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Dental maturity as an indicator of chronological age: the accuracy and precision of three methods

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Summary. The study was designed to investigate the accuracy and precision of three different methods for estimation of chronological age (Liliequist and Lundberg, 1971; Demirjian ci' al., 1973 and Gustafson and Koch, 1974), based on tooth formation.

Accuracy test. For each method, the mean difference and degree of linear correlation between estimated and true chronological age was determined in 300 3.5-12.5-year-old Swedish children. The data were arranged in subgroups according to sex and age.

Precision test. For each method, the inter-examiner variation was studied in terms of the mean difference between the estimated age obtained from independent readings of 60 panoramic radiographs of the teeth by the two examiners. The intra-examiner variation was studied by calculating the mean difference between two independent readings of the same 60 radiographs by the same examiner.

A high accuracy was found when the method proposed by Demirjian *et al.,* was applied to 3.5-6.5-year-old children. This method showed a low accuracy in the older age-groups, however. The accuracy of the method devised by Liliequist and Lundberg (1971) was found to be low in all age-groups, and age determination using this method resulted in systematic underestimation of age. The accuracy of the method described by Gustafson and Koch (1974) was high when applied to boys, but low in girls.

The precision was found to be high for the methods of Demirjian *et* al. (1973) and Liliequist and Lundberg (1971) but somewhat lower for the method of Gustafson and Koch (1974).

Estimation of age is preferably done during early childhood. Of the methods tested, the one proposed by Demirjian *et al.* (1973) is the most reliable at these ages, due to its comparatively high accuracy and precision.

Introduction

The chronological age of children with uncertain birth records is often estimated by evaluating the individual's somatic maturity. Owing to a comparatively low variability of tooth formation in relation to chronological age (Lewis and Garn, 1960), it seems that methods based on stages of tooth formation are more appropriate in assessment of chronological age than those based on other indicators of somatic development.

Several methods of estimating chronological age based on tooth formation have been devised (for review see Demirjian 1978). The methods comprise different numbers of permanent teeth and include various numbers of developmental stages of the teeth. The standards of dental maturity used in the different methods cover age

periods of different length and are based on varying sample sizes. Furthermore, the samples have been collected in different ways and from various ethnic groups. Thus, the accuracy presumably varies from one method to another.

Knowledge of the accuracy and precision of methods devised for estimation of age is of decisive importance when methods are applied routinely in clinical work. Nevertheless, these factors are in general neglected or incompletely investigated. For example, the possible variation in accuracy between different age-groups and between sexes has not been taken into consideration in any study. In addition, no direct comparison of the accuracy of different methods, tested on the same population and by the same examiners, has been performed.

The precision of methods for assessment of dental maturity has merely been determined in terms of frequency of identical and non-identical ratings of certain teeth by different examiners (e.g. Levesque and Demirjian, 1980). No studies are available for precision of the methods expressed in age-equivalents. This way of presenting these data tells the reader more explicitly what degree of divergence one can expect when a method is used by different investigators.

The aim of this study was to test the accuracy and precision of three different methods of estimating chronological age, suggested by Liliequist and Lundberg (1971), Demirjian *et al.* (1973) and Gustafson and Koch (1974), when applied to a sample of Swedish boys and girls. These methods were chosen as they represent different methodological approaches.

Material

The material consisted of 300 panoramic radiographs of the teeth (Orthopantomograph®) from 150 boys and 150 girls of known chronological age. The radiographs were taken from the files of radiographs of children born between 1962 and 1973 (e.g. school classes) who had been examined radiographically at the Department of Oral Radiology in connection with a primary clinical examination at the Department of Pedodontics (Group I) and the Department of Orthodontics (Group II and III) at the School of Dentistry, Malmö, Sweden. Each radiograph was coded to ensure a blind test procedure. The material was chosen so as to constitute three age-groups, each comprising an age range of three years, and to include an equal number of boys and girls:

I. 3.5— *6.5* years (x= *5.0,* SD=0.9)
II. *6.5— 9.5* years (x= 8.7, SD=0.4)
III. 9.5-12.5 years (=10.7, SD=0.7)

Methods

Method according to Gustafson and Koch (1974)

The dental development is determined from panoramic radiographs in terms of three developmental stages of tooth formation and clinical emergence of any of the primary and permanent teeth (third molars excluded) in the right lower and left upper jaws. Only those teeth whose development coincides with or is close to the brief criteria given for each of the four stages are included in the analysis for the individual subject. The developmental stage of each tooth included is marked off on a card on which the reference values of the dental indicators, combined for the sexes, are given. Thereafter, the dental age is estimated using a ruler to weigh together the plotted stages. The dental age is read on the y-axis of the card, on which even ages in years are marked. The method is based on a reference material collected from a number of studies from different parts of the world. In this study the dental age was read to the nearest 6 months.

Method according to Liliequist and Lundberg (1971)

Dental development S:assessed from panor-

arnie radiographs by judging the development of the seven left mandibular teeth. For each tooth dental development is divided into seven developmental stages. The same brief criteria for the developmental stages and same score for the same stage are used regardless of the type of tooth. The sum of the scores for the seven teeth is calculated. Tables to be used for transformation of a sum of scores to a dental age were not presented in the original paper (Liliequist and Lundberg, 1971) but were given in a later paper (Liliequist and Lundberg, *1975).* As the dental age was expressed as an age range rather than as a specific age, reference tables were established in this study by linear estimation of the relationship per 6 months between the sum of scores and chronological age. This transformation of data (Table 1) was based on an extended cross-sectional sample of 806 Swedish boys and girls, aged 2.5 to 15.5 years, presented by the originators in a separate paper (Liliequist and Lundberg, 1983).

Table I Transformation from sum of scores to dental age on the basis of the method developed by Liliequist and Lundberg (1971). The reference scores used in this table are based on the data published by Liliequist and Lundberg (1983) (see Methods)

Dental age	Dental scores: Boys	Dental scores: Girls
3.0	4.0<4.8	5.5<6.0
3.5	4.8< *5.5*< 6.3	6.0< 6.5< 7.1
4.0	6.3< 7.0< 7.5	7.1< 7.5< 8.0
4.5	*7.5*< 8.0< 8.5	8.0< 8.5< 9.0
5.0	*8.5*< 9.0<10.3	9.0< 9.5<11.0
5.5	10.3<11.7<13.3	11.0<12.5<14.0
6.0	13.3<14.5<15.6	14.0<15.5<16.8
6.5	*15.6<16.7<17.9*	16.8<17.8<19.0
7.0	17.9<19.0<19.6	19.0<20.0<20.8
7.5	19.6<20.0<20.6	20.8<21.5<22.4
8.0	20.6<21.0<21.3	22.4<23.0<25.0
8.5	21.3<21.5<21.8	25.0<27.0<29.0
9.0	21.8<22.0<24.0	29.0<31.0<31.3
9.5	24.0<26.0<28.0	31.3<31.5<31.8
10.0	28.0<30.0<30.8	31.8<32.0<33.0
10.5	30.8<31.5<32.3	33.0<34.0<35.0
11.0	32.3<33.0<33.8	35.0<36.0<36.5
11.5	33.8<34.5<35.3	36.5<37.0<37.5
12.0	35.3<36.0<36.8	37.5<38.0<38.5
12.5	36.8<37.5<38.3	38.5<39.0<39.5
13.0	38.3<39.0<39.5	39.5<40.0<40.3
13.5	39.5<40.0<40.5	40.3<40.5<40.8
14.0	40.5<41.0	40.8<41.0<41.3
14.5	41.0	41.3<41.5<41.8
15.0	41.0	41.8<42.0

Methods according to Demirjian etal. (1973)

The development of the seven left permanent mandibular teeth is determined. Tooth formation is divided into eight stages and criteria for the stages are given for each tooth separately. The authors supply the user with detailed written critieria with supplementary illustrations (Demirjian *et al.,* 1973). Each stage of the seven teeth is given score according to a statistical model, which has also been used for assessment of skeletal maturity (Tanner *et al., 1975).* Standards are given for each sex separately. The sum of the scores for the seven teeth is transferred to a dental age (Demirjian *etal.,* 1973; Demirjian, 1982). The reference values for the assessment of dental age used in this study are based on the revised data (Demirjian and Goldstein, 1976; Demirjian, 1982) obtained from 5,447 panoramic radiographs from a French-Canadian mixed longitudinal sample of girls and boys between the ages of *2.5* and 19 years (Levesque and Demirjian, 1980).

Accuracy test

To test the accuracy of the three methods of estimating chronological age, each of the two examiners read 150 radiographs *(25* of each sex in each of the three age-groups) and the data were pooled. All 300 radiographs were read using the method of Gustafson and Koch (1974), then by the method of Liliequist and Lundberg (1971), and thirdly by the method of Demirjian *et al.* (1973). This order was used as the criteria given for the stages were more briefly expressed in the first and second methods than in the third method. The

chronological age and sex of the subjects were unknown to the examiner. For each sex and age-group, the mean difference (d) and standard deviation $_{(Sd)}$, and the correlation coefficient (r) between estimated and true chronological age were calculated.

Precision test

Inter-examiner variation. The inter-examiner variation for each method was calculated as the mean difference (d) and standard deviation $_{(Sd)}$ between the estimated ages obtained independently by the two examiners from 60 of the 300 radiographs (10 of each sex in each of the three age-groups).

Intra-examiner variation. The 60 radiographs that were read in the inter-examiner test were re-evaluated one month after the first reading by each of the two examiners. The mean differences (d) and standard deviation $_{(Sd)}$ between the first and second readings by each of the examiners were determined for each method.

Calibration procedures

Pre-experimental calibration. Before the start of the study, chronological age was estimated on panoramic radiographs from 12 Swedish children not included in the main study. The readings were performed separately for each method. The results were then compared and discussed. This procedure was repeated once.

On a calibration set of panoramic radiographs* (Levesque and Demirjian 1980), the dental development was determined by the method of Demirjian *et al.* (1973). The results of the calibration in terms of identical and non-identical ratings of each of the seven, left mandibular teeth were in agreement with those reported by Levesque and Demirjian (1980), i.e. a mean inter-observer precision of about 80 per cent. Transformed to dental age, a slight tendency to underestimate the dental age in relation to the originators was noted (Table 2).

Calibration during the study. Parallel to the main study, five out of every 25 radiographs were read by both examiners and the results were compared and discussed in order to reduce the discrepancies in interpretation of the criteria between the examiners.

Results

Accuracy test (Table 3)

Gustafson and Koch (1974). The main difference between estimated and true chronological age in the groups of girls varied from 4 to 7 months. The lowest value was found in the oldest group. The standard deviation of the differences was about the same in all groups of girls. In boys, the mean difference between estimated and true chronological age was low in all age-groups. The highest

* The calibration set is available on request and at nominal cost from Dr Demirjian (see Levesque and Demirjian, 1980).

Table 2 Results from the pre-experimental calibration of the method devised by Demirjian *et al.* (1973) in a series of 21 radiographs. Mean differences (d) and standard deviations of the differences $_{(Sd)}$ (in months) and degree of linear correlation (r) between the age assessed by the originators of the method and the two examiners in this study are given T-test for paired observations applied.

Examiners	d	Sd	t	r
Examiner 1—Levesque and Demirjian (1980)	—0.9	5.1	—0.77	0.98
Examiner II—Levesque and Demirjian (1980)	—2.9	5.6	—2.35*	0.98
Examiner I—II	2.0	5.1	1.78	0.98

*p<0.05

standard deviation of the differences was found in the oldest age-group. In both sexes the estimated chronological age was higher than the true chronological age in all age-groups, except in the oldest group of boys.

Liliequist and Lundberg, (1971). In girls, the mean difference between estimated and true chronological age varied from 4 to 8 months in the different age-groups. The highest difference was found in the oldest group, in which the highest standard deviations of the differences were also noted. In boys, the mean difference between estimated and true chronological age in the different age-groups varied from 3 to 7 months. The highest difference was found in the youngest group. The highest standard deviation was noted in the older groups. An underestimation of the chronological age was seen in both sexes and in all age-groups, except in the *6.5-9.5-year-old* boys, where an overestimation was noted.

Demirjian et al. (1973). The mean difference between estimated and true chronological age in the three age-groups of girls varied from 0.3 to 11 months. The lowest value of the mean difference was seen in the youngest age-group. The mean differences were about the same in the two groups of older children, which also showed higher values of the standard deviations of the differences. In boys, the mean difference between estimated and true chronological age varied from 1 to 9 months in the different age-groups. The lowest difference was found in the youngest group. The standard deviation of the difference was highest in the oldest group. The estimated chronological age was higher than the true chronological age in all age-groups and in both sexes.

Correlation analysis (Table 3). Irrespective of the method used for assessment of dental age, the highest linear correlations between estimated and true chronological age were found in the youngest group (r=0.74.9), while in the two older age-groups lower correlations were seen (r=0.3-0.6).

Precision test (Table 4)

Inter-examiner variation. The mean difference between the estimated chronological ages for the 60 radiographs read by both examiners independently according to the three methods varied from 0.3 to 2 months (Table 4). The highest difference was found

Table 3 Accuracy test. Comparison between estimated and true chronological age (in months) in boys and girls in different age-groups. Mean differences (d), standard deviations of the differences (Sd) and degree of linear correlation (r) are given.

	3.5-12.5 years[a]		3.5-6.5 years			6.5-9.5 years[b]			9.5-12.5 years[b]		
Methods	d	Sd	d	5d	r	d	5d	r	d	Sd	r
Girls											
Gustafson and Koch (1974)	5.7	10.2	6.7	9.5	.69	6.5	10.9	.51	3.9	10.0	*.51*
Liliequist and Lundberg (1971)	-5.6	9.1	-5.1	6.6	.82	-4.0	6.8	.55	-7.6	12.3	*.54*
Demirjian *et al.* (1973)	7.3	12.2	0.3	7.6	.79	11.0	12.8	.51	10.3	12.6	.51
Boys											
Gustafson and Koch (1974)	0.1	9.6	0.2	7.0	.85	1.7	9.2	.32	-1.8	11.8	.45
Liliequist and Lundberg (1971)	-1.7	9.6	-7.4	*5.5*	.82	5.4	7.7	.47	-2.8	10.3	.56
Demirjian *et al.* (1973)	6.1	10.4	1.4	7.9	.82	9.4	9.5	.48	7.9	11.9	.54

[a] 150 girls and 150 boys
[b] 50 girls and 50 boys

Table 4 Precision test. Inter- and intra-examiner variation for estimation of chronological age from a series of 60 radiographs. Mean differences (d) and standard deviations (Sd) (in months), and degree of linear correlation are given. T-test for paired observations applied.

	Examiner I			Examiner II			Inter-examiner			
Method		Sd			Sd			Sd		
Gustafson and Koch (1974)	-0.3	6.5	-0.36	-6.3	8.1	−599***	2.0	7.4	2.10*	.97
Liliequist and Lundberg (1971)	-0.9	4.8	-1.45	0.4	4.5	0.68	0.3	4.9	-0.48	.99
Demirjian *et al.* (1973)	0.4	6.3	0.49	1.4	5.6	1.95	-0.6	5.0	-0.92	.99

* $p<0.05$
$p<0.001$

for the method proposed by Gustafson and Koch (1974), this difference being statistically significant.

Intra-examiner variation. The mean difference between the two estimates of chronological age, based on readings of 60 radiographs according to the three methods by each of the examiners, was low (0.3-1.4 months) for both examiners when the methods proposed by Liliequist and Lundberg (1971) and Demirjian *et al.* (1973) were used. A low mean difference of estimated chronological age was also noted for one of the examiners when using the method proposed by Gustafson and Koch (1974), but a statistically significant difference between the two readings was found for the other examiner when this method was tested.

Discussion

The accuracy and precision of three methods of estimating chronological age (Liliequist and Lundberg, 1971; Demirjian *et al.,* 1973; Gustafson and Koch, 1974), based on assessment of tooth formation on radiographs, were investigated. The methods were chosen to repfesent different methodological approaches, as well as different sample sizes and sampling procedures for the standards. The three age-groups in this study were chosen to represent individuals with different types and numbers of stages of tooth formation. Furthermore, a methodological approach was used which would allow comparison of the accuracy of the methods where both age and sex are considered. The reliability of the methods was studied by calculating the intra-examiner and inter-examiner variations of estimated age.

In this study, certain sets of radiographs were used for calibration before the main study started. Systematic cross-checking of the readings was performed during the main study. Dental age was assessed by means of the latest standard for each method (Gustafson and Koch, 1974; Demirjian, 1982; Liliequist and Lundberg, 1983).

Accuracy test (Table 3)

Gustafson and Koch (1974). In earlier studies the accuracy of this method has been reported to be high (Gustafson and Koch, 1974; Crossner and Mansfeld, 1983). Gustafson and Koch (1974) reported a mean difference between estimated and true chronological age of only 2 months and a very high degree of linear correlation (r=0.998). However, this high correlation is misleading since the correlation test was performed on a sample of children ranging widely in age. This will automatically increase the value of the correlation coefficient as the scores become greater with increasing ages of the individuals (Lee *et al., 1965;* Liebgott, 1978). However, when subgrouping the material in the present study, a more complex picture was seen, the mean difference

between estimated and true chronological age being low in boys but markedly higher in girls, in whom a systematic overestimation of age was noted. An equal numerical difference in validity, corresponding to a sex difference in dental development, is to be expected as the standard reference of this method has been calculated from samples of both boys and girls.

In this study the approximate *95%* confidence limit (± 2 SD) for a single estimation of chronological age was ± 15-25 months (Table 3), which should be compared with the ± *5-6* months reported previously (Gustafson and Koch, 1974; Crossner and Mansfeld, 1983). The latter figures are far below the expected variation since the time of attainment of any of the included developmental stages of the teeth displays a greater variation.

Liliequist and Lundberg (1971). When this method was applied in the present study, an almost consistent underestimation of chronological age was noted (Table 3). The method is based on simple numerical scores for the stages. However, it is essential that the scores of the various stages are not identical, for a number of reasons. One of the most important is the varying duration of the different stages of the seven teeth included (Demirjian and Levesque, 1980). If this is not considered, error is introduced when the method is used for estimation of chronological age.

A conceivable explanation for the underestimation of chronological age found in this study may be difficulties in interpreting the brief criteria given by Liliequist and Lundberg (1971). We endeavoured to apply the given criteria strictly, which may lead to a lower dental score and lower estimated chronological age compared to when criteria for the stages as 'just to be attained' are used, as may have been done by the originators. From the paper by Liliequist and Lundberg (1971) it is not possible to establish how the criteria of stages were applied when obtaining the reference standards.

Another conceivable explanation for systemic underestimation may be differences between the population from which the standards have been obtained and the test population. Such differences are unlikely, however, as both samples were taken from a Swedish population.

Demirjian et al. (1973). When the method proposed by Demirjian *et al.* (1973) was applied, only a small difference was found between estimated and true chronological age in the youngest group (Table 3). In the two older groups, however, marked differences were seen and a systematic overestimation of chronological age was noted in both sexes (Table 3). The overestimation ranged from a mean value of 8 to 11 months, corresponding to an average 'error' of one stage for every tooth included in the system, except those which had reached the final stage. The high agreement between estimated and true chronological age found in the youngest group argues against the assumption that a systematic error in interpreting the criteria of the stages has been introduced by the examiners in this study. In addition, when our readings of the calibration set were compared with those of the originators of the system, good agreement was found (Table 2).

A conceivable explanation for the low accuracy of the method in the older groups may be that after a certain chronological age, dental age does not exhibit a Gaussian distribution (Hagg and Taranger, 1984a). This would result in a distortion of the results, leading to systematic overestimation of age when chronological age is estimated from dental development.

A possible explanation for the low accuracy of the method when applied to older children could be population differences, accentuated in the ages around puberty. However, when tooth development, indirectly studied by assessing the emergence of the seven permanent lower teeth, was compared between the French-Canadian sample (Demirjian and Levesque, 1980) and Swedish standards (Hagg and

Taranger, 1984b) no significant differences were seen. Moreover, the fact that the method is based on data from a certain population does not guarantee that the accuracy of the method is high when it is applied to that population.

The 'Demirjian system' (Demirjian and Goldstein, 1976) comprises eight stages of development for each of seven left mandibular teeth, altogether *56* stages. Only the late 43 of the *56* stages are given separate scores, specific for sex. The standard does not cover the remaining 13 stages. According to the figures on median age of attainment given by Demirjian and Levesque (1980), 19 of the 43 stages are attained within the age range of the youngest group of the present study, 9-10 stages within that of the middle group, 6-8 stages within the age range of the oldest group and 4 stages after the age interval covered. Moreover, 3-4 stages attained in the age range covered by the two older groups of this study are final stages. According to the intervals between median attainment age for consecutive stages given by Demirjian and Levesque (1980), the stages occurring earlier in life are generally of shorter duration than the stages occurring later. Stages of short duration are more informative than those of long duration (Roche, 1978). Thus, the higher accuracy of age determination found in the youngest group can probably be explained by the high number of stages with short duration in young children.

In older age-groups, a systematic overestimation of age was found. The mean duration of several of the late stages is about 3 years, and as soon as the subject has attained such a stage he will be given the appropriate score. However, the method proposed by Demirjian *et al.* (1973) is based on the same methodological approach as the TW2-method (Tanner *et al.,* 1975), which means that the standard is based on the age when the mid-point between two consecutive stages of development is reached. This discrepancy between the standard and the application of the system may lead to a systematic overestimation of age. The relatively smaller mean difference between estimated and chronological age in the oldest group than in the middle group is probably due to the increasing impact of scores from final stages, which are based on the average age at attainment. Similar effects of that scoring system have been reported for skeletal maturation when the TW2-method (Tanner *etal.,* 1975) was used in a study of somatic development of Swedish children (Taranger *et al.,* 1976).

If the duration factor has an impact on the system, as described above, this could be taken into consideration when the system is used for age determination. In this study, using recent standards (Demirjian and Goldstein, 1976; Demirjian, 1982), a mean difference of 8 to 11 months between estimated and true chronological age was found. Proy *et al.* (1981) found a consistent overestimation of age of about 7 months when the original standard (Demirjian *et al.,* 1973) was tested on a French sample of 3.5 to 14.5-year-old children, and proposed adjusted scores for French children. The new scores (Demirjian and Goldstein, 1976; Demirjian, 1982), which were used in this study, were apparently well suited for the younger group in this study, but for the older groups an adjustment of the scores may be desirable.

Precision test (Table 4)

Data on the precision of methods used for age determination are scarce. Lilieqnist and Lundberg (1971) tested the precision of their method by assessing the inter-examiner variation, as did Levesque and Demirjian (1980) for the system proposed by Demirjian *et al.* (1973). The precision of the method devised by Gustafson and Koch (1974) does not seem to have been tested.

In this study, the precision expressed as the intra- and inter-examiner variation, of the methods proposed by Liliequist and Lundberg (1971) and Demirjian *etal.* (1973) was high, as shown by the small mean differences between the readings. The inter-

examiner variation was also reasonably small for the method described by Gustafson and Koch (1974). In the intra-examiner test of the latter method, however, one of the examiners displayed a more pronounced systematic error between the two readings. All three methods contain the element of subjectivity implicit in the criteria of the tooth development stages. The method of Gustafson and Koch (1974), however, also contains the subjective component inherent in weighing together the tooth development stages using a ruler and reference card. This procedure increases the subjectivity and affects the precision of the method. The calculation of numerical developmental scores which automatically give the dental age of the individual, as in the method proposed by Demirjian *et al.* (1973) and, in the present study, in the method of Liliequist and Lundberg (1971), probably gives a higher precision.

In the method devised by Gustafson and Koch (1974), the examiner selects the teeth to be included in the analysis-and plotted on the card, which also increases the subjectivity of the method. Another factor which must be taken into consideration is that the criteria for the four stages of dental development used in this method are not strictly defined. For example, definitions of the stages as 'just to be attained' are used. In the other two methods, the same seven, left permanent mandibular teeth are always included in the analysis, and strict descriptions of the criteria are given, although those in the method proposed by Liliequist and Lundberg (1971) are briefly formulated.

In this study, the results of all tests of precision were presented as mean differences of estimated age. In their tests of intra-examiner variation, Liliequist and Lundberg (1971) compared the total scores, and Levesque and Demirjian (1980) compared individual tooth ratings. The method of presenting the data used in this study was chosen because it shows more explicitly what degree of divergence one may expect when these methods are used by different examiners for age determination in individuals. These differences in presentation of the data make direct comparison between the results from earlier studies and the present one difficult. When converting the total dental scores from the inter-examiner test performed by Liliequist and Lundberg (1971) into estimated ages, it was noted, however, that the inter-examiner variation was markedly larger in their study than in this one. The higher conformity between the examiners in this study may be due to the thorough calibration procedure before and during the study.

General remarks

From the results of this study. it is obvious that the validity of the methods tested differs between different age-groups, a factor that has to be taken into consideration when the methods are used in clinical work. The lowest mean differences and the highest linear correlations were generally found in the *3.5* to 6.5-year-old children. Thus, estimation of age is preferably done during early childhood, when many indicators of short duration are available. After that, the biological variation increases considerably, as indicated by the wider 95% confidence interval found with all methods. The number of indicators also falls with age, and an increasing number of teeth reach their final stages. It should be stressed, however, that even though the accuracy seems to be higher in younger children, the difference between estimated and true chronological age, expressed as a percentage of age, may be just as great as in older children.

In this study, the accuracy of estimation of age based on dental development, expressed as the approximate *95%* confidence interval for a single estimation, was at least ±12 months for all the methods in the youngest age-group and ±20 months in the older groups. This finding, in combination with a precision, expressed as the 95% confidence interval, of at least ± 10 months, indicates that methods of estimating chronological age by means of the dental develop-

ment should be used with caution. All methods contain more or less strong subjective elements, which, in combination with the biological variation in tooth development, makes uncritical use of the methods hazardous.

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