Computerized measurements of the lower third molar related to chronologic age in young adults

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Chronologic age is an utmost important birth record in many industrialized Western countries. When the date of birth is unknown, there is a demand for establishing the chronologic age. Dental methods for age estimations are considered more reliable than most other methods by the majority of researchers and are among the most commonly used means to determine age. Traditionally, these methods have most often been based on subjectively estimated, radiographic stages of tooth development. In the present study metric measurements of the length of the forming root have been used and are compared with one standard method. The formed part of the root of the lower third molar as seen in a panoramic radiograph was digitized. Data were directly stored in a computer for subsequent statistical analysis. The technique of collecting data with the aid of a computer had some statistical advantages. The precision of age estimations was, however, slightly inferior to the standard method. □ *Age estimation; computer; digitized measurements; panoramic radiographs; root length*

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In Sweden and many other Western societies chronologic age is important—for example, when deciding about the year of school start or the earliest age when a person is eligible to marry or go to prison. For example, when a crime is committed in Sweden, imprisonment may be sanctioned only when the condemned is more than 18 years old. This has put pressure on the authorities to establish the chronologic age of many immigrants when the date of birth is uncertain. The best results of age estimations are obtained during childhood. In spite of somewhat more uncertain results, such estimations may, however, be important also with regard to young adults.

Age estimations based on dental methods seem to have a low correlation with other medical methods, such as skeletal and somatic development (1–3), and it has been proposed that the dentition might be a separate entity independent of other growth factors (4).

Advantages of dental methods have been stressed by, among others, Anderson et al. (5) and Demirjian et al. (2), who found that the teeth seem to be independent of hormonal and nutritional factors. When estimating the chronologic age of an individual, therefore, dental methods seem to be the most reliable. Other medical methods are more relevant when estimating somatic maturity as, for example, when planning orthodontic treatment (2, 6).

Dental methods consist of counting erupted primary or permanent teeth or studying the mineralization process and development of the teeth as seen in radiographs. The findings are compared with compiled charts for a reference population. The accuracy and precision of some of these dental methods have during the last few years been studied and found to be rather weak (7, 8).

Age estimations at ages above 14 years are more difficult than during childhood. All permanent teeth except the wisdom teeth have completed their development. Generally, the development stage of the teeth according to their radiographic appearance is used (9–14). The recorded development stage is then compared with the same stage in a population with known ages. The estimation of the development stage is based on a subjective evaluation, and many shortcomings may, a priori, be expected. Therefore, new objective methods that are more observer-independent seem necessary (15). One approach could be to measure the length of the forming root in radiographs with a digitizer (16). Then, measurements will be expressed by intervals on a continuous scale with equal distances between stages and base line at zero (ratio scale). In the mentioned study by Kullman & Martinsson (16) graphic computer measurements of, among other things, bone height were analyzed. The authors concluded that this method gave reliable results. The accuracy of this computer method was proved in a subsequent work (17). Accurate measurements of tooth and root lengths could be performed in intraoral radiographs; consequently, the method is useful for dental age estimations. With the same approach metric measurements of the third molars could probably also be performed in panoramic radiographs.

Table 1. Classification of root stage on the basis of digitizer measuring

Root length/tooth length in percentage	No. of lower third molars*	
	Female	Male
–12	7	7
13–25	30	15
26–38	47	23
39–51	99	73
52–65	86	77
65–	11	8
	280	203
Total no.	483	

* Molars from both sides are pooled.

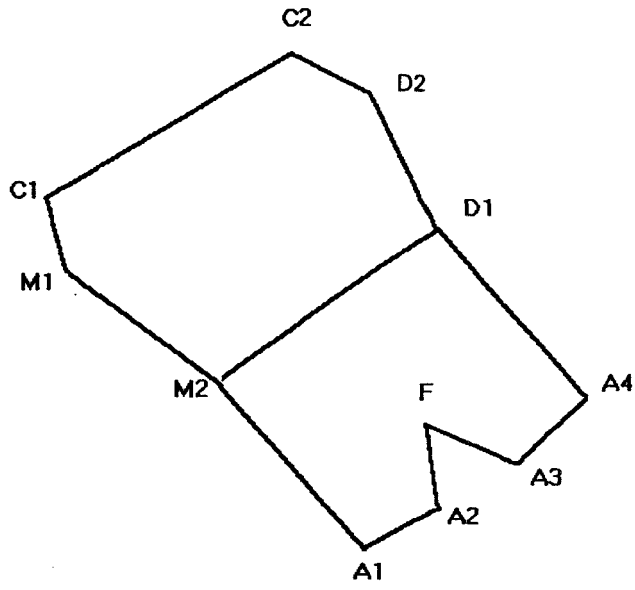

Fig. 1. Schematic figure of the reference points of the tooth during registration with the PCDIG software. The coordinates of the points are stored by the computer, and different distances in the tooth can be calculated.

Panoramic radiographs have many advantages but are subject to inherent distortion effects. Several studies demonstrate that measurements in the vertical dimension may be reliably performed in panoramic radiographs (18–20). However, measurements must be corrected by means of the proper magnification factor. The degree of magnification is dependent on the panoramic equipment and the positioning of the patient during exposure. When relative values of dimensions within one and the same tooth are used, directly applicable and reliable measurements may be obtained, since the magnification may be considered equal within different parts of the radiographic image of the tooth.

The aim of the present study was to test whether age estimations based on the development of wisdom teeth could be improved by using computer techniques to measure root length instead of subjectively estimating development stages. An additional aim was to establish the magnitude of the error when measuring lengths in panoramic radiographs.

Materials and methods

A material described in a previous study (13) was used. It consists of panoramic radiographs of young adults. A total of 1261 lower third molars were registered, but the statistical analysis was then performed on only 691. The reason for this was that all fully developed teeth were excluded. Six predefined root stages remained and were used. It was in the present study decided to break root length measurements into the same number of stages. Measurements were expressed in percentages of the total length of the forming teeth. The percentage measurements were then divided into six stages, each stage covering about 12% of the length of the root.

In panoramic radiographs only measurements in the vertical dimension are reliable. Therefore, an additional number of previously used third molars were excluded—that is, all those that were inclined more than 45° in the horizontal dimension. Thus, the final material consisted of 483 lower third molars (Table 1). Left and right sides were analyzed together, since the previous study had shown that no systematic side differences were indicated.

Table 2. The same tooth registered 100 times with the digitizer and 75 teeth double-registered

	Relative root length (% of total tooth length)			
	Same tooth			Double-registered lower third molars: First measurement – second measurement (difference)
	Masked	Unmasked	Pooled	
Sample	50	50	100	75
Mean	46.6	46.5	46.6	−0.04 NS
Standard deviations	2.8	2.7	2.7	6.1

Table 3. Mean age and standard deviation (SD) in years in different root stages

	Subjectively estimated root lengths												Digitizer-measured root lengths											
	Male						Female						Male						Female					
Stage	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
Mean age (years)	15.2	16.0	17.0	17.3	18.2	19.5	15.4	16.7	17.0	17.9	19.4	20.1	15.1	15.6	17.1	17.7	18.5	19.2	15.7	16.4	17.2	18.4	19.1	20.1
SD	1.4	0.9	1.1	0.9	1.4	1.2	0.6	1.8	1.8	1.5	1.7	1.6	1.6	1.1	1.4	1.3	1.5	1.7	1.3	1.7	1.8	2.3	1.7	1.4
Sample size	12	9	43	47	43	49	14	36	58	52	56	64	7	15	23	73	77	8	7	30	47	99	86	11
Total no.				203					280							203					280			

A reason for using the same material as in a previous study was to make comparisons between the precision of two methods for age estimation. The precision of individual age estimations was defined as the 95% tolerance interval (± 2 SD) around the estimated mean.

Registration method

Metric measurements of tooth and root lengths were made with a digitizer with a maximum resolution of 0.025 (Numonics model 2210, Numonics Corp., Montgomeryville, Pa., USA) connected to an IBM-compatible personal computer.

The panoramic radiographs were placed on the transparent board of the digitizer, which was illuminated from below. The software, PCDIG, was developed by the Center for Dental Technology and Biomaterials, Karolinska Institutet, Stockholm, Sweden. With this program, x and y coordinates of defined points in the radiographs are registered by means of a button cursor with a cross. The accuracy of this registration technique has been shown to be sufficient (21).

Reference points for measurements are defined in Fig. 1. The program calculated distances between reference points in millimeters and with a precision of one decimal point. The following distances were calculated and stored for later analysis: mesial tooth length defined as the distance between point C_1 and the mean of A_1 and A_2; distal tooth length defined as the distance between C_2 and the mean of A_1 and A_2 in case of single-rooted teeth and between C_2 and the mean of A_3 and A_4 in case of double-rooted teeth; crown width defined as the distance between M_1 and D_2; mesial crown height defined as the perpendicular distance from C_1 to the line connecting M_2 and D_1; and distal crown height defined as the perpendicular distance from C_2 to the line connecting M_2 and D_1.

To study the precision of the digitizer measuring method, two tests were performed before the final collection of data. First, 100 repeated measurements of the same tooth were made by one person. During this procedure the last 50 measurements were performed while extraneous light outside the radiographs was masked. Second, 75 teeth with different root lengths and development stages were measured. These teeth were evenly distributed across all development stages. For each tooth two registrations were made at an interval of several months. This was performed to test the hypothesis that a great part of the total error depends on biologic variation.

All collection of digitized data was performed by one person (L. Kullman). When the lengths of the roots were subjectively estimated, the registrations were made in accordance with the instructions in the foregoing study (13).

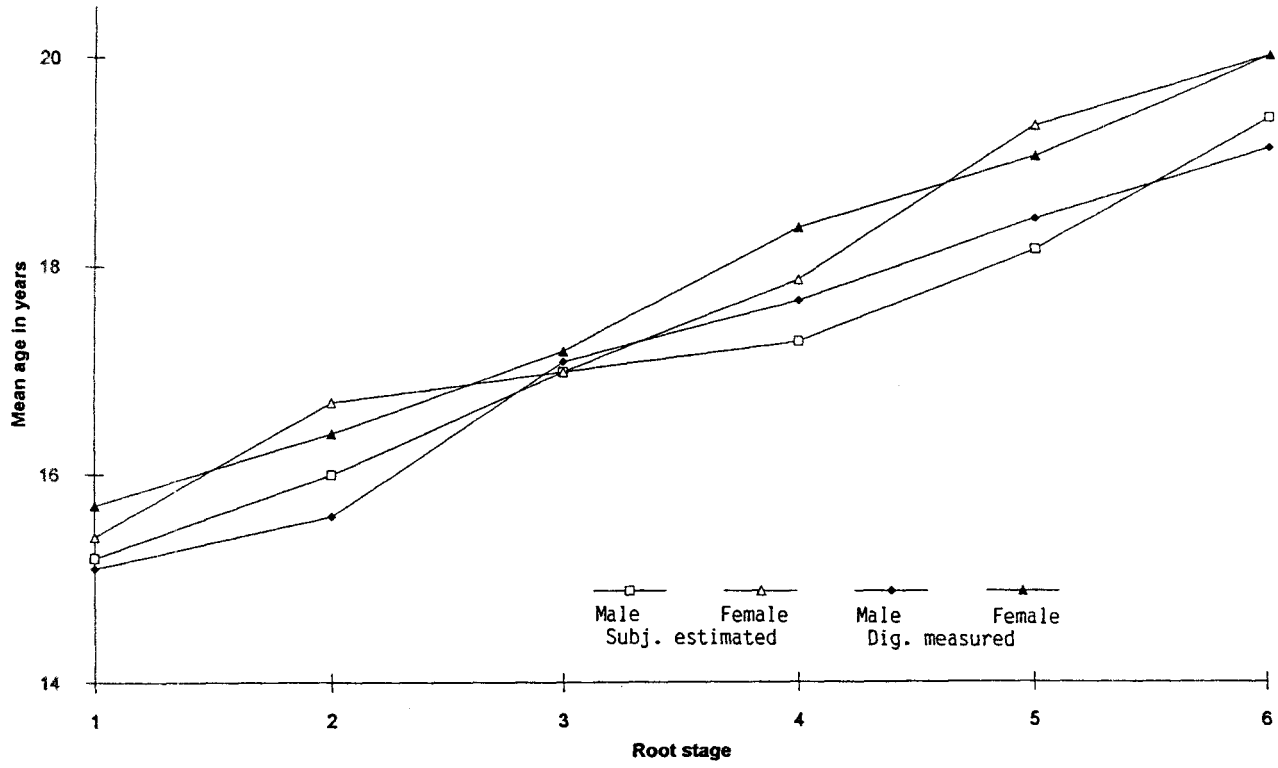

Fig. 2. Mean ages in years of the root stages for the two sexes and different methods.

Statistical analysis

Parametric statistical methods were used throughout the study and included the following variables:

Mean ages and standard deviations were calculated for the different groups of digitized and estimated root stages. Correlations were calculated between the variables, including analysis of variance and multivariate regression analysis with two independent variables.

Student's *t* test was used to compare differences between means or paired observations.

Results

Precision pretest

Results of the precision pretests are presented in Table 2. When repeated measurements were performed on the same tooth, no significant difference was indicated between data collected with masked and unmasked radiographs, and, therefore, the two sets may be pooled. Doubled measurements on 75 different teeth indicated a good precision, but the standard deviation was markedly higher than that for measurements performed on one and the same tooth—6.1 as compared with 2.7%. This difference may be contributed to problems of identifying the reference points in different teeth.

Main or final test

Mean ages and standard deviations for the different root stages are presented in Table 3 and Fig. 2. There is a minor difference between the sexes: males are slightly ahead of females in development. This difference varied with root stage and was significant on the 5% level for the last three development stages. Standard deviations have higher values in the 'digitized' groups as compared with subjectively evaluated groups.

When using multiple regression analyses to find the best predictors for age estimation, a significant but weak correlation was noted for both sexes between subjectively estimated root stages and chronologic age (Table 4). This can be expected when a biologic development variable is studied during growing. However, for digitizer measurements the same correlation was not significant. The coefficient of determination (R^2), using both the dental-independent variables as predictors, was strongest for males (0.52).

Discussion

Measurement errors affecting the precision of the applied approach originate from different sources. Basically, there are errors dependent on the radiographic

Table 4. Multiple regression analysis with chronologic age as dependent variable

Predictor (independent variables)	Regression coefficient		Standard error		Significance	
	Male	Female	Male	Female	Male	Female
Subjectively estimated root stage	0.89	1.04	0.10	0.11	$p < 0.001$	$p < 0.001$
Digitized relative root length	−0.55	−1.36	1.02	1.16	NS	NS
$R^2 =$	0.52	0.44				

projection, image unsharpness, and general image quality. These are all inherent in radiographic images and will affect the identification of the reference point. Moreover, there are errors created during the registration phase due to the precision of cursor positioning (observer-dependent) and also inherent measurement errors in the digitizer. The mentioned errors are inherent in all digitizer-based radiographic measurements. In the present study the sum of these errors varied between 3% and 6% of root lengths. This precision generally conforms with results presented by Larheim et al. (18), who measured tooth lengths in panoramic radiographs. They are also mainly in accordance with the findings of Thanyakarn et al. (19) based on digitized data from the same type of radiographs.

In general, computer-based metric radiographic measurements using digitizers seem to have many advantages. They are markedly time-saving, and registered values may be directly stored and later retrieved for statistical analysis. Differences between different observers will probably be minimized when such measurements are performed. Using various more traditional approaches, observer performance has proved to be unreliable, demonstrating both low interreliability and intrareliability (13, 22–24).

When analyzing the precision in age estimations, some additional conclusions must be drawn. Normal biologic variation in tooth development is a factor to be added to the measurement errors. Therefore, in the main test of this study, standard deviations can be calculated to reach a maximum value of 14% when single measurements were performed on all root lengths in the different development stages. This is a shortcoming when analyzing biologic development variables. If 95% tolerance limits are to be established, the total precision in making age estimations will be 1.96 × SD years around the mean age. As may be noted in Table 3, the standard deviations found are usually high, and it was not possible to increase the individual precision in age estimations by using digitized measurements. The standard deviations are lower for subjective estimations of tooth development stages.

The magnitude of the tolerance intervals found in this study conforms with findings presented recently by Mincer et al. (25). They concluded that, since other accurate and reliable variables are lacking, the third molar may be of great importance in age estimation.

Another finding during this study confirms the results of Mincer et al. (25) and of Levesque et al. (10). During the final root development, the third molar develops earlier in males than in females. This is a unique finding valid only for third molars.

The present work has shown that the precision is low for age estimations based on the teeth in young adults. Still, it is important to establish the accuracy of these methods. This accuracy will establish whether any systematic errors exist. There are scientifically proven differences between people of different ethnic origins, and, therefore, compiled charts with mean ages and standard deviations must be created for different ethnic groups.

Thorsson & Hägg (12) compared the accuracy of age estimations on the basis of the method of Demirjian et al. (26) and Levesque et al. (10) in youths of Scandinavian origin. They found a systematic underestimation of chronologic age in Swedish youths when the development of the third molar was used. One possible explanation, besides observer variations, could be ethnic discrepancies. This explanation was also put forth by Staaf et al. (8) in a study in which Demirjian's method was used in young children. Because of ethnic differences, Finnish dental maturity standard curves have been constructed for children up to 17 years old by Kataja et al. (27). The wisdom tooth was not included in their study.

Therefore, further studies in Scandinavian populations are needed to establish the accuracy of age estimations in young people. To avoid confounding effects, completely new materials must be collected and used to establish accuracy.

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