three systems are not measuring precisely the same underlying quantity and that relatively large differences can occur in moving from a 4-tooth to a 7-tooth system.

	7 teeth $-M_2$, M_1, PM_2, PM_1		7 teeth $-M_2$, PM_2, PM_1, I_1		M_2, M_1, PM_2, PM_1 $-M_2$, PM_2, PM_1, I_1	
Age	Boys	Girls	Boys	Girls	Boys	Girls
2·5– 3·5	3·7	4·0	3·6	4·1	3·8	4·0
3·5– 4·5	3·9	4·2	3·7	3·8	3·4	3·6
4·5– 5·5	3·6	3·8	3·6	3·5	3·0	3·2
5·5– 6·5	3·4	3·6	3·3	3·3	2·9	3·1
6·5– 7·5	3·4	3·5	3·3	3·2	2·8	3·0
7·5– 8·5	3·3	3·3	2·9	2·9	3·8	3·0
8·5– 9·5	3·2	2·9	2·7	2·6	2·7	2·9
9·5–10·5	2·9	2·4	2·4	2·2	2·7	2·8
10·5–11·5	2·4	2·1	2·0	1·6	2·6	2·5
11·5–12·5	1·7	1·6	1·5	1·1	2·4	1·8
12·5–13·5	1·3	1·2	1·0	0·8	1·7	1·3
13·5–14·5	0·9	0·9	0·7	0·6	1·1	0·8
14·5–15·5	0·6	0·6	0·5	0·5	0·4	0·4
15·5–16·5	0·4	0·4	0·4	0·4	0·1	0·1
16·5–17·5	0·2	0·2	0·2	0·2	0·0	0·0

Table 7. Standard deviations of differences between individual scores on new 7-tooth system and the 4-tooth systems.

Smoothed values.

4. Discussion

The dental maturity system presented earlier by Demirjian *et al.* (1973) has been updated. The sample size has been increased, especially at the older and younger ages, and the new system, based on the same seven teeth, utilizes two additional stages and covers the age range 2·5 years to 17·0 years. The 3rd and 97th percentiles have also been estimated and presented in maturity standards. The differences between scores derived from the original and updated systems are small. Where some individuals have been scored on the old system and the original ratings are available, they may readily be assigned the new scores. Alternatively it would be possible to use the average differences given in the first two columns of Table 6 to provide an approximate conversion.

It was pointed out in the earlier paper that where a single tooth was missing or could not be rated for any other reason it was impossible to obtain a valid estimate of the 7-tooth maturity using just the scores on the remaining six teeth (unless the corresponding tooth from the right side of the mandible was available for substitution). The best that could be done is to estimate seven separate scoring systems, one for

each combination of six remaining teeth. This is still not completely satisfactory however, since it appears that each six-tooth system is measuring a slightly different aspect of maturity. This raises the whole question of which set of teeth should be used to define dental maturity. During the developmental period when the assessment of the maxillary teeth was technically very difficult using X-rays, we confined our study to the evaluation of the mandibular ones. In the original system, all mandibular teeth were studied and after taking account of the symmetry of the mandible, the seven teeth of the left side were chosen as the basis for estimating overall dental maturity.

Within the overall development of the dentition however, there may be certain groups of teeth which have a distinctive developmental pattern of their own, contributing a sub-system of dental maturity. At present we have insufficient knowledge to say which sub-systems are the important ones requiring their own scoring system. What we have done, therefore, is to choose two sub-systems which form convenient groups of teeth for rating purposes. The results of comparing each system with the 7-tooth system and with each other raises the possibility that somewhat different aspects of maturity are being measured. In order to study the question of whether they are measuring different aspects, we should need to compare children with longitudinal records using the different systems. Where one of the 4-tooth systems is used, either because a full panoramic radiograph is unavailable or because a tooth is missing, this fact should be recorded in reporting a maturity score.

When using the scoring system and standards presented in this paper, it should be remembered that the sample is entirely of French-Canadian origin. We do not as yet know how far the results will generalize to other populations. We would conjecture, however, that the scores for the stages will not vary too much between populations, but that the maturity standards may change appreciably. It would be possible to study differences in average maturity for different populations using the present scoring system with relatively small samples.

We plan to extend our results in two directions. First we are accumulating a longitudinal series of radiographs taken one year apart on the same children in order to derive longitudinal standards. Secondly we are studying the relationship of dental maturity to measures of skeletal maturity.

Acknowledgments

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References

Demirjian, A., Goldstein, H., and Tanner, J. M. (1973). A new system of dental age assessment. *Human Biology*, **42**, 211–227.

Healy, M. J. R., and Goldstein, H. (1976). An approach to the scaling of categorised attributes. *Biometrika*, **63**, 219–229.

Tanner, J. M., Whitehouse, R. M., Marshall, W. A., Healy, M. J. R., and Goldstein, H. (1975). *Assessment of Skeletal Maturity and Prediction of Adult Height: TW2 Method.* London: Academic Press.

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Zusammenfassung. Es wird ein aktualisiertes System zur Schätzung der Zahnreife vorgestellt. Es erweitert das ursprüngliche System (Demirjian u. a., 1973), basierend auf Röntgenaufnahmen von sieben Zähnen, durch Einschluß zweier weiterer Stufen und durch Vergrößerung der zugrundeliegenden Stichprobe auf 2407 Knaben und 2349 Mädchen. Für beide Geschlechter werden Perzentilnormen für 2,5 bis 17,0 Jahre gegeben. Weiterhin werden Punktsysteme und Perzentilnormen für zwei unterschiedliche Sätze von vier Zähnen vorgestellt und alle drei Systeme verglichen. Es wird geschlossen, daß sie wohl etwas unterschiedliche Aspekte der Zahnreife messen.

Résumé. Un système mis à jour pour estimer la maturité dentaire est présenté. Il étend le système précédent (Demirjian *et al.*, 1973) basé sur des radiographies de 7 dents par l'inclusion de deux stades supplémentaires, et par l'élargissement de l'échantillon normatif à 2407 garçons et 2349 filles. Les percentiles pour les âges de 2,5 à 17,0 ans sont présentés séparément pour les garçons et les filles.

Les systèmes de cotation et les percentiles standard sont présentés pour deux ensembles différents de 4 dents, et une comparaison des trois systèmes est faite. Il est suggéré que ces systèmes pourraient mesurer des aspects quelque peu différents de la maturité dentaire.