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Dental age in Dutch children

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SUMMARY Dental age was studied in a sample of 451 Dutch children (226 boys and 225 girls) according to the method of Demirjian. They were born between 1972 and 1993 and were between 3 and 17 years of age at the time a dental pantomogram (DPT) was obtained. All children were placed in the age group closest to their chronological age. All 451 DPTs were scored by one examiner. A subset of 52 DPTs was scored by a second examiner and the intra-class correlation coefficient (ICC) and Cohen's kappa were calculated. The ICC was 0.99 and Cohen's kappa 0.68. Boys and girls were analysed separately.

A significant difference was found between chronological age and dental age. On average, the Dutch boys were 0.4 years and the girls 0.6 years ahead of the French–Canadian children analysed by Demirjian. Therefore, the French–Canadian standards were not considered suitable for Dutch children.

New graphs for the Dutch population were constructed using a logistic curve with the equation $Y = 100*\{1/(1 + e^{-\alpha(x-x0)})\}$ as a basis. The 90 per cent confidence interval was calculated. To determine whether the logistic curve was correct, a residual analysis was carried out and scatter plots of the differences were made. The explained variance was 93.9 per cent for the boys and 94.8 per cent for the girls. Both the residual analysis and the scatter plots indicated that the logistic curve was appropriate for use with Dutch children. In addition to the graphs, tables were produced which transfer the maturity scores calculated by the method of Demirjian into Dutch dental age.

Introduction

Children with the same chronological age may show differences in the developmental stages of different biological systems. Several indices have been developed to determine the developmental stage of a child for a certain biological system, namely indices for sexual maturity, somatic maturity, skeletal age, and dental age. In the literature, a strong correlation was found between skeletal age and sexual and somatic maturity (Demirjian, 1985). With reference to dental age, low correlations have been found with skeletal age, and sexual and somatic maturity (Prahl-Andersen *et al*., 1979; Demirjian, 1985). Filipsson and Hall (1975) showed that skeletal age correlated strongly with dental age. However, as those authors did not use partial correlation, this result is limited. The low correlations show that dental age is an independent measurement for biological age and should be measured separately. To be able to measure dental age directly is important because it is a useful tool to estimate the chronological age of a child with an unknown birth date (Lewis and Garn, 1960).

Several methods have been described to determine dental age. One of these uses the 'time of eruption' as a parameter. The time of eruption is described as the moment the tooth pierces the gingiva/keratinized mucosa (Filipsson, 1975). This is actually the 'time of emergence'. A disadvantage of this method is that the exact time of emergence is hard to determine. Premature loss or extraction of primary teeth can influence the time of emergence of permanent teeth (Demirjian, 1978). Moreover, the method can only be used during relatively short periods because between the ages of 2.5–6, 8–10 and 13–18 years no teeth will emerge. The determination of the emergence is further dependent on the timing of observation and, when determined longitudinally, it is dependent on the time span between observations. Finally, the time of emergence of third molars shows a large variation and in approximately 20 per cent of all patients third molars are absent. Emergence is a discontinuous process, in contrast to calcification of the teeth, which is an ongoing process. Thus, the time of emergence must, for the above-mentioned reasons, be considered a less reliable predictor for the developmental stage of a child (Demirjian, 1978).

Methods using measurements on radiographs as a basis for the determination of dental development use the length of the tooth, crown or root as an indicator of dental age (Gleiser and Hunt, 1955; Grøn, 1961; Lilliequist and Lundberg, 1971). Although some of the methods show good validity, it might be difficult to determine whether, for example, a root is one-quarter or one-third of its length, if the definitive length of the root is not known (Mörnstad *et al.*, 1995).

Demirjian based a dental age scoring system on objective criteria and relative values rather than on absolute lengths (Demirjian *et al.*, 1973; Demirjian, 1978). Radiographs of 21 328 French–Canadian children, ranging from 2 to 20 years of age, were used for standardization. In practice, each tooth on the left side of the mandible (except the third molar) is given a letter from A to H depending on its stage. Each letter corresponds to a score. The summed scores of all seven teeth represent the dental maturity score (from 0 to 100). The dental maturity score can be converted directly into dental age using either a graph or a table of standards (Demirjian *et al.*, 1973). Different standards are used for boys and girls. Because Demirjian used radiographs, this method can be used continuously during childhood.

It has been shown that different patterns of dental maturation exist in different populations. In Europe, comparisons have been made, for example, between the French–Canadian standards and Finnish, Swedish, Norwegian, and south German children. The dental ages of these subjects were all different from the French–Canadian children (Nyström *et al.*, 1986; Mörnstad *et al*., 1995; Nykänen *et al*., 1998; Frucht *et al*., 2000). The children from south Germany were ahead of the French–Canadians until the age of 8 years, but after that they stayed behind the French–Canadians (Frucht *et al*., 2000). For the Finnish, Swedish, and Norwegian children the dental age was advanced at all times compared with the French–Canadians (Nyström *et al*., 1986; Mörnstad *et al*., 1995; Nykänen *et al*., 1998). The Norwegian children were less advanced than the Finns and the Swedes.

Because different standards have been found in several countries, and because dental age assessment is considered important, the aim of the present study was to evaluate the suitability of the French–Canadian standards in the Dutch population and, if not appropriate, to develop a new standard for the Dutch population.

Subjects and methods

Subjects

The sample was derived from young patients attending the general dental clinic at the Academic Centre for Dentistry Amsterdam (ACTA), The Netherlands, and consisted of 451 children (225 boys and 226 girls). The inclusion criteria were that the children had to be between 3 and 17 years of age at the time the dental pantomogram (DPT) was obtained, the DPT had to be of good quality, no agenesis or extractions in the left lower quadrant and no twins were allowed. The children were all born between 1972 and 1993. The study was retrospective and therefore ethnicity may, in a few cases, be questionable, but every effort was made to exclude patients with surnames suggesting a non-Caucasian background.

All the children were grouped in the age group closest to the median age of each of the year age groups (3.5 up to and including 4.4 became age group 4 etc.). For the precise distribution of age, see Figure 1a, b. Boys and girls were analysed separately.

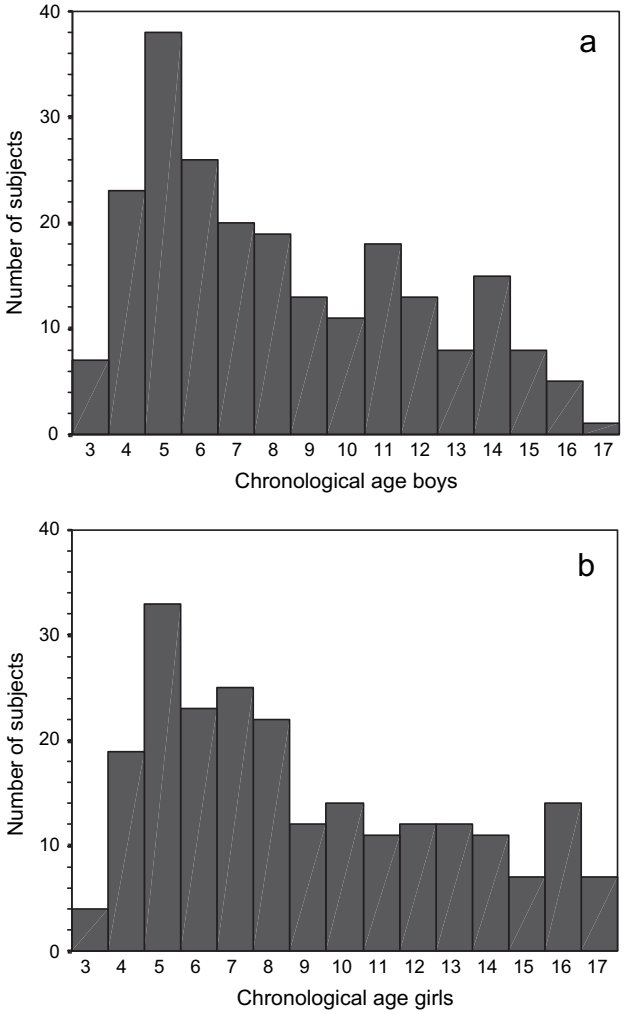

Figure 1 The number of subjects and age distribution of the Dutch (a) boys and (b) girls.

Methods

To determine whether the French–Canadian standards for estimating dental age (Demirjian, 1978) were appropriate for the Dutch population, the dental scores of the 451 children were computed by one examiner (MvK) according to the method of Demirjian (1978). Fifty-two of the DPTs were scored again by another examiner (IL) who was calibrated using the tutorial programme available on a CD-ROM produced by Demirjian. The inter-examiner reliability on the level of maturity scores was assessed with the intra-class correlation coefficient (ICC) (Fleiss *et al.*, 1979). To analyse inter-examiner agreement on the level of the separated scorings for each tooth (A–H), percentages of absolute agreement and Cohen's kappa were calculated.

For each gender and age group in the study sample, the mean scores of the dental age determined from the French–Canadian standards and the actual chronological age of the child were compared with paired *t*-tests.

To develop new standards for the Dutch population, a logistic curve, normally used for growth curves, with the equation $Y = 100*\{1/(1 + e^{-\alpha(x - x0)})\}$, where x stands for age, was drawn through all points to determine the mean age for each of the dental maturity scores. To determine the 90 per cent confidence interval, each individual's deviation was calculated by determining and quadrating all distances from every point to the logistic curve. A graph was made from all the deviations and a mean deviation for every age group was determined. At every point in the table, 1.65 times the deviation was added and subtracted to calculate the 90 per cent confidence interval. In the new set of points a logistic curve was drawn representing the 95th and 5th percentiles.

A residual analysis was carried out by calculating the explained and unexplained variances in order to verify the logistic curve. Additionally, scatter plots for the logistic curves were made of the difference between the observed age and the predicted dental age.

Results

Reliability

The ICC to calculate the inter-examiner reliability for the whole group of scores on the level of the maturity scores was 0.99. The percentages of absolute agreement on the level of the separate scorings (A–H) varied between 60 and 81 per cent, with a mean of 73 per cent. The difference between two scores did not exceed one stage for any tooth. The kappa coefficient on the level of the separate scorings (A–H) varied between 0.53 and 0.76, with a mean of 0.68, which is substantial according to Landis and Koch (1977). The percentages of absolute agreement and the separate kappa coefficients are shown in Table 1.

Table 1 Percentage inter-examiner agreement and kappa coefficient of agreement on scorings of developmental stages (A–H) of each of the left mandibular permanent teeth according to the criteria of Demirjian (1978) performed on a subset of 52 dental pantomograms.

	I1	I2	C	P1	P2	M1	M2	Mean
Percentage	63	69	60	77	69	81	81	73
Kappa	0.53	0.62	0.65	0.72	0.63	0.75	0.76	0.68

Table 2 *t*-test between the dental age according to Demirjian and chronological age for Dutch boys and girls with the mean difference between both.

Age	Mean chronological age (± SD)	Mean dental age (± SD)	Mean difference	*P*-value
Boys				
4	4.00 (0.24)	4.43 (0.69)	–0.43	0.005*
5	5.00 (0.30)	5.90 (0.77)	–0.90	<0.001*
6	5.97 (0.27)	7.25 (0.62)	–1.28	<0.001*
7	6.98 (0.30)	7.60 (0.57)	–0.62	<0.001*
8	7.99 (0.21)	8.46 (0.83)	–0.47	0.020*
9	9.07 (0.30)	9.52 (1.06)	–0.44	0.118
10	9.98 (0.26)	10.35 (1.43)	–0.36	0.402
11	10.88 (0.31)	11.17 (1.36)	–0.28	0.384
12	11.87 (0.30)	12.18 (1.19)	–0.30	0.446
13	13.08 (0.29)	13.19 (1.01)	–0.11	0.785
14	13.81 (0.40)	13.53 (2.11)	0.28	0.799
15	15.38 (0.10)	14.70 (0.00)	0.68	0.063
Girls				
4	4.16 (0.29)	4.29 (0.62)	–0.13	0.322
5	5.02 (0.27)	5.78 (0.71)	–0.76	<0.001*
6	6.03 (0.31)	6.80 (0.45)	–0.77	<0.001*
7	7.07 (0.26)	7.65 (0.55)	–0.58	<0.001*
8	8.03 (0.30)	8.54 (0.88)	–0.51	0.010*
9	9.03 (0.22)	9.44 (1.20)	–0.41	0.240
10	9.97 (0.23)	10.54 (1.20)	–0.57	0.102
11	10.83 (0.29)	12.06 (1.48)	–1.23	0.017*
12	11.97 (0.30)	12.66 (1.74)	–0.69	0.188
13	12.87 (0.29)	13.79 (0.64)	–0.92	0.001*
14	13.93 (0.45)	13.98 (0.95)	–0.06	0.895

SD, standard deviation.
*$P < 0.05$ is statistically significant.

Comparisons between dental age in French–Canadian and Dutch children

For statistical analyses, age group 3 for the boys and girls was omitted because of the low numbers of children. Age groups 16 and 17 for the boys and 15, 16 and 17 for the girls were not analysed because all children, except one in each group, had reached a dental score of 100, in which case the dental age could not be computed.

The mean difference between the chronological age found in Dutch children and the dental age in French–Canadian children ranged from –1.28 to 0.68 in boys and from –1.23 to –0.06 in girls (Table 2). In boys, only age groups 14 and 15 showed a positive difference (delay), although the difference was not statistically significant. Age groups 4–13 all showed a negative difference (advance). In girls, age groups 4–15 all showed a negative difference (advance). On average the boys were 0.4 years and the girls 0.6 years ahead.

There was, for the boys, a statistically significant difference between the chronological age and the dental age of Demirjian from 4 up to and including 8 years of age (Table 2). A statistically significant difference between chronological age and dental age of Demirjian for the girls was present at 5, 6, 7, 8, 11 and 13 years of age (Table 2). The large statistical difference found between the chronological age of the Dutch children and the standards for French–Canadian children means that Demirjian's standards cannot be used for Dutch children.

Standards for Dutch children

New standard graphs were produced for Dutch boys and girls (Figure 2a, b). The function used for the 50th percentile curve of the boys and girls was, respectively, $Y = 100*\{1/(1+e^{-0.511(x-5.63)})\}$ and $Y = 100*\{1/(1+e^{-0.614(x-5.55)})\}$. The standard deviation (SD) for the steepness of the logistic curve for the boys and girls was 0.02. This means there was a statistically significant difference between the growth velocity of the boys (–0.051 ± 0.02) and the girls (–0.061 ± 0.02). The SD for the 50th percentile point for the boys and girls was 0.045, indicating that there was no statistically significant difference in the 50th percentile point between boys (5.63 ± 0.045) and girls (5.55 ± 1.96*0.045).

The residual analyses showed the explained variances when adapting a linear line or a logistic curve. For the boys, a linear line explained 83.0 per cent of the variance. In a logistic curve the explained variance was 93.9 per cent. For the girls the figures were 76.0 and 94.8 per cent, respectively. The scatter plots of the logistic curve showed that for both boys and girls the observed value and the predicted value of the logistic curve was evenly scattered around zero (Figure 3a, b). The mean value of those differences was 0.17 for boys and 0.22 for girls. The observed standard error over those differences was 0.44 for boys and 0.40 for girls. As can be expected, after the age of 14 years the line goes to zero. For these reasons the logistic curve seemed to be the best choice.

The 5th, 50th, and 95th percentile curves were drawn (90 per cent confidence interval). The graphs started at 3 years of age and ended at 17 years of age. Both graphs were plotted together to determine how the boys differed from the girls (Figure 4). A table was produced to transform the dental score to dental age for Dutch children (Table 3).

Discussion

Overall, Dutch children showed a more advanced dental age compared with French–Canadian children. This is in

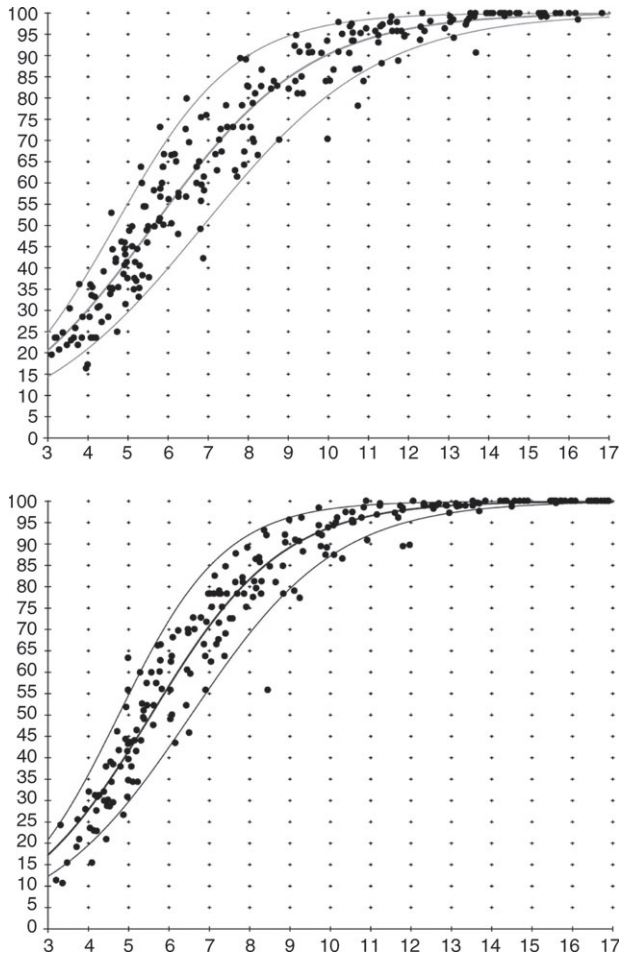

Figure 2 Standards for dental age for Dutch (a) boys and (b) girls from 3 to 17 years of age, according to the maturity score calculated using Demirjian's method. The 5th, 50th and 95th percentile lines are drawn.

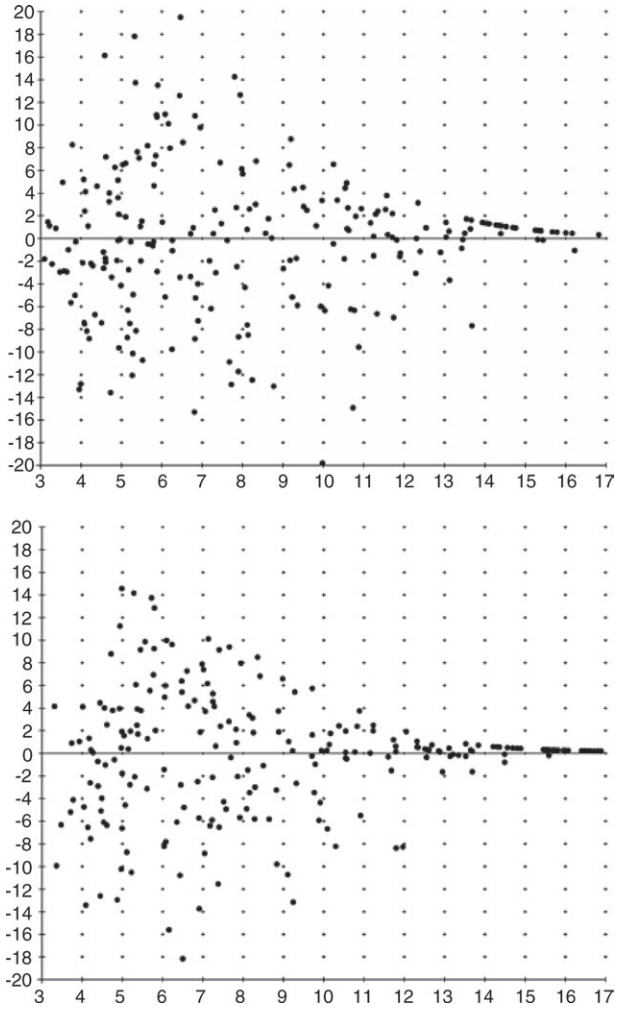

Figure 3 Scatter plots of the difference between the observed age and the predicted dental age for the logistic curve of the Dutch (a) boys and (b) girls.

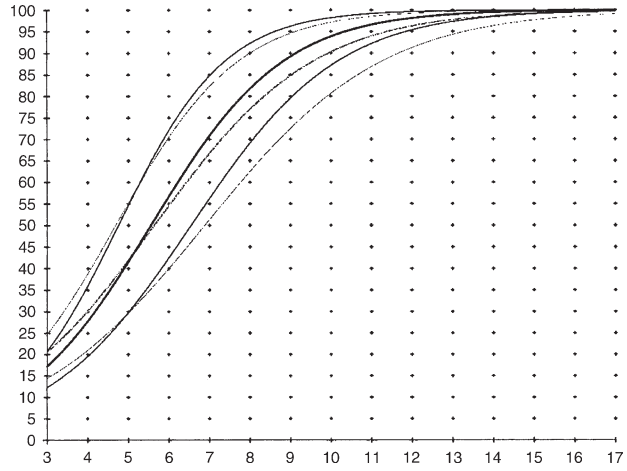

Figure 4 Combined logistic curves for the Dutch boys and girls. The 5th, 50th and 95th percentile lines are drawn. The solid lines represent the Dutch boys and the dotted lines the Dutch girls.

Table 3 Table to convert the maturity score calculated using Demirjian's method into the Dutch dental age for boys and girls.

Age	Score	Age	Score	Age	Score	Age	Score
Boys							
2.0	13.5	5.6	49.5	9.1	85.4	12.6	97.1
2.1	14.1	5.7	50.8	9.2	86.1	12.7	97.4
2.2	14.7	5.8	52.1	9.3	86.7	12.8	97.5
2.3	15.4	5.9	53.3	9.4	87.3	12.9	97.6
2.4	16.0	6.0	54.6	9.5	87.8	13.0	97.7
2.5	16.7	6.1	55.9	9.6	88.3	13.1	97.8
2.6	17.5	6.2	57.1	9.7	88.9	13.2	97.9
2.7	18.2	6.3	58.4	9.8	89.4	13.3	98.0
2.8	19.0	6.4	59.6	9.9	89.8	13.4	98.1
2.9	19.8	6.5	60.8	10.0	90.3	13.5	98.2
3.0	20.6	6.6	62.1	10.1	90.7	13.6	98.3
3.1	21.5	6.7	63.3	10.2	91.2	13.7	98.4
3.2	22.3	6.8	64.4	10.3	91.6	13.8	98.5
3.3	23.2	6.9	65.6	10.4	91.9	13.9	98.6
3.4	24.2	7.0	66.7	10.5	92.3	14.0	98.6
3.5	25.1	7.1	67.9	10.6	92.7	14.1	98.7
3.6	26.1	7.2	69.0	10.7	93.0	14.2	98.8
3.7	27.1	7.3	70.1	10.8	93.3	14.3	98.8
3.8	28.1	7.4	71.1	10.9	93.6	14.4	98.9
3.9	29.1	7.5	72.2	11.0	93.9	14.5	98.9
4.0	30.2	7.6	73.2	11.1	94.2	14.6	99.0
4.1	31.3	7.7	74.2	11.2	94.5	14.7	99.0
4.2	32.4	7.8	75.1	11.3	94.8	14.8	99.1
4.3	33.5	7.9	76.1	11.4	95.0	14.9	99.1
4.4	34.7	8.0	77.0	11.5	95.2	15.0	99.2
4.5	35.9	8.1	77.9	11.6	95.5	15.1	99.2
4.6	37.0	8.2	78.7	11.7	95.7	15.2	99.3
4.7	38.2	8.3	79.6	11.8	95.9	15.3	99.3
4.8	39.5	8.4	80.4	11.9	96.1	15.4	99.3
4.9	40.7	8.5	81.2	12.0	96.3	15.5	99.4
5.0	41.9	8.6	82.0	12.1	96.5	15.6	99.4
5.1	43.2	8.7	82.7	12.2	96.6	15.7	99.4
5.2	44.4	8.8	83.4	12.3	96.8	15.8	99.4
5.3	45.7	8.9	84.1	12.4	96.9	15.9	99.5
5.4	47.0	9.0	84.8	12.5	97.1	16.0	99.5
5.5	48.2						

Table 3 Continued

Age	Score	Age	Score	Age	Score	Age	Score
Girls							
2.0	10.2	5.6	50.7	9.1	89.8	12.6	98.7
2.1	10.7	5.7	52.2	9.2	90.4	12.7	98.8
2.2	11.3	5.8	53.8	9.3	90.8	12.8	98.8
2.3	11.2	5.9	55.3	9.4	91.4	12.9	98.9
2.4	12.6	6.0	56.8	9.5	91.8	13.0	99.0
2.5	13.3	6.1	58.3	9.6	92.3	13.1	99.0
2.6	14.0	6.2	59.8	9.7	92.7	13.2	99.1
2.7	14.8	6.3	61.2	9.8	93.1	13.3	99.1
2.8	15.6	6.4	62.7	9.9	93.5	13.4	99.2
2.9	16.4	6.5	64.1	10.0	93.9	13.5	99.2
3.0	17.3	6.6	65.5	10.1	94.2	13.6	99.3
3.1	18.2	6.7	66.9	10.2	94.5	13.7	99.3
3.2	19.1	6.8	68.2	10.3	94.8	13.8	99.4
3.3	20.1	6.9	69.5	10.4	95.1	13.9	99.4
3.4	21.1	7.0	70.8	10.5	95.4	14.0	99.4
3.5	22.1	7.1	72.1	10.6	95.7	14.1	99.5
3.6	23.2	7.2	73.3	10.7	95.9	14.2	99.5
3.7	24.3	7.3	74.5	10.8	96.2	14.3	99.5
3.8	25.4	7.4	75.6	10.9	96.4	14.4	99.6
3.9	26.6	7.5	76.7	11.0	96.6	14.5	99.6
4.0	27.8	7.6	77.8	11.1	96.8	14.6	99.6
4.1	29.1	7.7	78.9	11.2	97.0	14.7	99.6
4.2	30.4	7.8	79.9	11.3	97.1	14.8	99.7
4.3	31.7	7.9	80.8	11.4	97.3	14.9	99.7
4.4	33.0	8.0	81.8	11.5	97.5	15.0	99.7
4.5	34.4	8.1	82.7	11.6	97.6	15.1	99.7
4.6	35.8	8.2	83.5	11.7	97.7	15.2	99.7
4.7	37.2	8.3	84.4	11.8	97.9	15.3	99.7
4.8	38.6	8.4	85.1	11.9	98.0	15.4	99.8
4.9	40.1	8.5	85.9	12.0	98.1	15.5	99.8
5.0	41.6	8.6	86.6	12.1	98.2	15.6	99.8
5.1	43.1	8.7	87.3	12.2	98.3	15.7	99.8
5.2	44.6	8.8	88.0	12.3	98.4	15.8	99.8
5.3	46.1	8.9	88.6	12.4	98.5	15.9	99.8
5.4	47.6	9.0	89.2	12.5	98.6	16.0	99.8
5.5	49.2						

accordance with the findings for Finnish, Swedish, and Norwegian children (Nyström *et al.*, 1986; Mörnstad *et al.*, 1995; Nykänen *et al.*, 1998). The mean difference for Dutch boys was 0.4 years and for Dutch girls 0.6 years. In the sample of Norwegian children the mean difference was smaller. For boys it was 0.2 years and for girls 0.3 years. For the Finns the difference was almost the same as in the Dutch sample. The Finnish boys differed by 0.45 to 0.7 years and the girls by 0.35 to 0.9 years. In the Swedish sample the difference was greater. The Swedish boys differed by 0.4 to 1.8 years and the girls by 0.5 to 1.8 years. The French–Canadian children were born between 1957 and 1961, the Dutch between 1972 and 1993. A possible explanation for the differences between the Dutch and French–Canadian children might be a secular trend in dental development (Nadler, 1998).

The graph for the boys (Figure 2a) showed a broader band between the 5th and 95th percentile lines than the graph for the girls (Figure 2b), which means there was a larger variation within the boys than within the girls.

The larger variation is likely to be biological as for the entire period the variation found in boys was larger than the variation found in girls. The larger variation within boys has also been found for other parameters of development, such as height and weight (Venrooij-Ysselmuiden and Ipenburg, 1978). The combined graph of the data from the boys and girls (Figure 4) shows that until the age of 5.1 years the girls stayed behind the boys. After 5.1 years the girls caught up with the boys and their dental development was complete at an earlier age. This is in accordance with the earlier maturation of other parameters of development in girls, such as height (Venrooij-Ysselmuiden and Ipenburg, 1978), sexual maturation (Prahl-Andersen *et al*., 1979) and skeletal age (Venrooij-Ysselmuiden and Ipenburg, 1978). This earlier maturation can also be seen in the scatter plots (Figure 3a, b). The line for the boys equals zero at a later time than that for the girls.

The number of children was not the same in each age group. In the groups until 12 years of age (except age group 3), dental age is more precise because the number of children was larger. For the older age group, fewer DPTs were available and dental age may therefore be less reliable. This could have influenced the curve, but is unlikely. The most important development of the dentition occurs before 12 years of age. At 12 years of age the curve is complete for 96.3 per cent of the boys and for 98.1 per cent of the girls.

In this study, children with tooth agenesis were excluded. This was to ensure that the new Dutch standards were as precise as possible. In case of an agenesis, Demirjian (1978) developed two different scoring systems based on four teeth. These methods should be investigated to determine if they are accurate for Dutch children in combination with the new standards for Dutch children.

This study was retrospective and therefore ethnicity may, in a few cases, be questionable. Although efforts were made to exclude patients with surnames suggesting a non-Caucasian background, there still might be patients involved in this study who were not of Caucasian origin. For instance, children with a non-Caucasian mother but a Caucasian father.

Conclusion

To calculate the dental age for a Dutch child, scoring can be carried out according to the system of Demirjian (1978). The left mandibular seven teeth on the DPT of a patient are compared with the reference radiographs. Teeth are scored A–H according to the developmental stage of the tooth. The developmental stages A–H are transferred to their weighted score according to the tables giving the weighting applied to each Demirjian stage. All seven scores are summed to give the maturity score. The standards presented in Table 3 represent the Dutch dental age.

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