Validity of the Demirjian method for dental age estimation when applied to Norwegian children

Roy Nykänen, Lisen Espeland, Sigrid I. Kvaal and Olaf Krogstad
Department of Orthodontics and Department of Oral Pathology, University of Oslo, Oslo, Norway

Nykänen R, Espeland L, Kvaal SI, Krogstad O. Validity of the Demirjian method for dental age estimation when applied to Norwegian children. Acta Odontol Scand 1998;56:238–244. Oslo. ISSN 0001-6357.

Dental age was studied in a sample of 261 Norwegian children by using the maturity standards of Demirjian & Goldstein (1976) to examine the applicability of these standards as a reference for overall dental maturity in a Norwegian population. The sample comprised 128 boys and 133 girls included in 'the Oslo Growth Material', from whom orthopantomograms (total, 783) had been longitudinally obtained, with intervals of about 3 years and covering 3 age spans (5.5–6.5 years, 8.5–9.5 years, and 11.5–12.5 years), each divided into 3 half-year age groups. Reliability was analyzed by repeated assessments of 134 of the radiographs, and the overall mean difference between duplicate dental age determinations was 0.5 months for intra- and 1.8 months for inter-examiner comparisons. The Norwegian children were generally somewhat advanced in dental maturity compared with the French-Canadian reference sample. Among the boys the mean difference between dental age and chronologic age varied in the different age groups from 1.5 to 4.0 months. Among the girls the difference increased with age, varying from 0 to 3.5 months in the younger age groups (5.5 to 9.0 years) and from 4.5 to 7.5 months in the age groups 9.5 years and above. The variability in individual dental age was marked and increased with age. For the older age groups 95% of the individual age estimates were within ±2 years of the real age. The applied standards appear to be adequate for studying dental age in groups of children from a Norwegian population. Given the considerable individual variation in dental maturity, estimation of chronologic age in individual children should be supplemented by other indicators of biologic maturity. □ *Dental maturity; radiographic assessment; tooth development*

Lisen Espeland, Department of Orthodontics, University of Oslo, P.O. Box 1109, Blindern, N-0317 Oslo, Norway

Dental maturity, often expressed as dental age, is an indicator of the biologic maturity of a growing child. As tooth formation is a continuous morphogenic process, a sequence of developmental stages can be defined on the basis of progress of mineralization, as seen on radiographs. In addition to being relevant in clinical orthodontics and in studies of syndromes and growth disturbances, dental age is used to supplement other maturity indicators in estimation of the chronologic age of children with unknown or uncertain birth records. Mineralization of the teeth is less affected by variation in nutritional and endocrine status than other growth parameters (1, 2), and dental age is associated with less variability in relation to chronologic age compared with other indicators of maturity (3, 4).

Several methods for determination of dental development from radiographs have been described, and standards for determining dental age have been established (5, 6). Most methods imply that individual teeth are assigned a score according to defined stages of mineralization. The score, or the sum of scores, is then converted to a dental age. For a particular reference sample, the mean dental age equates with the mean chronologic age of the subjects.

Since the timing of dental development may differ among various population groups (5, 7), developmental standards based on data from one population may need to be adjusted when applied in determination of dental age of children from another population, and especially if the intention is to make estimations of chronologic age. The maturity standards proposed by Demirjian et al. in 1973 (8) and later revised by Demirjian & Goldstein (9) are based on a sample comprising French-Canadian children. The method has been widely used in studies of dental maturity (7, 10–15), and comparisons between various population groups are possible. Furthermore, this is the method proposed by the Swedish Board for Health and Welfare for age estimation in adopted children of unknown age. Studies on Nordic Caucasian samples have shown earlier tooth development among Finnish (7, 11, 16) and Swedish (10, 13, 15) children compared with the French-Canadian reference sample. Similar data for Norwegian children are not available.

In the present study dental maturity (dental age) in a longitudinal sample of Norwegian boys and girls was determined by applying the revised version (9) of the standards established by Demirjian et al. (8). The objective was to analyze the correspondence between the dental age and the chronologic age of the children to examine the applicability of these standards for use as a reference for dental maturity and in estimation of chronologic age among Norwegian children.

Table 1. Distribution of boys and girls in 3 longitudinal subsamples of 261 Norwegian children (128 boys, 133 girls) studied for dental maturity, according to age group at registration stages 6, 9, and 12 years. Age in years

	Subsample I	Subsample II	Subsample III
Number of subjects	74	119	68
Boys/girls	36/38	56/63	36/32
6-year stage			
Age groups	5.5	6.0	6.5
(Age range)	(5.41–5.56)	(5.91–6.07)	(6.32–6.73)
9-year stage			
Age groups	8.5	9.0	9.5
(Age range)	(8.27–8.75)	(8.77–9.25)	(9.31–9.75)
12-year stage			
Age groups	11.5	12.0	12.5
(Age range)	(11.26–11.75)	(11.76–12.25)	(12.30–12.74)

Materials and methods

Subjects

The sample was selected from healthy children of Norwegian descent who were participants in a longitudinal growth study at the Department of Orthodontics, University of Oslo (the Oslo Growth Material). The Oslo Growth Material comprises people from Nittedal, a community of about 16,000 inhabitants near Oslo. The children included in the present study represented six cohorts born in the period 1966–71. Orthopantomograms had been obtained of 1240 children at the ages 6, 9, and 12 years.

At each age stage the children were grouped in three half-year age groups, and three longitudinal subsamples (Table 1) were established by the following selection procedure: At the 6-year age stage, a sample of 220 boys and 220 girls was selected by including the children of the age closest to the median age of each of the half-year age groups (5.5 years, 6.0 years, and 6.5 years). From this sample the children who did not remain in the corresponding half-year age group at the follow-up registrations were excluded (42 boys, 43 girls). Also excluded were subjects with hypodontia in any quadrant (13 boys, 13 girls), extracted permanent teeth (7 boys, 6 girls), missing radiographs from complete series (4 boys, 3 girls), and children with radiographs of low quality of the left mandibular teeth (26 boys, 22 girls). Thus, the final sample consisted of 261 children (128 boys, 133 girls), from whom 783 orthopantomograms were available (Table 1).

Methods

The method introduced by Demirjian et al. (8) is based on scoring the developmental stage of the seven left permanent mandibular teeth. Eight stages of mineralization (A–H) for each tooth are described by written criteria, which are accompanied by photographic illustrations and schematic drawings. Each stage for the seven teeth is allocated a biologically weighted score, and the sum of the scores provides an estimate of the subject's dental maturity measured on a scale from 0 to 100. The overall maturity score may then be converted to a dental age by using available tables and/or percentile curves. The standards are given for boys and girls separately. The revised version of the standards is based on data derived from a reference sample comprising 4756 French-Canadian children aged 2–20 years (9).

Assessment of study sample. One examiner (R. Nykänen) rated all of the orthopantomograms. The examiner was trained by using a tutorial program available on CD-ROM (17), and more than 500 radiographs were rated for exercise and calibration purposes. The radiographs comprising the material were mixed and coded, and the chronologic ages of the children were concealed from the examiner. Prior to each scoring session the examiner was calibrated by using the CD-ROM program. Since only percentile curves are available for conversion of overall maturity score to dental age in the revised version of the method, magnified photographs of the percentile curves were obtained. Data from these curves were initially recorded in separate tables for boys and girls, which then were used for conversion.

For each sex and age group in the study sample, the mean difference between the dental age determined from the French-Canadian standards and the actual chronologic age of the child was calculated. A paired t test was used for statistical analysis.

Reliability tests. Intra- and inter-examiner reliability of the method were examined from a subset of 134 orthopantomograms. Every sixth radiograph from the male and female age groups at the three age stages (6, 9, and 12 years) was selected, and the radiographs were mixed before the ratings were performed. One examiner (R. Nykänen) rated the 134 radiographs on two different occasions, using the CD-ROM program for guidance. The first ratings were performed after the initial training,

Table 2. Intra- and inter-examiner agreement (in percent and Kappa coefficient of agreement) on scoring of developmental stages (A–H) of each of the 7 left mandibular permanent teeth according to criteria by Demirjian et al. (8) performed on a subset of 134 orthopantomograms

	I_1	I_2	C	P_1	P_2	M_1	M_2	Total
Intraexaminer agreement								
Percentage	89	82	90	80	84	93	87	86
Kappa	0.82	0.76	0.87	0.75	0.80	0.89	0.84	0.83
Interexaminer agreement								
Percentage	76	82	77	67	85	83	75	78
Kappa	0.60	0.75	0.71	0.60	0.82	0.75	0.69	0.73

Interpretation of Kappa (strength of agreement) according to guidelines by Landis & Koch (19):
0.00–0.20: slight 0.61–0.80: substantial
0.21–0.40: fair 0.81–1.00: almost perfect
0.41–0.60: moderate

whereas the second ratings were made after the total material had been assessed. The same radiographs were rated by a second examiner (S. I. Kvaal), who was also calibrated by using the CD-ROM program. The two examiners were not calibrated against each other.

To analyze intra- and inter-examiner agreement on scoring of the developmental stage for each of the seven teeth, the data were arranged in contingency tables. Agreement was assessed by the Kappa coefficient of agreement (18), which was calculated for each tooth, all age groups combined. Interpretation of the Kappa values was made according to guidelines by Landis & Koch (19). Intra- and inter-examiner variation in dental age recordings were examined for the 6-, 9-, and 12-year age stages separately. A paired *t* test was used for statistical analysis.

Results

Reliability tests

Agreement between duplicate scores by the same examiner of the mineralization stage varied between 80% and 93% for the various teeth (Table 2). The difference between the two scores did not exceed one stage for any tooth, and the first and second ratings differed equally often by an earlier and a later stage (7.4% and 7.3% of the scores, respectively). The Kappa coefficients of agreement were in the range interpreted as substantial or almost perfect agreement beyond chance. The mean differences between the duplicate dental age determinations are presented in Table 3.

When the scores made independently by the two examiners were compared, agreement on scores assigned to each tooth ranged from 67% to 85% (Table 2), and the difference between the two ratings did not exceed one stage for any tooth. Relative to the scores made by the first examiner, the second examiner differed by one earlier stage in 10.5% of the scores and by one later stage in 11.6%. Most Kappa values were interpreted to represent substantial agreement. The mean differences between the dental ages obtained by the two independent examiners appear in Table 3.

Comparisons between dental age and chronologic age

The mean difference between the dental age determined from the French-Canadian standards and the chronologic age ranged from 0.17 to 0.33 years in the boys and from −0.02 to 0.48 years in the girls. Except for the 8.5-year-old girls, both sexes were advanced in dental maturity compared with the reference sample (Table 4). In four of the male and five of the female age groups, the difference was significant at the 5% level.

The largest discrepancy between estimated age and chronologic age was observed among the girls in the 12.0-year age group. Among the girls the mean difference was larger in the older age groups (9.5 years and above) than in the younger groups. For the boys the greatest mean

Table 3. Intra- and inter-examiner variation in determination of dental age (in years) according to standards by Demirjian & Goldstein (9) performed on a subset of 134 orthopantomograms. Mean difference and standard deviation (*s*) of the difference are given for each age stage. Paired *t* test

Age stage (years)	*n*	Intraexaminer comparisons			Interexaminer comparisons		
		Mean	*s*	*P*	Mean	*s*	*P*
6	45	0.06	0.29	0.17	0.07	0.45	0.33
9	45	−0.17	0.33	0.001	0.29	0.59	0.002
12	44	0.00	0.50	0.98	0.10	0.60	0.26
Total	134	−0.04	0.39	0.26	0.15	0.55	0.001

Table 4. Differences between dental age determined by using the standards by Demirjian & Goldstein (9) and chronologic age (in years) among 261 Norwegian children (128 boys, 133 girls). Mean difference, standard deviation (*s*) of the difference, minimum (Min.) and maximum (Max.) values. Paired *t* test

Age group (years)	Boys						Girls					
	n	Mean	*s*	Min.	Max.	*P*	*n*	Mean	*s*	Min.	Max.	*P*
5.5	36	0.21	0.57	−1.06	1.35	0.04	38	0.18	0.57	−0.92	1.24	0.06
6.0	56	0.29	0.64	−1.31	1.76	0.001	63	0.15	0.51	−1.06	1.32	0.02
6.5	36	0.30	0.56	−0.84	1.38	0.003	32	0.28	0.52	−0.78	1.52	0.006
8.5	36	0.24	0.72	−0.77	2.26	0.05	38	−0.02	0.83	−1.50	1.92	0.91
9.0	56	0.17	0.69	−1.30	1.60	0.08	63	0.12	0.81	−1.27	2.34	0.24
9.5	36	0.28	0.96	−1.68	2.34	0.08	32	0.48	1.10	−1.40	3.59	0.02
11.5	36	0.11	1.09	−1.56	2.35	0.54	38	0.39	1.22	−1.70	2.66	0.06
12.0	56	0.17	0.92	−1.61	2.11	0.18	63	0.62	1.03	−2.60	2.49	<0.001
12.5	36	0.33	0.96	−2.40	2.49	0.04	32	0.46	1.12	−2.71	2.04	0.03

difference was observed in the 12.5-year age group. The tendency toward increasing discrepancy with age was not evident in the boys.

The variability of the difference generally increased with advancing age for both sexes. The standard deviation (*s*) of the difference was about half a year in the younger age groups and about 1 year in the older age groups. The difference varied from 2.22 to 4.89 years for the boys and from 2.16 to 5.09 years for the girls. In Fig. 1 the mean dental age and the variation (1 *s* and limits for total range) for each age group are illustrated for the boys and girls separately.

Discussion

The children included in the sample were selected from an ethnically and demographically rather homogeneous population, and the results may therefore be considered to be fairly representative for healthy Norwegian children in general. However, generalization of the results beyond the population of the southeastern part of Norway has to be made with caution. Studies on Finnish samples have reported a tendency toward differences in dental maturation among children within the country (7).

To reduce the variability across age stages introduced in a cross-sectional approach, subsamples of children with longitudinal records were selected. Furthermore, subsamples with a narrow age range, not differing more than 3 months in either direction from the given age, were established to reduce rounding errors.

The overall proportions of agreement between scores assigned to individual teeth were 86% for the intra- and 78% for the inter-examiner comparisons, which correspond with the results from the studies by Levesque & Demirjian (20) and Pöyry et al. (21). Furthermore, the scoring of developmental stages differed equally often at an earlier and a later stage, indicating that no systematic error was introduced. The results of the reliability tests in terms of mean difference between repeated determinations of dental age are comparable with findings from previous studies (10, 13, 22) and indicate fairly high reliability, as most mean values were less than 2 months. However, agreement between individual recordings varied, and 95% of all the duplicate age estimates made by the same examiner were within ±0.8 years (approx. ±2 *s*). The two examiners agreed within 1.1 years (approx. ±2 *s*) in 95% of all recordings. Variation in reliability over the developmental period is to be expected since there are situations where a scoring difference of one stage in a single tooth may result in an age difference of more than half a year. Previous observations of higher reproducibility when the method was applied to younger children, explained by the shorter duration of developmental stages at lower ages (14), were not evident in the present study. The observed lower reliability in the 9-year group is in accordance with findings by Reventlid et al. (22), who studied 5-, 6-, 9-, and 12-year age groups.

The results showed that in general the Norwegian children were somewhat advanced in dental maturity compared with the reference sample. This finding is in concordance with previous studies of Swedish and Finnish samples in which the Demirjian method has been applied (10–13, 15). The mean differences observed in the Norwegian sample were, however, generally smaller than reported in the other Nordic studies. The greatest mean difference was 0.6 years, compared with 0.9 years reported in a study of Swedish children (10). In the present sample overall mean differences of 0.2 years for boys and 0.3 years for girls were observed, whereas Staaf et al. (13) reported mean differences of 0.8 and 0.9 years for boys and girls, respectively, in a group of 5.5- to 14.5-year-old children from Sweden. In Fig. 2 the mean values for the 6-, 9-, and 12-year age stages are compared with a semilongitudinal sample of 248 Finnish children from the Helsinki area (11), and it appears that the overestimation of age was generally less for both sexes in the Norwegian sample.

The discrepancy between the estimated age and the chronologic age was most pronounced in the girls aged 9.5 years and above and in the 12.5-year-old boys. This tendency for the scoring system by Demirjian & Goldstein (9) to be less accurate in the older age groups is a common

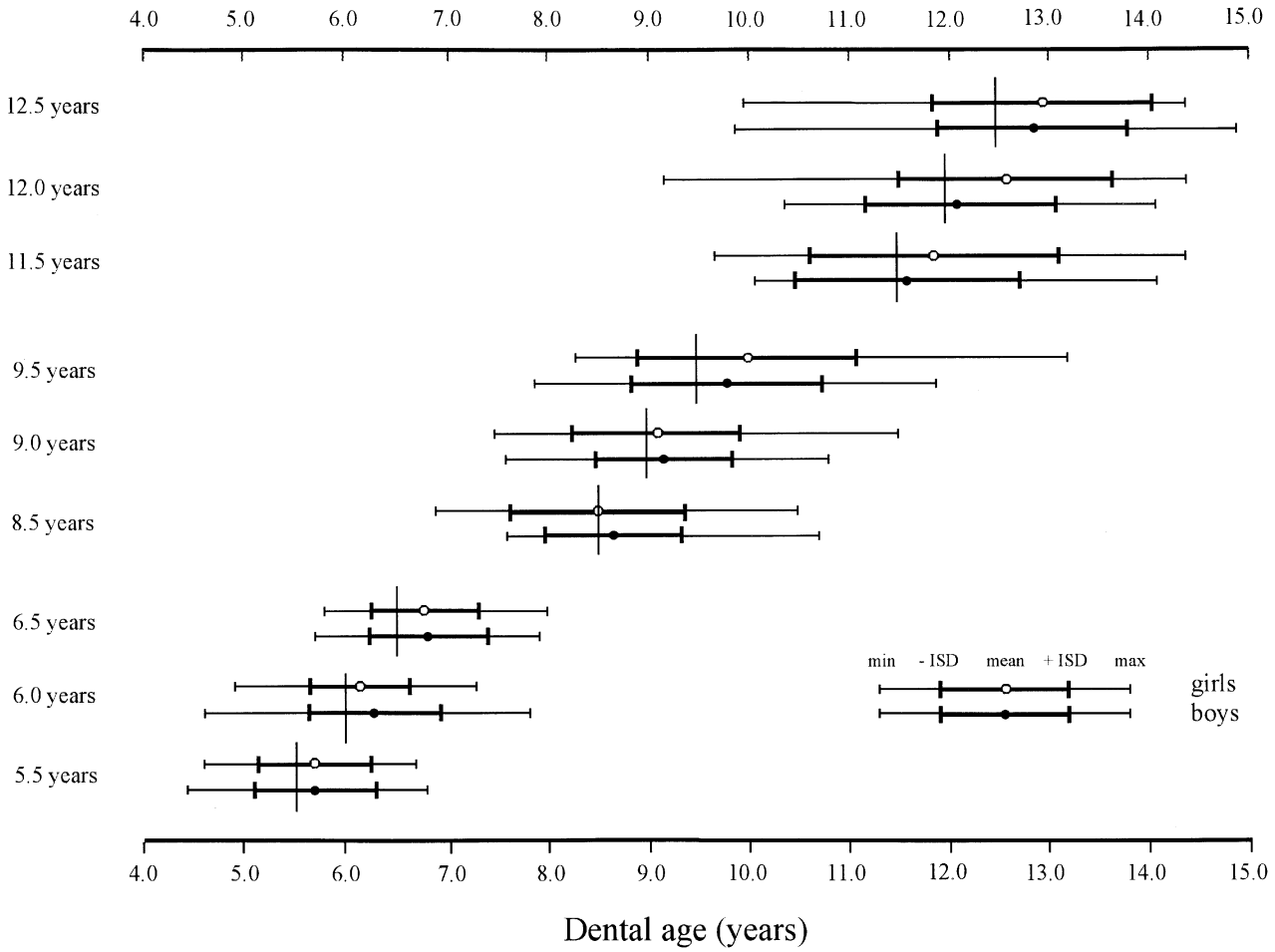

Fig. 1. Dental age determined by using the standards by Demirjian & Goldstein (9) among Norwegian boys and girls in nine age groups. The vertical lines indicate the actual median ages. The mean dental ages are indicated by the circles, the bold lines indicate 1 standard deviation, and the thin lines indicate the total ranges. For the number of subjects in each age group, see Table 1.

finding in the previous studies. The longer duration of the late stages of tooth development compared with the earlier (23) may in part explain this observation. Another explanation that has been suggested is that, after a certain chronologic age, dental age does not exhibit a normal distribution, and this may bias the results (10). From Fig. 1, a tendency toward a skewed distribution could be suspected, and this tendency also appeared when the 10th, 50th, and 90th percentiles were inspected.

The increased overestimation in older age groups could partly be related to the methodological approach, as suggested by Hägg & Matsson (10). The method devised by Demirjian et al. (8, 9) is based on the age when the midpoint between two successive stages is attained, whereas in use the appropriate score is assigned as soon as the particular stage is reached. The effect of this discrepancy relates to the first and final developmental stages, since transition into the former and out of the latter does not occur. Furthermore, the effect increases for the final stages of long duration, and thus may lead to overestimation of age in older children.

Although the mean differences between estimated and chronologic ages were relatively small, indicating rather good correspondence between dental maturity in the Norwegian children and the French-Canadian reference sample, the individual estimates varied considerably, in particular in the older age groups. For individual assessments the estimated age differed from the chronologic age by up to 1.8 years in the younger groups and up to 2.7 years in the older. Thus, two subjects of the same chronologic age could obtain age estimates that differed by more than 5 years. This observation of increased variability with age is a common finding from previous studies using various methods for age estimation from dental development (10, 11, 15, 22). In the present study 95% of the individual estimates were within about ± 1 year for the younger children and about ± 2 years for the older ones, findings that agree fairly well with other reports (10, 14, 22). From Fig. 2 it appears that the dispersion around the mean difference (± 1 *s*) was generally somewhat smaller in the Norwegian sample compared with the Finnish (11).

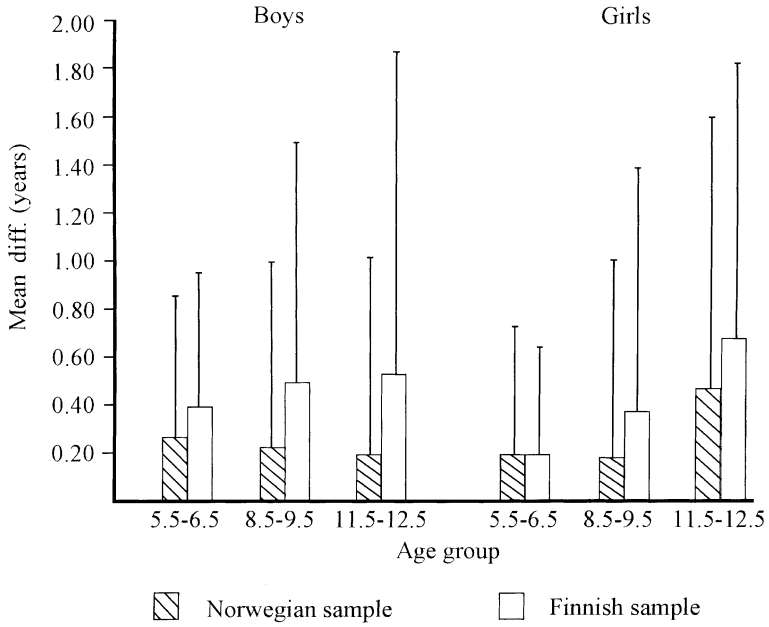

Fig. 2. Comparison between accuracy of dental age determinations using the French-Canadian standards established by Demirjian & Goldstein (9) in the sample of Norwegian children and a sample of Finnish children (11). The columns indicate the mean differences between dental age and chronologic age, and the thin lines with horizontal ends indicate 1 standard deviation. Each of the Finnish male and female age groups consisted of 30–40 children, whereas each of the Norwegian male age groups comprised 128 boys and each of the female age groups comprised 133 girls.

Some of the observed variation might be related to the reliability of the method. Most of the variation is probably a reflection of the biologic variability in tooth development reported by Garn et al. (24) and later observed by others (25–27). The present findings are in good correspondence with the observations by Garn et al. (24) that later-forming teeth are more variable than early-forming teeth, as variability increases with age, and that there is no consistent sex difference.

A further subject of interest would be longitudinal comparisons to examine whether children are consistently advanced or delayed in dental maturation during the developmental period. Studying dental maturity in Norwegian children aged less than 5.5 years and more than 12.5 years would also be of relevance.

In conclusion, since the average dental age in the Norwegian sample did not differ markedly from the French-Canadian reference sample, the applied standards may be adequate as a reference for studying dental maturity in groups of children, particularly in the younger age ranges. The use of the method for estimating chronologic age in individual children is, however, connected with uncertainties due to both the marked variation in individual dental age, especially among older children, and the variable consistency of examiners' assessments. Accordingly, in estimation of chronologic age, dental age needs to be supplemented by other indicators of biologic maturity.

Acknowledgements.—The authors wish to thank Dr. Marjatta Nyström for her assistance in interpretation and calibration.

References

1. Garn SM, Lewis AB, Kerewsky RS. Genetic, nutritional, and maturational correlates of dental development. J Dent Res 1965;44:228–42.
2. Garn SM, Lewis AB, Blizzard RM. Endocrine factors in dental development. J Dent Res 1965;44:243–58.
3. Lewis AB, Garn SM. The relationship between tooth formation and other maturational factors. Angle Orthod 1960;30:70–7.
4. Demirjian A. Interrelationships among measures of somatic, skeletal, dental, and sexual maturity. Am J Orthod 1985;88:433–8.
5. Demirjian A. Dentition. In: Falkner F, Tanner JM, editors. Human growth: a comprehensive treatise. 2nd ed. New York: Plenum Press; 1986. p. 269–98.
6. Smith BH. Standards of human tooth formation and dental age assessment. In: Kelly MA, Larsen CS, editors. Advances in dental anthropology. New York: Wiley-Liss; 1991. p. 143–68.
7. Nyström M, Ranta R, Kataja M, Silvola H. Comparisons of dental maturity between the rural community of Kuhmo in northeastern Finland and the city of Helsinki. Community Dent Oral Epidemiol 1988;16:215–7.
8. Demirjian A, Goldstein H, Tanner JM. A new system of dental age assessment. Hum Biol 1973;45:211–27.
9. Demirjian A, Goldstein H. New systems for dental maturity based on seven and four teeth. Ann Hum Biol 1976;3:411–21.
10. Hägg U, Matsson L. Dental maturity as an indicator of chronological age: the accuracy and precision of three methods. Eur J Orthod 1985;7:25–34.

11. Nyström M, Haataja J, Kataja M, Evälahti M, Peck L, Kleemola-Kujala E. Dental maturity in Finnish children, estimated from the development of seven permanent mandibular teeth. Acta Odontol Scand 1986;44:193–8.
12. Dahllöf G, Näsman M, Borgström A, Modéer T, Forsberg C-M, Heimdal A, et al. Effect of chemotherapy on dental maturity in children with hematological malignancies. Ped Dent 1989;11: 303–6.
13. Staaf V, Mörnstad H, Welander U. Age estimation based on tooth development: a test of reliability and validity. Scand J Dent Res 1991;99:281–6.
14. Davis PJ, Hägg U. The accuracy and precision of the 'Demirjian System' when used for age determination in Chinese children. Swed Dent J 1994;18:113–6.
15. Mörnstad H, Reventlid M, Teivens A. The validity of four methods for age determination by teeth in Swedish children: a multicentre study. Swed Dent J 1995;19:121–30.
16. Kataja M, Nyström M, Aine L. Dental maturity standards in southern Finland. Proc Fin Dent Soc 1989;85:187–97.
17. Demirjian A. Dental development on CD-ROM. Newton (MA): SilverPlatter Education; 1994.
18. Cohen J. A coefficient of agreement for nominal scales. Educ Psychol Measurement 1960;20:37–46.
19. Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics 1977;33:159–74.
20. Levesque GY, Demirjian A. The inter-examiner variation in rating dental formation from radiographs. J Dent Res 1980;59: 1123–6.
21. Pöyry M, Nyström M, Ranta R. Comparison of two tooth formation rating methods. Proc Finn Dent Soc 1986;82:127–33.
22. Reventlid M, Mörnstad H, Teivens A. Intra- and inter-examiner variations in four dental methods for age estimation of children. Swed Dent J 1996;20:133–9.
23. Demirjian A, Levesque GY. Sexual differences in dental development and prediction of emergence. J Dent Res 1980; 59:1110–22.
24. Garn SM, Lewis AB, Polacheck DL. Variability of tooth formation. J Dent Res 1959;38:135–48.
25. Moorrees CFA, Fanning EA, Hunt EE Jr. Age variation of formation stages for ten permanent teeth. J Dent Res 1963; 42:1490–502.
26. Anderson DL, Thompson GW, Popovich F. Age of attainment of mineralization stages of the permanent dentition. J Forensic Sci 1976;21:191–200.
27. Teivens A, Mörnstad H, Reventlid M. Individual variation of tooth development in Swedish children. Swed Dent J 1996; 20:87–93.

Received for publication 13 March 1998
Accepted 9 June 1998